Rob Dekkers
Laure Morel *Editors*

European Perspectives on Innovation Management

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Scientific Committee

Preface

The idea for this book goes back to conversations we had at the sidelines of conferences organised by the International Association for Management of Technology, two editions of the European Conference for Technology Management and a research visit to the Ecole Nationale Supérieure en Génie des Systèmes et de l'Innovation; all during the period 2005–2012. During these conversations, sometimes, we wondered about research, particularly at the dominating American perspectives and the drive of those researchers to demonstrate how they were performing well. This brought us to conclude that perhaps there were European perspectives on how innovation management should take place and how settings influenced not only the conduct of research, but also what was done its outcomes and how useful they were.

It was not until the end of 2018 that we picked up this thinking and casually decided to go for an edited book. At the same time, we started to realise how diverse Europe was in its approaches to innovation management and got intrigued by challenges this may pose for studies. The growing awareness coincided with inviting academics to join the scientific committee; even the responses of those that declined, often referring to the limited time available for exciting projects, encouraged us in this endeavour. That invited academics often cited time was a foreboding what was to come.

Though we had an excellent start, things turned upside down with the pandemic caused by COVID-19, its aftermath, contemporary turmoil and some personal circumstances. Notwithstanding these setbacks, the enthusiasm of those that engaged with the idea of the book kept us going. And, we witnessed some authors struggling, not only with available time as so many academics but also sharing their personal circumstances and stories with us, up until the final stages. We are glad that they did confide in us and kept going until the end. The few for which this was not possible and some others that we lost contact with due to the multiple contemporary challenges that appeared we wish you well and it was a pleasure conversing with you. At the end, we have succeeded in bringing contributions together of academics that otherwise would not meet.

In this undertaking for the edited book, we are grateful to the members of the scientific committee for willing to join us. Members of the scientific committee

conducted reviews that were often encouraging for authors. A special thank goes to Andrea Bikfalvi who reviewed several proposals for chapters.

Last but not least, we are thankful to Anthony Doyle and Rajan Muthu of Springer for their patience throughout. We sincerely hope that the book is worth waiting for.

May we have forgotten to acknowledge somebody who contributed to this book, directly or indirectly, accept this as our apology.

Glasgow, UK — Rob Dekkers
Nancy, France — Laure Morel
June 2023

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About the Editors

dr. ir. Rob Dekkers is a reader in Industrial Management at the Adam Smith Business School (University of Glasgow) since 2014. He holds an M.Sc. in Mechanical Engineering and a Ph.D. from Delft University of Technology. Before academia, he has worked as an internal consultant and a production manager at Philips, and as a senior project manager at AKZO Pharma. In 1992, he joined Delft University of Technology as a senior lecturer in the section Industrial Production and Management (Faculty of Mechanical and Maritime Engineering). This was followed by a position as a reader at the University of the West of Scotland in 2006. He has been a visiting professor at ESC Grenoble, Heilbronn Business School, Massey University, Radboud University, Tsing Hua University (Taiwan), University of Lorraine and University of Malay. Principal research interests cover systems theories, evolutionary biological models applied to organisations, innovation and technology management, production management and industrial networks. He has (co-) authored more than 200 publications, including papers in academic journals, books, chapters in edited books, reports and proceedings of conferences. Funding for his collaborative research was received from the Carnegie Trust, EU FP-6, Leverhulme Trust, NESTA, and the Royal Society of Edinburgh. He sits on the board of the International Foundation of Production Research and chairs its Doctoral Training and Early Career Researchers Programme. Also, he is the coordinator, RNI Global (Research Network on Innovation/Réseau de Recherche sur l'Innovation). He is an associate editor for the *International Journal of Information and Operations Management Education* and a member of eight editorial boards and reviews for more than 30 journals.

Dr. Laure Morel is a full professor on Management of Technology and Innovation at the Ecole Nationale en Génie des Systèmes et de l'Innovation of Nancy (Industrial Engineering School of the University of Lorraine—France). In 2014, she was awarded the title of Honorary Professor at the National University (UNAL) in Bogota, Colombia. After 10 years as the director of the laboratory ERPI (Research Group on

Innovative Processes), she is now the director of the ENSGSI school. She has a Ph.D. in Industrial Engineering from the National Polytechnic Institute of Lorraine. Her research interests span the field of new product development and innovation metrics. Her latest research has directed increased attention towards the evaluation of the innovative potential of small firms. The aim is to propose data collection approaches and data treatment models allowing a real comparison between companies considering their innovation management. In 2017, as an entrepreneur, she co-founded the start-up “Innovation Way”, which has developed a benchmark of best practices to assess innovative capabilities and internal processes of firms and became its scientific director. Alongside her roles as a laboratory director and then an engineering school director, she has been working within the French delegation for the development of the ISO 56001 series of standards in Innovation Management since 2015. She also is on the board of several scientific associations: the International Association for Management of Technology (IAMOT), the Research Network on Innovation (RRI) and the CDEFI (Conférence des écoles d’ingénieurs).

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Introducing 'European Perspectives on Innovation Management'

Laure Morel and Rob Dekkers

The starting point for this edited book is that European practices for innovation management in organisations and their settings are anchored in Anglo-Saxon, East European, Nippon-Rhineland, Nordic and Mediterranean socio-economic perspectives; this unique blend of social-economic perspectives also leads to different views on innovation management, new product and service development and their challenges. This becomes apparent in writings such as that of (Patel & Pavitt, 1994, pp. 90–92) when they distinguish between myopic and dynamic national systems of innovation; the first they associate with the United Kingdom and United States, and the latter with Germany and Japan. Also, (Wagner & Kreuter, 1998) point to differences in approaches between innovative firms in Germany, Japan and the United States. These differing approaches harbour diversity, which could be either beneficial or limit the growth of national economies, sectors and firms. Also, this may result in national cultures affecting creativity and innovation management in differing ways. Thus, these perspectives may lead to both subtle delimitations and pronounced differences for innovation policies, institutional settings, approaches to innovation management by firms and innovation performance, something that is explored in the chapters of this edited book.

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1 National Innovation Systems as Institutional Settings

In addition to socio-economic perspectives, institutional factors that differ across nations and regions play a role in practices that are adopted for innovation management. This thought is captured by the notion of national innovation systems, for example the writings by Lundvall (1998, 2007). Also, the conceptualisation of triple helix (Leydesdorff & Etzkowitz, 1996) instigates that institutional factors determine innovation outcomes, not only for nations, but also for firms. Not only can these institutional factors be found at the level of nations, they are also present in industrial districts, such as those constituting what is called the 'Third Italy' (Biggiero, 1998). The result is differing institutional contingencies across regions and nations, further augmenting the socio-economic perspectives.

Notwithstanding these fragmented socio-economic perspectives and institutional contingencies, there are specific commonalities. Perhaps the nature of these perspectives, possibly set in Kantianism guiding economic and legal institutional settings rather than utilitarianism and legalism, makes firms and institutions gravitate towards open collaboration rather than transactional approaches (e.g., Dekkers et al., 2019); the first is possibly linked with dynamics national innovation systems, and the latter most likely associated with myopic national innovation systems. The fragmented, distributed economies put a strong focus on internationalisation, including innovation management, new product and service development, even within the internally open market of the European Union. Therefore, the European institutional settings foster unique approaches to innovation and new product and service development.

Perhaps these unique approaches will also foster a more innovative Europe. This may lead to creating not only 'unicorns,' but also other high-growth firms, and stimulate other firms to engage more actively with innovation. In this sense, encouraging techno-entrepreneurship and facilitation of growth may also be shaped by the specific diversity of perspectives, institutional contingencies and collaborative modes. This extends to how firms interact with universities, research institutes and economic development agencies, while not forgetting consumers and citizens.

2 What Is Found in This Edited Book

Each chapter of this book brings a different perspective on how to perceive the management of innovation at different levels of aggregation, as we have already pointed out.

2.1 PART A: Management and Practices for Innovation

This first part contains studies with a general perspective on innovation management and associated practices. These practices and approaches to innovation management are discussed from processes and structures related to the context of settings arising from socio-economic perspectives, one could say a perspective held at a macro-level, to approaches for new product development and engineering, a micro-level. We have put the chapters in order from those that are more oriented towards approaches at macro-level to those at micro-level such as methods for new product and service development in order to understand the specificities of the studies.

First, in Chap. 2 we have the opportunity to read the work of *L. J. Lekkerkerk* who presents an organisational perspective of innovation management based on an original proposal: the model innovation and organisational structure (MIOS), rooted in socio-technical design. The latter diagnostic tool is a cybernetic model developed to systematically study and compare organisational structures in order to design guidelines for enhancing the performance of innovation and change management of organisations. It also derives inspiration from socio-technical design, closely related to systems theories and cybernetic approaches to design of organisations; he relates it to a specific approach known as the Low Lands' approach to socio-technical design. This chapter contains a comparison of seventeen applications of the model innovation and organisational structure (or 'the MIOS') in firms and leads to discernible results that ensure its robustness.

In Chap. 3, *Merih Pasin, Mehmet. N. Aydin and Ceyda Ovaci* are postulating that 'innovation management requires a holistic approach that involves interactive, strategy-oriented, sustainable processes and structure.' In this vein, they propose a semi-structured model for a corporate innovation system. This model for such a system provides a roadmap for companies based on six dimensions and twenty key target indicators to establish a corporate innovation system that will enhance the diffusion of an innovative milieu d'interieur in organisations, in turn supporting the improvement for innovation processes and structures. They claim that this model has been successfully implemented in 129 companies contributing to a nationwide innovation programme in Turkey, which highlights its potential pertinence for broader deployment.

Sofia Börjesson, Joakim Netz and Fredrik Lagergren are giving us in Chap. 4 a Swedish perspective on what innovation management is in a self-managed organisation. The authors affirm that the classical hierarchical management posture can be replaced by a new one leading to more creative capabilities, ultimately creating more sustainable and innovative organisations. Through a longitudinal case study they show how the redistribution of executive power, including the role and responsibilities of the CEO, and the removal of the traditional managerial hierarchy can lead to a more innovative milieu d'interieur. This chapter provides an original perspective to the strand of research into innovation capabilities considering that there is a missing component, i.e. a participatory dimension, in existing models for building these capabilities.

Then, in Chap. 5, *Rob Dekkers, L. J. Lekkerkerk and Peiran Su* bring in a different perspective for assessing the influence of national innovation systems based on the dichotomy of dynamic and myopic national innovation systems in order to get a better understanding of technological activities by firms. They propose a novel research instrument to position and compare firm behaviour in the continuum of dynamic and myopic national innovation systems. Their objectives are to better understand how decisions by firms, and potentially, other actors are made and what is considered during the decision-making processes. Furthermore, to support diagnosis of organisations and design research for innovation management, they use models for innovation processes based on systems theories to study innovation management by firms.

In Chap. 6, *Julie Roberts* is presenting the results of an empirical study that investigates open innovation practices for acquisition of knowledge and technology commercialisation by conducting qualitative research into medical technology sector (Med-Tech) companies. A presentation on the context of the Scottish Med-Tech sector precedes demonstrating that the concept of open innovation, popularised by Chesbrough, is a controversial one, alas not so new as many presume. Indeed, an exhaustive review of the literature on open innovation and technology valorisation leads onto a deliberation on the novelty of open innovation and a proposal for conducting interviews with representatives of companies. The results of the study give us an overview of the situation for Scottish Med-Tech firms: both a lack of systematic practice for managing open innovation and framework for Med-Tech companies to carry out open innovation more systematically.

The next Chap. 7 by *Michael Hertwig, Joachim Lentes, Adrian Barwasser and Frauke Schuseil* is giving us another use of the conceptualisation open innovation by proposing the original concept ‘crowd engineering’ as an approach adapted to new trends in product development, such as a better involvement of consumers and users in product creation. They show how crowd engineering is a pertinent and suitable approach to product innovation in small- and medium-sized enterprises by presenting a use case, the Roboy project done in Germany: ‘A robot as good as the human body.’ Before sharing their results, they advise some key organisational and technological prerequisites to be considered. The adoption of the crowd engineering mindset combines methods of the stage gate model with methods from agile development to facilitate or enable collaboration within a community. At the end, the authors confirm that crowd engineering is a powerful new approach for managing innovation on product development using crowdsourcing to accelerate innovation and reduce costs.

Chapter 8, written by *Marianna Koukou and Rob Dekkers*, highlights the importance of conditions for successful end-user involvement in new product development (NPD). Through explorative qualitative research comparing two French, one Russian/Greek and three UK companies, they focused on the impact of end-users involvement in the NPD process and end-product. Their holistic literature review focuses on three well-known approaches and their associated tools and describes the scale of involvement continuum: design for (using quality function deployment), design with (paying attention to the customer voice) and design by (favouring the co-creation with end-users during the entire process). The major findings of the study for us are in providing information which one of the end-user involvement approaches is best suited for creating more effective and more efficient NPD processes and when depending on a company's goals, resources and (organisational) culture.

Finally in Part A, *Rob Dekkers* in Chap. 9 deals with a not so well covered topic: the place and role of non-practicing or non-producing entities (NPEs) in the innovation process. Explaining that NPEs are 'companies or entities that do not invent new technology directly but acquire IP [intellectual property, ed.] from third parties and strive to sell licences and obtain licence royalties or any other income stream from exploiting that ownership situation,' he highlights the potential impact of NPEs on the effectiveness of the innovation process. An exhaustive literature review helps the reader to understand both the context and concepts. This leads to empirical research that confirmed that actually little is known about the impact of NPEs on innovation processes. The consultation of experts and a group were used for data collection. One major finding of this chapter is to show that the headline cases by NPEs have increased awareness in firms to actively manage a portfolio of patents, particularly in industries such as software and data processing.

2.2 PART B: National and Regional Innovation Systems

Within this second part of the book, studies highlight how the ecosystems of innovation can be a driver in innovation dynamics both at national and regional level. Some of these studies address the regeneration of regions, others trends such as digitisation and living laboratories, and two a sector. All together the chapters provide insight in changes that are taking place in Europe, different for regions, industries and firms.

In Chap. 10, *Stefanie Bröring and Simon Ohlert* explore the recognition of entrepreneurial opportunities when companies are directly or indirectly affected by the German government's decision to phase-out coal mining in Germany, particularly in regions reliant on this industry, in order to switch to novel bioeconomy regions. They assume that the emergence of new regional innovation systems is crucial to support the development of novel inter-industry segments as entrepreneurial opportunities. They describe the INNOSpace®2Agriculture network as an illustrative case for various entrepreneurial opportunities arising between distant industries in terms of cognition and knowledge such as agriculture and space. They draw some interesting conclusions among which start-ups function as a bridge between separated industry fields thanks to their agility and flexibility, competence-building processes and ability to work collaboratively and networked. At the end, this chapter gives direction to a new potential for transitions of European coal mining regions and beyond arising from sustainability.

Then, in Chap. 11, *Carsten Dreher, Oliver Som and Martina Kovač* are presenting another side of the German manufacturing industry by discussing how and to what degree the existing landscape of German and European innovation policy instruments meets the specific needs and requirements of heterogeneous innovation patterns found in SMEs. A theoretical framework based on evolutionary economic theory and the resource-based view to explain the heterogeneity in firms' innovation behaviour was used to analyse a sample of 23 national and four European SME innovation policy instruments. The findings lead to a recommendation: they suggest that a demand-side-oriented, sustainable SME policy portfolio is necessary, while recognising that it can be a daunting challenge.

Chapter 12 presents the result of an empirical study in three European provinces, across France, Austria and Sweden, in order to provide a description for key characteristics of ecosystems formed around digitalisation, their practices and internal collaborative dynamics. The authors, *Vincent Boly, Laure Morel, Brunelle Marche, Davy Monticolo, Mauricio Camargo and Marianne Hörlesberger,* first delve into the scientific background of the study, mainly focused on the concepts of digitalisation and ecosystems to better understand how different stakeholders act and interact. Their objectives are to identify the actors and structures that foster digitalisation of provinces and regions (characterising ecosystems), the description of their stimuli (ecosystem activities) and finally, how they all interact (internal collaborative forms in ecosystems). This leads to a sampling model containing thirty-six practices and associated digital maturity grids that fit with local objectives and policies.

Next, in Chap. 13, *Raphaël Bary, Laure Morel and Valentine Labouheure* address an original topic linking innovation capabilities to the approach of living laboratories. Derived from a systematic literature review into innovation capability of participants in living laboratories from a European perspective, they propose a competency-based approach for individuals to contribute to innovation; that is to say, mobilising user-centric and open innovation approaches that aim at enhancing the acceptability of new products and services. The main result of this chapter is to offer a better understanding of the importance of co-creation to enhance Europe's innovation capability. Highlighting the existing differences in terms of individual innovation capabilities among European countries, they proposed that living laboratories could be considered as a first step towards a European learning culture for innovation.

Whereas to increase the innovativeness industry ever since has collaborated with science, *Anne Spitzley, Antonino Ardilio, Sonja Stöffler, Tabea Dietrich, Isabelle Jahnel and Wilhelm Bauer* are presenting in Chap. 14 the emergence of multilateral collaboration between university and industry in the age of digitalisation. They show that even if bilateral collaboration is a common research topic to define the classical collaboration between university and industry, research on formats for multilateral research cooperation are still not so well addressed. An explorative study was conducted in order to obtain an overview of this new topic by identifying patterns. Informed by a comprehensive literature review, a framework was developed in which multilateral collaborations between science and industry are mapped in ten characteristics of research collaborations. Seven interviews were performed to validate the ten characteristics and highlight their practical implications. Finally, success factors are presented leading to the success of research collaborations from both a scientific and business perspective.

In Chap. 15, *Katalin Erdős and Zsolt Bedő* are addressing a touchy subject: the contribution of the universities in the development and implementation of smart specialisation policies at regional level to improve innovation capabilities of industrial ecosystems. They consider the case of a university-centred entrepreneurial ecosystem for a large Hungarian university with ten faculties, located in a small town. They analyse the role that the university can play in the creation of an entrepreneurial ecosystem that supports entrepreneurial thinking and acting within the region. One major result of their research is to confirm that knowledge spillover is highly context dependent and so relies on the (local) structure of creating and disseminating scientific knowledge and entrepreneurial attitude.

Considering that research into innovation management has to contribute to a paradigm shift to better fit with an increasingly volatile, uncertain, complex and ambiguous environment, *Jean-Pierre Segers, Dirk V. H. K. Franco, Didier Van Caillie, Elina Gaile-Sarkane and Janaina Macke* are developing in Chap. 16 a holistic approach for measuring sustainable performance generated by innovative projects. Focusing on energy efficiency of educational buildings in Belgium and assuming that interpretive methods such as multiple case studies are the preferred method to study complex phenomena within a real-life context such as energy transition and novel insights in energy business models, they present an interpretive case study for the model of Energy Service Companies—'the ESCO energy transition case.' The results are twofold: confirming the effectiveness of their proposal and presenting a multilevel classification of business models adapted to meet goals for energy transition.

2.3 PART C: Comparative Studies

The contribution by *Ewa Cieślik* in Chap. 17 leads to a realistic and enthusiastic perspective for Central and Eastern European economies (CEEs) in rebuilding their participation and position in global value chains in the services sector in general, with a focus in ICT services due to the great importance commonly recognised of this sector in European countries in the last years. By analysing 11 countries (sometimes called EU-11), she explains how the accession to the European Union (EU) structures in 2004 was a milestone for these countries, gaining the status of free-market economies and participation in global business networks. More particularly, she underlines the proactive actions of all CEE countries in this high-growth market during the studied period that have introduced programmes promoting the development of Industry 4.0, including ICT services and innovative technologies. To analyse the participation and position of the CEE economies in global value chains, the author assesses the role of these economies in international production links using the methodology of value-added flows, relying on trade in value-added data retrieved from the OECD's Inter-Country Input–Output Database, available during the period 2005–2018. So, a multiregional input–output model was used, which also included value-added in industries and sectors. Even if the conclusions are mitigated when comparing fluctuations in relative positions in global value chains in services to manufacturing and in the ICT sector, the author assumes that the service sector seemed to be more promising than manufacturing for strengthening the CEE's position in global production networks, and that, in general, all countries occupied the upstream market in ICT services during the entire analysed period.

In Chap. 18, *Martina Baglio, Claudia Colicchia, Alessandro Creazza and Emanuele Pizzurno* are addressing the position of innovation management in the logistics sector based on systematic review with bibliometric analysis of European studies. They highlight very interesting results, i.e. sustainability-oriented innovation emerges as a key topic, along with technology, transport-related innovations and the customer's role within innovation processes. This highlight that the logistic sector shows a significant pace of technological innovation and is being either a key sector in the economy of the continent and one of the main sources of negative externalities for the environment and the society. So, they maintain that it is time to develop more types of innovative practices in the logistic sector addressing environmental challenges and fostering a more resilient and equitable future.

In Chap. 19, *Rob Dekkers and Laure Morel* are comparing organisational patterns for Innovation between scottish and French firms. Their objectives are to understand the management of innovation processes with an emphasis on the impact on the business model and the different organisational structures necessary for innovation, without avoiding the impact of the national innovation system on the innovation dynamics. To understand the implications of innovative capabilities, they opted for a case-oriented methodology based on a framework for assessing the innovative capabilities that focuses on the organisational patterns for the innovation processes. Indeed, the authors are assuming that the effectiveness of (traditional) metrics can be questioned and that more integrative approaches of necessary to complement literature review by observation and interviews. They tested their proposal by comparing the results obtained with Scottish firms and French ones. Thanks to this exploratory study, the authors highlight some differences between the myopic view, typical for the Anglo-Saxon business model, and the dynamic view of the Nippon-Rhineland model when evaluating innovative capabilities.

3 An Afterthought

Although we are aware that we cannot claim to be exhaustive in our viewpoints, we believe that the work done by the authors who contributed to this book is inspiring and may lead to studies based on the proposals that are found in the epilogue (Chap. 20). To this purpose, it reflects on idiographic and nomothetic studies in the European context and based on the chapters sets out pathways for further research.

We hope you will enjoy the read.

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Management and Practices for Innovation

The Model Innovation and Organizational Structure: A Zoom Lens on Organizational Structure

L. J. Lekkerkerk

Abstract This chapter presents a comparison of the first 17 applications of the Model Innovation and Organizational Structure (or 'the MIOS') in organizations. This MIOS is a cybernetic model containing 'necessary and sufficient' functions that should be fulfilled in an organization that aims to remain viable. It is both a research and diagnostic tool developed to study organizational structures, including the 'innovation structure', by making a systematic description. By systematically comparing organizational structures of successfully innovating organizations, the ultimate aim is to deliver concrete design guidelines for a well-integrated embedded innovation structure. This should help to improve the persistently low performance of innovation and change activities (less than 30% success on average) by organizations. To date, seventeen organizations have been studied. In spite of the pragmatic sampling by the student researchers and the limited number of very different cases, the comparison shows a few promising results:

- The comparison yields seven observations on the innovation structures and the way they are designed.
- This allows us to conclude that the MIOS is usable for further empirical research and diagnostic application.

Keywords Structure · Organization Design · Innovation Structure

Reviewing the applications of a cybernetic tool for researching and diagnosing an organizational structure and the embedded innovation structure.

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1 Introducing the Background of the Research

It is generally believed that innovations are needed to keep organizations viable and competitive in a 'VUCA world'. For such an important process, including innovation and other change projects, the success rate was and is staying at a frustratingly low 30% for decades (an overview in Lekkerkerk, 2012, p. 261). How can that be improved?

In their book 'Competing by design' Nadler and Tushman (1997) focus our attention to organizational structure design as an important factor to improve operational performance. The twelve cases presented by Laloux (2014) also show that their organizational structure design improves their competitive advantage. They perform well on the market and at the same time offer good quality of work to their employees. The latter improves their position on the labour market where a war on talent is going on.

From these two points the idea follows: organizations may innovate more successful 'by design', that is by organizational structure design. Unfortunately, most if not all approaches to organization design focus on operations or the primary process of organizations (e.g. the two books mentioned above, lean (Womack & Jones, 2003), Business Process Redesign (Hammer & Champy, 1993), configurations (e.g. Mintzberg, 1989), contingency or fit (e.g. Burton et al., 2015). Even the Lowlands sociotechnical systems design approach (L-STSD) lacked concrete 'innovation structure' design guidelines admits founder De Sitter in his last book. He concludes this after an attempt to develop such guidelines in the final chapter via a theoretical line of reasoning. He challenged 'young business administration scholars' to develop more concrete design guidelines for the innovation structure, including new product development (1994, p. 403).

During my first work experience upon graduation, as an employee at Fokker Aircraft's Composite Structures Division between 1985 and 1996, I witnessed both the lack of success of many innovation projects and the success of an organizational redesign of the Composites Plant's Operations. The OD approach used in this redesign was mainly an early version of L-STSD (De Sitter & Groep Sociotechniek, 1987), combined with insights from 'The Delft Systems Approach' (In 't Veld, 1994, Veeke et al., 2008). Based on this experience I decided later to take on De Sitter's challenge mentioned above by doing a PhD. Because he failed to develop the guidelines theoretically, I decided to try to empirically study the organizational structure, including the innovation structure, of preferably successfully innovating organizations.

At the start it was clear that the relation between (innovation) structure and performance is not easily laid. Crossan and Apaydin concluded in their review that innovation research did not lead to generalizable insights into the link between innovation and organizational performance (Crossan & Apaydin, 2010, p. 1176). One can safely assume that the link between the innovation structure and organizational performance is not yet firmly established either. The improved organizational performance in the reorganized Composite Plant cannot be credited to the new structure alone, because at the same time several capable new team leaders and ‘flow managers’ were appointed. Additionally, all team members were educated in the new way of working, e.g. by a Lego-simulation game named ‘The JIT game’.

Another problem that popped up when drawing a research proposal to address De Sitter’s challenge was the huge variation in organizational structures; each organization is different. A method or tool to describe organizational structures, and especially the embedded innovation structure, in a way that enables systematic comparison was not available (Lekkerkerk, 2012). Even with a set of cases that can be compared using such a systematic ‘structure photo’, it would still be another challenge, based on Crossan and Appaydin’s findings, to causally link the innovation performance of these cases, e.g. in time-to-market for new product development, in commercial success rate of innovation projects, to the characteristics of their (innovation) structure and thus innovation to organizational performance.

Against this background, Lekkerkerk (2012) developed the Model Innovation and Organizational Structure (acronym the MIOS) to systematically describe structures. This chapter aims to describe this model, to report on its application in practice and reflect on its usability for further research.

The chapter is built as follows. First the MIOS, a recursive function model, will be explained. Then, the ‘grey literature’ case selection is explained in a brief methods section. The 17 suitable studies are then presented and compared, leading to seven interesting observations.

Given the complexity of the problems at hand, this chapter presents a modest step forwards by showing the usability of the MIOS for researching (innovation) structures and also for making some practical recommendations to improve the structure. This proof of usability opens the way to further research.

Restructuring: Step by Step Towards a Flow-Based Organization

Restructuring the Composite Structures Division in flows.

Composite aircraft parts were fibre reinforced plastic parts and metal-bonded structures. The operational units were divided in product/customer groups, mainly serving final assembly units for Fokker F27/50, Fokker F28/100 and Airbus A300/310. Exterior parts are either in a left and right pair or one-per-aircraft (e.g. radome, vertical stabilizer). Interior parts are in small numbers (e.g., cabin overhead luggage bins and side panels, airco-ducts) or in one-per-aircraft (cockpit, lavatory, galley). Exterior and interior parts used different materials (fibres, resins, sandwich) and different processes and skills. Especially both Fokker units had to deal with this variety in batch sizes (1–40), materials and processes. For Airbus only exterior parts were delivered (e.g., flap track fairings).

Starting in 1985 the structure within Operations was redesigned into a flow-based structure. The three flows were formed using a simple group technology approach that linked to material and process of interior one-per-aircraft, interior series and exterior. This structure reduced the variety in the units leading to simpler planning and resulted in much improved lead time, better quality and higher efficiency.

At first several other functional supporting departments were left untouched, but after a while these started internally to form subgroups linked to each of the flows in Operations. After another, all people involved agreed that it would make sense to split these functional supporting departments and form a Support unit in each of the Operations flows. This effectively formed three autonomous business units within the Composites Plant.

The approach used to redesign was mainly an early version of L-STSD (De Sitter and Sociotechniek, 1987) combined with insights from 'The Delft Systems Approach' (In 't Veld 1994, Veeke et al., 2008).

2 Elaborating on the Reasons for Developing the MIOS

By redesigning their organizational structure from bureaucratic, functional structures to a structure with independent flow-based units, many organizations showed much enhanced performance in their operations, e.g. increased controllability, less cost, shorter lead times, less work in process, higher on-time delivery, more customer value and higher quality of work. Such a redesign may be inspired and guided by approaches or theories such as:

- Business Process Redesign, BPR (Hammer, 1996; Hammer & Champy, 1993).
- Lowlands sociotechnical system design, L-STSD (De Sitter et al., 1997; De Sitter, 1994; Van Hootegem et al., 2008; Kuipers et al., 2010, 2018, 2020).
- Lean thinking, LT (Womack & Jones, 2003), and preceding work about the Toyota Production System, Just-in-Time-management and Kaizen.

A common characteristic of these OD approaches is the design of an operations structure consisting of autonomous units with an end-to-end responsibility for a subset of all the types of customer orders the organization fulfils. The classic functional, activity-based or 'silo' structures, seeking to obtain economies of scale, are abandoned because they can be characterized as 'complex structures (with simple, narrow jobs)' with a high need for coordination. These approaches favour 'Simple structures with complex (i.e. meaningful, high quality) work'. Both De Sitter et al. (1997) and Hammer and Champy (1993) use this statement.

By analogy, the question arises:

> Would redesign of an 'innovation structure' lead to innovation performance improvements such as those seen in operations?

Unfortunately, neither BPR nor lean nor the Lowlands sociotechnical design approach present concrete guidelines for the redesign of the innovation (sub)structure; not as an independent subsystem and not as part of an integral redesign of the entire structure (De Sitter, 1998, p. 397).

Hence, a first problem is: how can these innovation structure design guidelines be obtained? Studying the organizational structures of successfully innovating organizations and how these integrate their 'innovation structure' with it might reveal these design guidelines. Applying these will eventually improve innovation performance.

To obtain these design guidelines, organizational structures will have to be studied in detail. To date, quantitative studies relating structure to organizational performance operationalized structure using insights from Pugh et al. (1968), as Andersen and Jonsson did:

> All organization structures (designs) can be expressed in these terms. The degrees of complexity, formalization and centralization/complexity vary in organizations. Nevertheless, these dimensions are found in all organizations. (Andersen & Jonsson, 2006, p. 239)

However, Crossan and Apaydin (2010) concluded that studies such as these, trying to link innovation and performance, did not reveal much guidance on organizational structure design.

A potential reason for this may be that the way structure was operationalized in these surveys, based on Pugh et al. (1968), does not capture those dimensions of structure that are essential for high (innovation) performance. To fruitfully study organizational structures, the operationalization should be able to surface whether a structure is functional (activity-based), 'lean' (flows, product based) or customer based (product/service/geographical/market-segment based). The latter two use autonomous units as mentioned above, and such structures have less interfaces and hence a much lower need for coordination, a lower risk of coordination problems and a higher controllability as De Sitter's (1994) showed. He demonstrates that the redesign of the production structure influences the quality of the organization, including controllability and innovativeness, as well as the quality of work.

Now the trouble is that these three truly different structures may have the same degrees of formalization (high) and centralization (low), and yet at the same time one would expect quite an increase in performance when changing the functional structure in a flow-based one using indicators like order lead time and work in process (e.g. Womack & Jones, 2003), but also in absenteeism and employee turnover due to differences in quality of work (De Sitter, 1998; Pot, 2022).

Another (partial) explanation for why the relation between structure and (innovation) performance is not yet clear also follows from Lowlands sociotechnical systems design thinking (De Sitter et al., 1997), which states that controllability can only be influenced by integrally redesigning an organizational structure using De Sitter's design guidelines. Low performance is an effect of a lack of controllability caused by a complex design of the production structure and hence of a complex coordination and control structure. A complex structure has many interfaces, such as 'handovers' in a relay race, in all of its (order) processes, and each interface requires coordination effort and is a potential source of disturbances. Another characteristic of such a complex network of related activities is the propagation of disturbances through the network, e.g. how a problem at the first station of an assembly line eventually stops the whole line. Following Ashby (1956), innovation can be regarded as a ‘regulatory activity’, and in the integral sociotechnical view, innovation performance is negatively influenced by a complex production structure to which the control structure, including the innovation structure, should be properly linked. Therefore, to study the effects of structure on innovation performance, not only the innovation structure but also the whole organizational structure should be integrally studied. This requires such an amount of intricate details in the data that it seems impossible to use a survey. Additionally, the lack of clearly defined, unambiguous and objectively measurable organizational structure concepts, well understood by all practitioners filling in the questionnaires, does not help survey research on organizational structure either.

Therefore, qualitative research is needed here, but doing detailed comparative case studies with large numbers of cases on such a complex object as the organizational structure is much work collecting and analysing data. First and foremost the question now to be answered is:

How can organizational structures be meaningfully and efficiently compared?

Hence, before even starting research to answer the ultimate question ‘how to integrally redesign an organizational structure, especially the embedded innovation structure, to positively influence (innovation) performance?’, a research tool for comparatively studying organizational structures with an emphasis on the innovation structure was needed. Lekkerkerk (2012) developed such a tool and named it the Model Innovation and Organization Structure (acronym: the MIOS) in his PhD project. His work is firmly based in Dutch and European systems thinking (or cybernetics), and all empirical data were collected in Dutch SMEs that are embedded in an economy that is considered to be part of the European Rhineland tradition (Peters & Weggeman, 2019 *Het grote Rijnland boekje*, Business contact).

3 Closer Look at Lowlands Sociotechnical Systems Design and the Gaps

System theory (e.g. Ashby, 1956; Beer, 1994, 2000) and Lowlands sociotechnical theory (e.g. De Sitter et al., 1997; De Sitter, 1994; Achterbergh & Vriens, 2009) provided ingredients for a framework or model to enable comparative case studies on organizational structures and their effect on performance. Sociotechnical organization design originated in research by the Tavistock Institute in the Durham coal mine in the 1950s (Kuipers et al., 2020; Mumford, 2006; Trist & Bamforth, 1951; Van Hootegem et al., 2008). In the Netherlands, further development was led by De Sitter (1998) (e.g., Achterbergh & Vriens, 2009, 2019), starting with his study for the Dutch Scientific Council for Government policy (1981) until his retirement in 1995. A unique systematic design sequence was developed: top-down for the ‘production structure’ and bottom-up for the three-layered ‘control structure’, as is visualized in Fig. 1.

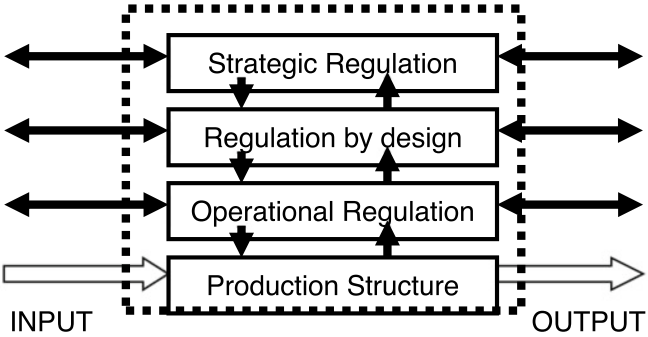

Fig. 1 Lowlands sociotechnical design-view of an organization as an open system

3.1 Production Structure

The production structure (PS), encompassing the operational activities of the primary process, which is selling and delivering the products and services of the organization, should be designed in a way that minimizes the number of interfaces between organizational units. In the usual functional structures, each customer order is handled by numerous departments between intake and delivery. A handover between departments is an interface, requiring coordination between the departments, and interfaces are a notable source of trouble (such as in relay races and in ICT between hardware components and between different software systems). By assigning the activities needed for each type of customer order to one organizational unit or group, 'parallel flows' are created, which are similar to the flows designed in a lean approach to manufacturing (Womack & Jones, 2003) and to a BPR rule to assign end-to-end responsibility for a workflow to one organizational unit (Hammer, 1996). Most former handovers in the order fulfilment process are now *within* these groups, and hence coordination can be by mutual adjustment. Apart from activities that transform input (material, customer, data, energy and combinations) into output, the production structure (PS) includes two other types of work. The first is named 'preparatory activities' (order intake, process planning, invoicing), which are linked to the individual orders but not transforming the main input, and the second is 'supporting activities' (HR, logistics, maintenance, catering, ICT, other facilities) with an indirect link to orders and as basic purpose 'to keep the primary process up and running'. Adding these preparatory and support activities, as much as feasible, to the tasks of the parallel groups responsible for the independent order flows makes these groups even less dependent on the previously existing functional staff and support departments. The primary task of the Lowlands sociotechnical organization designer is to find such independent flows to reduce the number of interfaces, with an at least threefold aim,

- To reduce the interface-related coordination effort and chance of disturbances,
- To prevent disturbances from propagating through the network of tasks of the system,

- To lay a foundation for job enrichment and enlargement because of the larger variety of tasks in autonomous units and to introduce self-management (a.k.a. self-managing, self-organizing teams) in a meaningful way (Lekkerkerk, 2017).

It is worth mentioning that PS design is performed top-down, starting with the whole organization. A first divide may be in the familiar 'independent divisions or business units' or 'flows' at a macro-level of recursion. While Mintzberg (1989) shows his divisionalized form to exist of functionally organized little machine bureaucracies, L-STSD tries to divide these in subflows, and subsubflows, as many times as is needed to arrive at work floor units that have a teamwork enabling size of approximately 6–12 employees (with extremes 4–20). Explaining this design approach is beyond the aim of this chapter, so for further details, use the latest handbook, recently translated into English (Kuipers et al., 2020). De Sitter et al. (1987) may have also been inspired by Simon's concept of nearly decomposable systems (Simon, 1996, p. 197).

3.2 *Control Structure*

The control structure is modelled in three layers following Ashby (1956): operational control, regulation by design and strategic regulation (shown in Fig. 1). In addition, it is designed 'bottom-up'.

To enable the independent PS groups to truly function as 'plants-within-the-plant' or 'hospital-within-the-hospital', as much of the operational control activities as possible should be decentralized to the members (including a team leader) of these groups. Furthermore, some or all of the group members may contribute to 'regulation by design' and even to 'strategic regulation'. This may range from being a part-time member of a product development project team to just attending joint biannual discussions on the strategy.

After implementing the newly designed structure, the group leaders may be responsible for all control activities assigned to the teams at first. However, these groups may develop into self-directing work teams and gradually divide not only prepare and support tasks over a larger part of the members but also control tasks. This team development process may easily take 2–4 years according to Kuipers et al. (2020). Jumping to that blue print end state of team development immediately, or even worse just relabelling all departments to 'self-directing work team' and lay-off the supervisors, so without any change in the production structure at all, proved a recipe for failed 'social innovation'-projects in practice. This may explain why (Dutch) managers lost interest in sociotechnical redesign in the 1990s. However, one should never accuse a theory that it 'doesn't work' because of such poor implementation practices.

The next control structure layer, 'regulation by design', entails all activities aimed at adapting the organization to changes or opportunities in the environment or to fresh strategic insights and new goals developed internally. Achterbergh et al. (1999)

explain that innovation and change projects are the core of 'regulation by design' and coined the term 'innovation structure'. De Sitter (1998) uses 'innovation structure' for this control structure layer and even splits it into 'innovation production structure' and 'innovation (operational) control structure'.

De Sitter (1998) concluded at the end of his last book that developing concrete design guidelines for the innovation structure is needed and presents this as 'a challenge for young scholars' (1998, p. 397). Given that the need for innovation and for higher innovation success rates is still present, this gap in Lowlands sociotechnical design theory should be closed to help achieve that.

3.3 Diagnosing a Structure

Another task for organization designers is to diagnose existing organizational structures first and later on their proposed redesigns for it. They need to answer the following question: when is a structure or redesign good, and when is it a source of trouble? De Sitter (1998) developed seven design parameters to help answer this question, but it is beyond the scope to explain them.

However, if in a redesign project only the present activities carried out by the employees of an organization are taken into account for redistribution, the designer might overlook something. If he would have a model containing 'necessary and sufficient' functions for viability of the organization, he might use that too to find essential activities that are not done at all, probably explaining another part of the problems of the organization. Such a function model is lacking in Lowlands sociotechnical theory, and this is a second gap, next to the innovation structure design guidelines.

These two gaps in Lowlands sociotechnical systems design are linked in the following way. A model containing 'necessary and sufficient' functions will serve as such a diagnostic device but also as the framework needed to systematically describe any organizational structure. An organizational chart only shows the hierarchical reporting lines, and the names of the departments in the boxes hint at what their tasks may be (e.g. quality assurance, operations, marketing). However, an org-chart alone will not do, and by listing tasks per department in the chart, the resulting descriptions of the structures of various organizations become incomparable.

By looking instead through the lens of the functions in such a model, the researcher may put aside the charts and their departments and 'map' the contributions of various employees, groups, (sub)departments, etc., to these functions for each of the organizations in his study. By doing so for each function and for the relations between the functions, the question of which individuals, project teams or departments are involved is answered.

Such an analysis may be described in text and then summarized in a table with two columns; left the functions and right those responsible for each function (see Table 3 in the results section). By adding a third column with data on a second organization, differences between the structures may appear (see Table 4). Now suppose that two competitors, similar in size, product, technology and market, but different in innovation success, are compared, a link may be established between their innovation performance and their organizational and innovation structure. Such a comparison is much more systematic than just comparing processes (e.g. innovation project management, innovation portfolio management), the boxes appearing on the two organization charts or the engineering departments only. In this way, the structures of the cases are studied in an integral way, which is mandatory according to De Sitter:

> So innovation is not a 'separate' topic. From the structure design perspective, it would be wrong to see innovation as a partial problem, to be solved via a redesign of an 'innovative subsystem" (De Sitter, 1998, p. 354, translated Lekkerkerk)

3.4 Reorganizing and Diagnosing Innovation Capabilities and Processes

Following De Sitter (1998), it does not make much sense to study the structure of one part of the organization. This unit is part of a whole, and it has a number of coordination and control relations with other parts of the organizational network. In activity-based structures, as noted before, the number of relations is quite high, which is a reason to call such a structure complex. Reorganizing one of the nodes of such a complex network internally may help slightly, but it is in no way reducing the number of coordination and control relations that must be maintained.

Now, suppose an organization has a functional 'innovation department', and there are signals that the overall innovation performance can be improved. Needless to say, this innovation department has many linkages with most if not all of the other units of the organization. Any innovation project it undertakes will eventually bring about change in several units, so for each project, the interfaces of the project team with each of these units must be defined. When organizing innovation, these interfaces are to be part of the design effort.

Another point is the question of what can be done to diagnose and then improve the innovation process and performance. The literature provides several innovation audit tools, and Lekkerkerk already listed approximately 50 (2012, App. C). Using these tools may be helpful, but they focus on innovation as a functional subunit and/or do not include the organizational structure perspective in sufficient detail according to Lekkerkerk. Therefore, these audits will at best lead to some observations leading to partial improvements. These tools do not incorporate an integral organizational structure perspective advocated by De Sitter (1998, p. 354).

However, Beer (2000) takes such an integral perspective when 'diagnosing the system for organizations' with his Viable System Model, but only one of the five functions (Function 4 or 'outside and then') can be considered the larger part of the innovation structure.

Because innovation audits are partial and because both De Sitter and Beer lack a detailed view on innovation, in spite of the integral nature of their respective approaches, it is necessary to expand their models or in systems thinking jargon 'to open the innovation structure black boxes' to see which subfunctions are needed.

3.5 Defining Innovation

Innovation is a core concept here and should be defined first because so many different definitions may be found both in the literature and among practitioners. Below, a specific definition that is useful at the organizational level and fits with our organizational structure design purpose is outlined. Additionally, the distinction with continuous improvement used in this research is described.

Several *types* of innovations are distinguished, e.g. technological, social, organizational, product, process, ICT, service, market or business model innovation. The OECD defines most of them in the Frascati Manual (OECD, 2002) and Oslo Manual (OECD, 2005, 2018). However, these manuals only mention as an aside that innovation projects done by organizations usually deliver several types of innovation, e.g. the new innovative product, the new process needed for it, a new group in the sales department to sell it to the new market and the new channel to be developed. In the latest Oslo Manual, this point is stressed more: '*Many innovations are bundled, presenting characteristics that span more than one type*' (OECD, 2018, Sect. 3.49). Practitioners tell the author that in their view, multiple, 'bundled' innovation-type projects are the rule rather than the exception. This aspect in the definition underpins the need to form multidisciplinary teams for innovation projects. Additionally, the basic or applied research projects a company may do that will eventually lead to new products and processes via advanced engineering and subsequent detailed development can best be considered innovation projects being part of the total 'innovation and change portfolio'. This fits with the Oslo Manual's listing of innovation activities of businesses (2018, Sect. 4.8).

Apart from the *type* of result, innovations are also often characterized by their degree of *newness*. An innovation may be new to the world (the very first car, computer, smartphone), but it is always new to the organization developing (or sometimes just buying) and implementing it. Tidd and Bessant (2021) use newness to distinguish two basic kinds of innovation projects:

1. 'discontinuous innovation' for radical or explorative innovations, adding something new to the market,
2. 'steady-state innovation' for incremental or exploitative innovations related to the existing set of products and services.

According to them, each kind has its own approach or 'funnel', which they draw as parallel processes, indicating different approaches and perhaps even different organizational units or groups. In fact, rather than a dichotomy, this is more a continuum, ranging from very similar to current practice to truly very new to the innovating organization. Apart from being new to the innovator, it may be new to the world outside the organization (or not). Usually, 'new to the world' innovations are of a more radical nature. In practice, this continuum does not lead to an endless variety of project approaches; organizations usually limit themselves to two or three combinations of project type and a matching approach. The degree of newness translates into the predictability of the results at the start of a project, which largely determines the approach.

The classic sequentially phased project approaches (e.g. Cooper's stage-gate, the 'waterfall' or in ICT the systems development methodology, SDM) are still suitable for steady-state innovation projects, and a business case will provide a financial section without large uncertainty margins (e.g. ROI or NPV calculations).

For the radical, explorative type of ideas, approaches such as rapid application development, rapid prototyping or 'the lean start-up' (Ries, 2011) seek market feedback by showing consecutive prototypes, usually of software apps, and proceed (or not) based on responses from target customers to launch the 'minimum viable product' (Ries, 2011) that may be further developed in subsequent releases.

Tidd and Bessant (2018) also describe that balancing the 'innovation and change portfolio' is necessary with only 15–20% of projects and resources in the riskier discontinuous, explorative innovation funnel.

3.6 A Practical Distinction Between Innovation and Continuous Improvement

The distinction between (incremental) innovation and continuous improvement (CI) is not clear, and the subjective degree of newness will not provide a clue. Organizations usually carry out innovation on a project-by-project basis, with each project based on a 'business case' (or innovation project proposal), which at some point was formally approved by higher management or an 'innovation board'. In contrast, continuous improvement is mainly carried out within and by employees in any department alongside their daily work, and they are empowered to implement the changes without prior higher management approval and without much involvement of other departments. From a systems theory perspective, finding, evaluating and implementing such small improvements are considered to be part of an operational control loop (Kuipers et al., 2020, p. 73). Because every activity or process needs operational control, continuous improvement (or 'kaizen' or 'high involvement innovation' (Bessant, 2003)) has its logical place there, which does not mean that it gets done. The fact that continuous improvement (CI) has to be deliberately organized and managed according to TQM and lean theory and its importance for overall performance improvement means that one should pay explicit attention to CI when diagnosing and redesigning a structure. CI being part of operational control implies that there is no separate organizational 'CI function' needed from a systems theory perspective.

To summarize, innovation is defined here as (the results of) an innovation project, incorporating at least one, but usually more types of innovation, and done by a multidisciplinary and temporary project team. Depending on the degree of newness, for the firm and perhaps for the market or wider environment, and some other factors, the project team may choose a semi-linear stage-gate approach or a more experimental, rapid prototyping approach. Contributing to incremental improvement is part of each job, e.g. using 'kaizen'-tools and/or quality control tools (Mizuno, 1988).

4 Development of the Function Model: The MIOS

As was already mentioned, for an integral approach to the innovation structure embedded in the whole organizational structure, the (function) models described by De Sitter and Beer need further development. A 'function model' of an organization is a concept from organizational cybernetics (systems thinking is near synonym). Function here refers to the contribution of an element or subsystem to the system it is part of (In 't Veld, 1994). Therefore, it should not be confused with 'function' referring to 'an individual's job' or to a functional (or activity-based) structure. 'Model' refers to a simplified representation of the complex reality to highlight certain characteristics, in this case, the different functions and their relations that are needed to keep an organizational system 'viable'.

Beer (1994, 2000) developed a function model, known as the Viable System Model (VSM), and like De Sitter, he is building on Ashby (1956). Given the expectation that detailed design guidelines for the embedded innovation structure are the ultimate result of comparative case study research, the question is now whether Beer's VSM is useful for this study. It has some advantages. Based on systematic reasoning, not challenged to date (Achterbergh & Riesewijk, 1999), Beer claims that his VSM incorporates 'necessary and sufficient' functions for viability. It incorporates the logic of recursion that fits well with the sociotechnical idea of a production structure consisting of (near) autonomous units, which (depending on the size of the organization) may be further divided into again (near) autonomous subunits. For example, there are three divisions of Philips, each divided into business units, and so on, until groups and individuals at the shop floor are reached as the lowest practical level of recursion (Beer, 2000, In't Veld, 1994).

A first drawback of the VSM is that it only contains five functions, and only one or two functions are directly involved in innovation, with a third as a strategic innovation control function. For a detailed comparison of innovation structures that is not sufficient. Another disadvantage is its abstract nature and terminology that prevent practitioners from intuitively understanding it. Therefore, the VSM serves as a basis, but a model containing more functions to represent the innovation structure and giving all function names that appeal to practitioners is deemed necessary.

In't Veld (1994) supplied the first ingredient for development of the new model. He developed two models based on systems thinking and pragmatic engineering logic that contain more innovation-related functions using understandable names (Veeke et al., 2008).

Second, the innovation management literature supplies the steps in any innovation process: search, select, implement and capture (Tidd & Bessant, 2009, p. 44).

The distinction between exploration and exploitation (March, 1999, p. 133), linked to radical and incremental innovation, with the idea that any organization should do both in an 'ambidextrous' way (O'Reilly III & Tushman, 2004), was also used.

Closely linked to ambidexterity is the notion of a balanced innovation portfolio of projects (Kester et al., 2009, p. 328).

Combining newly developed and existing knowledge is related to innovation (Hislop, 2005), so organizational memory is important.

Due to the size limits of a chapter, only the outcome of the theoretical work using the ingredients listed above is presented. In Lekkerkerk (2012), the full line of reasoning can be found. The resulting model is named 'the Model Innovation and Organizational Structure' (acronym: the MIOS). Figure 2 presents the model. The names of the functions contain a verb, according to system theory custom and a code (I, C and V for **i**nnovation, **c**entral and supply (**v**oortbrengen in Dutch), respectively, and a number) serving as a practical shorthand when discussing how functions are assigned.

The contributions of the twelve functions of MIOS to an organizational system are summarized in Table 1, and continuous improvement is added for the reasons

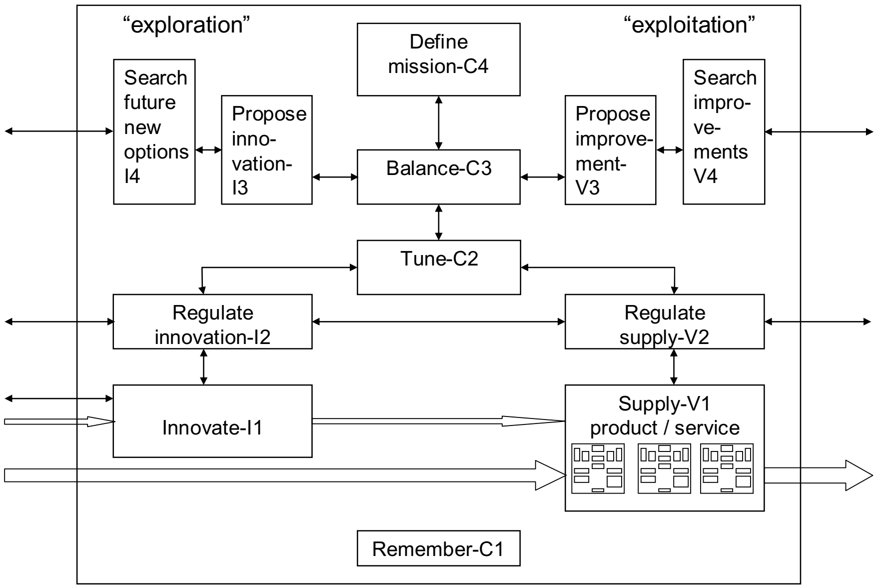

Fig. 2 Developed function model: the Model Innovation and Organizational Structure or 'the MIOS'. (Lekkerkerk, 2012, p. 296). *Note:* Many relations between all functions, e.g. those of Remember-C1 with all other functions, are omitted for clarity of the drawing only

explained above. Being based on the logic of Beer's VSM, this new model also contains 'necessary and sufficient' functions. This implies that an organization that implements all these functions and their relations in its structure, and of course assigns them to competent employees who execute them well, is able to remain viable, i.e. 'able to maintain its separate existence' (Beer, 1994, p. 113).

Like the VSM, the MIOS incorporates the idea of recursion, meaning that the Supply-V1 function may consist of separate, independent parts that are (or should be) viable subsystems. In Fig. 2, the small versions of the MIOS in the function Supply-V1 symbolize this recursion. Large companies may have independent divisions, which consist of business units, and in such organizations, the 'right' degree of

Table 1 Brief description of the functions in the MIOS (Lekkerkerk, 2012, p. 297)

Name code	Contribution of function to organization
Supply product service-V1	Represents the primary process supplying products and/or services by transforming inputs in output Includes order-related activities: logistics, process planning, sales, finance, procurement, etc. Includes supporting activities: maintenance, HR, facilities management, etc.
Regulate supply-V2	Operational regulation of the various aspects of the primary process including continuous improvement
Propose improvement-V3	Make project proposals for the best opportunities for improvement received from V4
Search improvements-V4	Search for and find ways to improve exploitation of current products, markets, facilities, etc.
Innovate-I1	Carry out all approved innovation projects and improvement projects
Regulate innovation-I2	Operational regulation of individual innovation projects and operationally manage the portfolio of projects in progress
Propose innovation-I3	Make project proposals for the best future options for innovation received from I4
Search future new options-I4	Exploration of environment and search for future options for innovation, aimed at new and existing markets
Remember-C1	Organizational memory storing codified knowledge relevant for the organization
Tune-C2	Tuning V1 and I1 enabling smooth implementation of innovations and tuning the upper six functions contributing to the strategic planning process
Balance-C3	Balancing the project portfolio by strategically choosing which new proposals (from V3 and I3) should be funded and at the same time which of the projects in progress should be continued, paused or aborted
Define mission-C4	Define the mission, vision and strategy for the company and deriving lower level strategies for supply and innovation including performance indicators and budgets
Continuous improvement	Small-scale improvement or 'kaizen' activities within each functions operational regulation

(de)centralization of control, which includes regulation by design or innovation, is a challenging task for the structure designer.

These MIOS functions are related to the innovation management and sociotechnical literature briefly described above. The generic, somewhat simplified innovation process steps from a well-known textbook (Tidd & Bessant, 2009, p. 44) mentioned above link to the MIOS functions in the following way:

Search	Both Search functions (V4/I4) and both Propose functions (V3/I3)
Select	Preliminary selection is part of both Search and Propose
	Final selection of proposals by Balance-C3
Implement	Carrying out and operationally managing the selected innovation projects by Innovate-I1 and Regulate innovation-I2

Figure 3 presents this in a visual form, highlighting the distinction between explorative and exploitative innovation projects. Because both types have to be present in a 'balanced' innovation portfolio, the function Balance-C3 cannot be divided. The execution of innovation projects (Innovate-I1) may also depend on this distinction, but that is not shown here. Opening the Innovate-I1-box may, for example, reveal a research subfunction (delivering new knowledge to the system), feeding into a radical innovation project function. Parallel to these, an incremental innovation project function will be present.

The Lowlands sociotechnical theory matches the MIOS functions in the following way. The production structure as defined by De Sitter (1998) equals Supply-V1.

The three layers of his control structure are incorporated as follows. Regulate supply-V2 is his operational regulation layer, and Define mission-C4 equals strategic

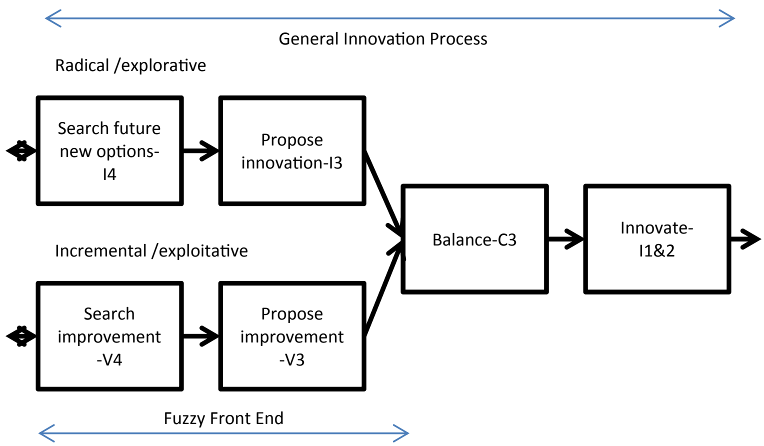

Fig. 3 MIOS functions and a general innovation process model

regulation. The remaining functions are detailing the layer regulation by design (or the innovation structure).

Remember-C1 supports all other functions by serving as organizational memory.

After combining elements from various existing models in the new MIOS, the question of whether it actually serves its intended use as a research tool for comparative case studies and as a diagnostic tool for practitioners was answered by testing it. To that end, Lekkerkerk (2012) presented it first to four experienced sociotechnical organization designers and management consultants. They were positive about the completeness of the model and did not miss a function. In their opinion, it would indeed be usable for diagnosing both existing structures and redesigns.

Second, the MIOS was applied in five organizations by Lekkerkerk, and the results reported in his PhD thesis defended in 2012 at Radboud University (Nijmegen, The Netherlands). Following Lekkerkerk's project, several MSc students in business administration at Radboud University applied the MIOS in their graduation projects.

5 Methodology of the Review of the Case Studies

This chapter can best be seen as a 'grey literature review' because it searches for applications of the MIOS and then analyses the papers that contained sufficient data to enable a comparison.

To increase the amount of data, the studies conducted in five companies by Lekkerkerk (2012), listed in Table 2, were included. The methodological details of this part of the research are in the PhD thesis (Lekkerkerk, 2012). Data collection took place in 2010.

The other selected papers presented here obviously also applied the MIOS. All were the result of a successful graduation project of MSc students in Business Administration at Radboud University, and all were supervised by Lekkerkerk. Each paper, or rather Master Thesis, was rated independently as defendable by the supervisor and a second examiner. After presenting and defending the thesis to this two-person exam committee, the members agreed upon a final grade. Therefore, they all meet the minimum standards of sound academic work. They followed a case study approach

Table 2 Five anonymous companies (Lekkerkerk, 2012, Table 6.1.1, translated)

#	Name	MPS*, main product	Sites	Employees	Interviews
T1	Eline	EtO, electrotechnical	3	120	4
T2	Amelie	EtO, marine electrotechnical	9	580	7
T3	Ezra	MtO, seed improvement	11	300	4
T4	Leon	AtO, trailers, OEM modules	1	130	5
T5	Rik	AtO, mobile cranes	1	140	9

Note MPS master production schedule, indicating what part of the primary process is on customer order, *EtO* engineer to order, *MtO* make to order, *AtO* assemble to order

(Yin 2003), and were done and defended between 2011 and June 2014 by fourteen MSc students. They were coded as S1, S2 … S14 (Table 5).

Because one student made an organizational structure redesign and used the MIOS to check whether his redesign covered all necessary and sufficient functions, it was excluded. A redesign of a structure is not suited for linking it to the actual performance of an existing innovation structure, so this case (S9) is left out (Table 5).

Another student studied a software firm (S3) with a cell structure, and his case was left out of the table because it was too different, both the kind of organization, the structure and the way he applied and reported the results of the various 'cells'.

Because master's students are required to acquire their own research object, the strategy for selection of the cases is rather 'pragmatic', and as an inevitable consequence, the possibilities to 'fruitfully' compare this collection of 'apples and oranges' will appear to be somewhat limited. Most of these studies were diagnostic projects in which the innovation and organizational structure were studied using the MIOS, usually adding an innovation management problem of the organization. This increased the practical relevance of the project for the organization as a kind of reward for making time of respondents and a company supervisor available to the student.

In all organizations, students collected data on the innovation and organizational structure using an approach similar to that of Lekkerkerk (2012). They conducted approximately 8 semi-structured interviews, made full transcripts and coded the transcripts using the MIOS functions and their relations as a basis for part of the questions and subsequent coding. The transcripts were sent to the respondents for their approval. Existing organizational documents, e.g. quality manuals and job descriptions, were gathered and analysed to determine the formal organization and compare or check with the interview data. The company supervisors approved the final draft of the theses, so the data on their organization can be regarded as correct.

Thus, twelve of the companies studied thus far by students delivered results suitable to present along the five from Lekkerkerk (2012), so Table 5 in Appendix 1 shows 17 organizations. The first 5 companies studied by the author are coded T1-T5, as shown in Table 2. The student organizations are anonymously coded S1, S2, etc. (chronological according to the dates of defence of the master's theses).

All organizations are based in the Netherlands.

6 Results Based on the Cases

The first few rows of the large Table 5 (Appendix 1) contain some basic data of the organizations, which are sorted by the size in number of staff of the organization (-al unit) that was studied. There is a mix of large and small product and service companies, a large hospital department and one government agency (supervising authority).

For industrial companies, their 'MPS' or master production schedule type is mentioned to characterize the customer interaction they have. Appendix 2 lists the references to the student cases used. Fortunately, because even 'apples and oranges' have a lot in common (fruit, size, skin, seeds, edible, from a tree), some interesting observations can already be made, and these are presented below.

In each of the organizations, the structure was described and diagnosed using the MIOS and judged using mainly additional Lowlands sociotechnical theory and insights from the innovation literature. The judgement in Table 3 on Remember-C1 is based on Hislop (2005) and that on Balance-C3 is backed up by innovation portfolio management (Kester et al., 2009). Some cases go one step further and give some judgement on how well the function is performed. It is beyond the scope of this chapter to elaborate on that.

It should be noted that a diagnosis using the MIOS only is limited to a near-binary one: a function is (in)formally fulfilled or not and more or less well related to the other functions in the organization. Therefore, there are three diagnostic outcomes for each function: missing, fulfilled informally and fulfilled formally.

As an example, Table 3 presents a part of the diagnosis of Eline (T1). Lekkerkerk (2012) and the master's theses (listed in Appendix 2) show full tables of all organizations.

No missing function appeared in the seventeen organizations. For T1-T5, this was no surprise because innovation success was one of the selection criteria. To show that this may actually happen serves the example from a consultancy assignment by Lekkerkerk (personal data). All members of the management team of the Dutch branch of the organization agreed that for the last couple of years, no radical innovation projects were proposed. Reasons for that may be that 'Searching future new options-I4' is not fulfilled at all. Alternatively, as an alternative explanation, such ideas were all rejected before these managers became aware of them. For example, when the preliminary investigations were done at some central unit, assigned with the Propose innovations-I3 function and showed only problems and no market potential to develop a sound business case (or innovation project proposal).

Looking at the informal-formal option, it seems interesting to note that the functions in the upper half of the model (both Search and Propose functions and Balance, Define mission) were often just done informally (Table 5, Appendix 1).

When a function is fulfilled, its outputs are present or concrete, such as a strategy document for Define mission-C4 or proposed business cases for both propose functions (I3/V3). That enables the researcher to determine, e.g. in dialogue with the respondents or by analysing the available formal job descriptions, to what extent such a function is informally done or is a formal part of one or more job descriptions.

Obviously, action-oriented managers would like to hear more than just: this function is not fulfilled or assigned informally or formally. They need more details than the summary in the third column 'judgement' to determine whether action is needed. To reach such a more detailed conclusion and maybe give advice on a solution, researchers or consultants using the MIOS need additional (normative or prescriptive) theory to compare current practice with the state of the art on innovation portfolio management (related to Balance-C3), innovation project management (Innovate-I1, Regulate innovation-I2) or knowledge management (Remember-C1).

The comparison of organizational structures using the MIOS-based descriptions can be summarized in a table, which is briefly illustrated in Table 4, presenting the

Table 3 Partial diagnosis of the organizational structure of Eline (T1) (based on Lekkerkerk, 2012, Table 6.2.6)

Function	Assigned	Judgement (using additional theory)
Innovate-I1	Formal	Sufficient
Regulate innovation-I2	Formal	Mixed with regulate supply-V2
Propose innovations-I3	Informal	Sufficient
Search future new options-I4	Informal	Sufficient
Remember-C1	Informal	Insufficient
Tune-C2	Informal	Sufficient
Balance-C3	Informal	Too little incremental projects

Table 4 Comparison of the innovation functions of Leon and Rik (based on Lekkerkerk, 2012, Table 6.7.2)

Function	Leon (T4)	Rik (T5)
Innovate-I1	A project team mainly engineering staff	By R&D and production engineering staff sales manager
Regulate innovation-I2 per project	Project leader may report to managing owner	Head R&D, head prod. engineering
I2 portfolio	Market team	'R&D-meeting'
Propose innovations-I3	Members of market team + various other (ad hoc)	Ideator or R&D/PE staff
Search future new options-I4	Managing owner, management team and engineers	Managing owner and sales managers

four innovation functions of Leon (T4) and Rik (T5). Both companies employ 130 and 140 employees who design, manufacture and service wheeled equipment, respectively. Both had approximately 10 people in a research and (product) engineering department.

6.1 *Analysis of the Cases or Attempting to 'Compare Apples and Oranges'*

For each organization, Table 5 in Appendix 1 indicates which of the MIOS functions were formally assigned to, or informally done by, employee(s) or departments in the companies (or not done at all). Seven observations are drawn from the table and the case descriptions listed in Appendix 2.

First, Table 5 shows that larger companies (in number of employees) tend to assign more functions formally than smaller ones. Even small units within these larger units are formally organized, as the 2nd column (case S7) shows. This confirms common knowledge.

A second observation is that the functions that represent the primary process, or operations, are nearly always formally assigned (Supply-V1 and Regulate supply-V2). One exception for both functions is S12 (extreme left column), which is small (4 employees) and relatively young and dynamic. The partial exception for Regulate supply-V2 is S14, which is also a small company. In the fifteen other cases, the primary process responsibilities are formalized. Given the number of employees involved this is what you would expect. Apart from size, organizations holding an ISO9000 certification are required to formalize tasks and responsibilities in their customer order-related primary processes.

Third, the table shows that fifteen organizations, with S4 and S12 as the exceptions, have formally assigned Innovate-I1 and Regulate innovation-I2. Contributing and managing innovation projects involves many human and financial resources, so formalizing the core of the innovation process seems logical.

A fourth observation relates to the distinction between explorative and exploitative innovations. Some of the organizations (T1, T2 and T4) did not make an explicit distinction between the two pairs of Search and Propose functions. Therefore, the pairs V3/I3 and V4/I4 are 'combined' and performed by the same employee(s). Nevertheless, it is worthwhile to make this distinction because it is obvious that for ideas concerning present products, markets and processes, employees have to search (V4) somewhere else (e.g. mainly among customers and frontline employees). Searching future new options-I4 may involve a quest for disruptive innovation to be expected in mature technologies (Christensen, 1997). The criteria applied to the preparation (and selection) of the business case are different because these kinds of innovations are incremental and less uncertain (V3).

Although the fifth observation relates to only 8 out of 17 cases, it is worth mentioning that in only one of these eight organizations continuous improvement is formally organized. Because the importance of continuous improvement has been advocated since at least the mid-1980s, in publications on just-in-time, statistical process control, total quality management, ISO9000, 'six-sigma', lean and (high involvement) innovation, the author expected that this would have been incorporated into formal job descriptions and routines by all organizations after nearly 30 years. The excuse of T2 was that the company had to downsize the workforce by nearly 50% approximately a year before the interviews due to the 2008 economic crisis, and their lean project manager was among those fired. At the time of the interviews, T2 management had other priorities above reviving and finishing the lean implementation with an improvement mechanism. The informal ways of working at improvement were similar: employees know who to turn to with a suggestion (usually to their own manager but also directly to a product engineer), and if feasible, the ideas are implemented. However, no records were kept of the number of suggestions, rejection rates or total savings.

A sixth observation links to the general innovation process and to the concept of the 'fuzzy front end' (FFE) of innovation (Koch & Leitner, 2008). In the 'innovation journey' process model by Van de Ven et al. (1999), a similar period, from the generation of an idea or opportunity and the decision to select and hence formally start and fund the innovation project, is labelled the 'gestation period'. The three steps 'Search-Select-Implement' and the distinction between radical and incremental innovation projects are linked to the functions as explained and shown in Fig. 3 above. Both Search functions (V4 and I4) and Propose functions (V3 and I3) were formally assigned in approximately one-third (4–7) of the 17 companies only. As Kurkkio et al., (2011, p. 134) already noted, the lead time between the generation of an idea and deciding upon the business case or innovation project proposal based on it (Select by Balance-C3) can be shortened by introducing a procedure for the FFE. Talke et al., (2006, p. 378) see 'select' as part of the FFE too. From a structure perspective, this implies that such a procedure makes clear to employees who have responsibilities in this FFE procedure and who may be involved in searching and converting ideas into business cases. Both 3M and Google allow certain employees to spend 10 or 25% of their working time to tinker with ideas and try to determine whether they are technically feasible and economically promising. If so, the business case can be written and presented to the 'innovation board' or a decision team with any other label that performs the function Balance-C3. If time-to-market (TtM) is measured from the generation of a product idea through to introduction on the market, formalizing the FFE may shorten TtM considerably, also enabling 'failing fast', i.e. trying to determine the feasibility of an idea as soon as possible to prevent wasting resources.

The seventh observation relates to larger companies and may not be directly visible from Appendix 1. The bigger an organization grows, the larger the number of dedicated innovators in its workforce becomes, and they are usually grouped in a department. Medium-sized companies such as T2, T4 and S4 had one separate department of approximately 10 employees, of approximately 130 employees in total, responsible for most of the (product) innovation activities. When organizations successfully grow, they develop new PMCs and may organize their activities in separate business units. This was the case with T3 having three business areas and T5 having two independent divisions. As soon as each BU grows large enough to potentially have its own separate 'innovation department', the problem arises regarding whether innovation-related functions should be assigned at the corporate level or at the divisional/business unit level or both. For (radical) ideas, with a development lead time beyond the horizon of the BU management that makes them reluctant to start and fund such innovations, a central innovation function seems necessary. Alternatively, when a radical idea cannot possibly be sold at the existing markets or via the existing channels of the BU's or requires a different business model, the BU-level does not seem appropriate for such an innovation at all (e.g. the IBM-PC was developed within and sold by a new unit completely separate from the mainframe computer division). At T3, with 300 employees distributed among 11 sites all over the world serving three business areas, a central research department already existed, which was linked to university research groups and responsible for delivering proof of concept to a central 'Development' group working together with Operations at the main site to scale up and implement. On the other hand, company T5, nearly four times as large with 1.100 employees in two divisions, did not have a central innovation group, and its two divisions did not do innovation projects together, in spite of the fact that they have a common knowledge base. At first sight, T5 seemed to miss opportunities by not sharing innovation results across the units. The Marine division that participated in the study might benefit from the results of a lean-EtO project that the other division did, but respondents did not even know about it when asked by the researcher who heard about this project at a seminar he attended. Apart from T3 and T5, students doing cases S4, S6, S7, S8, S11 and S13 were faced with the multiple levels of recursion problem.

With this seventh observation, the potential for analysing the data collected thus far seems exhausted.

7 Conclusion, Discussion and Reflection

The cases did reveal that the MIOS serves its intended purposes as a diagnostic tool for practitioners and as a descriptive tool for researchers. The systematic descriptions of the structures along the MIOS functions provided sufficient detail (not shown here, see Lekkerkerk, 2012 and the 12 theses) to compare and contrast them. Although it may seem somewhat superficial at first sight, to just summarize whether functions are fulfilled (or not), and assigned formally or done informally (only because someone likes to do it, or sees the need). However, these descriptions served as a solid, systemic basis for further diagnosis and redesign. For example, zooming in on the Supply-V1 organization, using organizational design theory as a lens, may show opportunities for simplifying the production structure in autonomous product-, service- or market-based units. Then, redesigning the innovation structure is possible whereby each (business) unit may have its own decentralized innovation function. Alternatively, zooming in on Innovate-I1 and Regulate innovation-I2 may lead to rethinking innovation project management approaches. For example, are there at least two funnels like Tidd and Bessant (2009) suggest? Does each have a state-of-the-art way of managing the projects and proper evaluation criteria for business cases?

It is too early to translate the observations into the detailed additional design guidelines for the innovation structure that the Lowlands sociotechnical systems design methodology needs (De Sitter, 1998). Additional data on innovation performance and more details about the actual organizational structure seem to be needed to single out the best practices.

Additionally, the fact that only relatively small Dutch organizations were studied, and their variety, should be mentioned. They are part of the Rhineland tradition of organizing, which is more stakeholder oriented, compared to the Anglo-Saxon tradition, where shareholder value prevails and profit maximization is the main goal and where functional structures based on economies of scale logic are the norm. Because Rhineland tends to put the work floor professional first and is more inclined to decentralize regulation and control responsibilities to the shop floor, it may be that their structures show less formality, which is not only explained by their relatively small size compared to SMEs outside the Netherlands.

7.1 Relatively Easy to Apply and Quick Results

The two to three weeks per case study by Lekkerkerk may be more consultancy hours (80–120) than a client organization can afford to pay for a diagnosis, but for research purposes, this amount of work does not seem to be prohibitive. Especially not when research is done by MSc students for which labour costs are low.

Additionally, the MIOS proved to be a suitable tool for use in graduation projects of students without much work experience. None reflected negatively upon their experience with using the MIOS, although they were explicitly encouraged to be truly critical by their supervisor ('If you find a flaw this will honestly improve your grade!'). Two quotes as an example:

> "In all, it was found that the MIOS is appropriate for diagnosing organizational structures, given that the researcher is aware of the broad theoretical basis underlying the model." Case S3, De Hosson (2011, p. 76).

> "The MIOS has proven to be truly useful and applicable in practice, although it is important that the person using the model is familiar with sociotechnical theory." Case S5, Dijkhuis (2012, p. 70).

Some of the students were determining the structure in larger organizations with multiple levels of recursion (some divisions, with business units and even subunits), and they struggled with the organizational complexity, but in the end, the MIOS helped them to cope with these recursions. In such organizations, the responsibility for innovation projects may be distributed over and assigned to subunits, to business units, to the divisions or centralized and reported to headquarters. This depends on the scope of the project. A project such as ERP implementation would be central because the entire organization would have to work with it, whereas implementing a specific piece of software, only useful for one subunit, may be done by employees from the unit, with maybe an IT architect as part of the team to ensure fit with existing ICT.

7.2 Practical Relevance and Usability

When MSc students in Business Administration, educated in the underlying theory (social system theory, Lowlands sociotechnical system design) but without much working experience, can successfully use the MIOS as a diagnostic tool in their graduation assignments, it can be assumed that consultants and managers with some education in business administration can apply it for diagnostic purposes.

Diagnosing can be done by an 'expert' interviewing a sample of employees and processing the results in (less than) a month, but a small team of organizational members may need a few days together and maybe even fewer.

Additional experience on two other occasions indicated that this assumption may indeed be correct. In a seminar (November 2013) for various managers and in a one-day workshop with the management team of the Dutch subsidiary of a multinational (February 2014), where the author briefly presented the MIOS, the participants fruitfully applied it to their own organization. The latter team was slightly shocked to determine that despite their many years of combined experience in the firm, they could not indicate who of their 16,000 colleagues in North and Western Europe might be involved in or responsible for Search future new options-I4. The MIOS helped them find a/the cause for the incremental nature of their firm's innovation projects.

More detailed diagnosis may be carried out by adding additional theories or audit frameworks. For example when the innovation portfolio management responsibilities (related to Balance-C3) appear to be absent or unclearly assigned, or when the production structure seems highly complex, insights can be added from portfolio management literature or L-STSD, respectively. This will lead to additional benefits for the organization, while at the same time the case can retain its usefulness for the theoretical multiple case comparison.

7.3 Reflections on Further Research

For further research, the suggestions by Elsahn et al. (2020) can be taken into account. From this review, three potential improvements to the case research protocol surfaced from trying to analyse and compare these students' cases.

First, a further standardization of the format in which students have to report the data on their case would facilitate the comparison and prevent missing data on the organization (e.g. on continuous improvement, on general organizational performance and on its innovation success rate).

Second, the recursive thinking appeared to be difficult, so some additional guidance should be developed on how to use MIOS in large organizations with multiple divisions, each consisting of strategic business units, and business units. This can help to map out what innovation responsibilities and activities are done by all units at each of the levels; central, divisional, SBU, BU and even below to some innovation done by operational work floor teams next to their daily duties.

Third, with a relatively limited number of cases and the wide diversity of the organizations, no clear patterns can yet be expected to appear in the organization of innovation. It would be worthwhile to try to gather sets of cases done in more comparable organizations, e.g. all having one site, roughly equal number of employees, same industry or main technology, same degree of volume and variety in product/service and same or similar markets and customers (BtB or BtC). This is based on the assumption that their innovation challenges would also be similar.

8 Towards Multiple Value Creation and Innovative Workplaces

Debates on Environmental, Social and Governance (ESG) are getting stronger and strengthen the need to use a triple bottom line, People-Planet-Profit, for organizations to help solve many problems.

Currently, too many employees (*people*) suffer from stress and burnout, so improving the quality of work by redesigning the structure is greatly needed. Others propose improving the 'meaning quotient' of work (Cranston & Keller, 2013) and creating the best workplace on earth (Goffee & Jones, 2013). This social responsibility extends along the supply chain to low-wage-countries where payment and labour conditions are poor.

At the same time, innovation is deemed necessary to solve sustainability issues, and more innovation success will both increase the chances of finding solutions on time to save the *planet*, lead to more income and *profit* from successful innovations and reduce innovation costs, which may also improve *profit*.

All this requires jointly optimizing the quality of organization and of work. Lowlands sociotechnical system design is already quite capable of doing that for the primary process. Further developing this design approach by using the MIOS in sets of comparative case studies, ultimately leading to design guidelines for 'innovation structures', might speed up innovation and improve innovation success. This leads to innovative and responsible workplaces and implies that the same amount of resources will yield more innovations delivering multiple values.

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Appendix 1

See Table 5.

Table 5 Combined and condensed data on 17 cases (5 by author and 12 by students supervised by author + peer review of master thesis at defence)

OrgCode	S12	S7	S14	S1	T1	T2	S4	T4	S5	S13	T3	S11	S2	T5	S10	S6	S8	
Emplo	?	1400	30	80	120	130	140	140	210		300	300	390	1100		2164		
In BU	4	4								250				580	1100		11 k	
Since	2008	1997	1884	1975	1959	1959	1987	1987	1932	< 1900	1968	1850	1884	1900	1850	1893	1881	
MPS[a]	serv	sw	AtO	EtO	EtO	AtO	EtO/MtS	AtO	AtO	MtO	MtO	care	EtO	EtO	cons	gov	fin	
MIOS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Sum
Function																		# F
V1	i/F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	16
V2	i	F	i/F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	15
V3	i	F	i	i	i	i	F	i	F	F	F	i	i	i	F	F	i	7
V4	i	i	i	i	i	i	F	i	i	i	F	F	i	i	F	F	i	5
I1	i	F	F	F	F	F	i	F	F	F	F	F	F	F	F	F	F	15
I2	i	F	F	F	F	F	i	F	F	F	F	F	F	F	F	F	F	15
I3	i	F	i	i	i	i	i	i	i	F	F	i	i	i	F	i	F	5
I4	i	i	i	i	i	i	i	i	i	i	F	F	i	i	F	i	F	4
C1	F	F	i	n	i	i	i	F	F	i	F	i	i	i	F	L2	i	6
C2	i	F	F	F	i	F	i	F	i	F	F	i	i	F	F	F	i	10
C3	i	F	i	F	i	F	i	F	F	F	F	i	F	F	F	F	F	12
C4	F	F	F	F	i	F	F	F	i	F	F	F	F	F	F	F	F	15

(continued)

Table 5 (continued)

OrgCode	S12	S7	S14	S1	T1	T2	S4	T4	S5	S13	T3	S11	S2	T5	S10	S6	S8	
# Form	2	10	5	7	4	7	5	9	7	9	12	7	6	7	12	9	8	n.a
CImpr	?	?	?	i	i	i	?	F	?	?	i	?	i	i	?	?	i	

Appendix 2

References to Student Case Studies

Archives of all MSc theses, including digital versions and most of the transcripts and other data, with the author.

The nine non-confidential theses are publicly available in the Nijmegen School of Management MSc thesis collection (a.k.a. Radboud Repository).

S1 Geukers, J. (2011). *Innovation in an engineer-to-order organization. A case-study in the superyachting industry.* **(confidential)** MSc-thesis, Business Administration, Radboud University, Nijmegen

S2 Sadelhoff, A. van (2011). *A recommendation regarding process planning for Royal Huisman Shipyard.* MSc-thesis, Business Administration, Radboud University, Nijmegen

S3 Hosson, F. de (2011). *The structural dilemma of Topicus. A story of cowboys and chameleons: evolution of an extraordinary organism.* MSc-thesis, Business Administration, Radboud University, Nijmegen

S4 Maas, J. (2012). *Can structure fix multiple problems? A diagnosis of the current and future organizational structure of "S4".* **(confidential)** MSc-thesis, Business Administration, Radboud University, Nijmegen

S5 Dijkhuis, K. (2012). *Organizing the future.* **(confidential)** MSc-thesis, Business Administration, Radboud University, Nijmegen

S6 Melgers, D. (2012). *A diagnosis of the innovation structure of the Nederlandse Voedsel- en warenauthoriteit.* MSc-thesis, Business Administration, Radboud University, Nijmegen

S7 Biesmans, mrs. M. (2012). *The reorganization of "S7". A research project focusing on the organization structure of "S7" and the involved parties at "mother company" in order to increase performance.* **(confidential)** MSc-thesis, Business Administration, Radboud University, Nijmegen

S8 Hogeveen, J. (2012). *Innovation structures for firms in the financial servces industry. A case study analysis at ING Bank the Netherlands.* MSc-thesis, Business Administration, Radboud University, Nijmegen

S9 Fikken, T.W. (2012). *Design of the organizational structure fitting the Wwnv. A research project aimed at the design of an organizational structure fitting the demands arising from the 'Wet werken naar vermogen'.* (for Delta Zutphen), MSc-thesis, Business Administration, Radboud University, Nijmegen

S10 Korteweg, M.E.H. (2012). *How to measure the innovation performance of KPN Consulting. A design-oriented case-study on how the innovation performance can be measured.* MSc-thesis, Business Administration, Radboud University, Nijmegen

S11 Bouwhuis, P.M. (2013). *Diagnosing the Radiology Department of the CWZ. A diagnostic research, focused on the organization structure of the radiology*

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S12 Rozemeijer, S.W. (2013). *The infrastructure of the future for an urban freight transport sustainability concept.* (for Binnenstadservice Nederland). MSc-thesis, Business Administration, Radboud University, Nijmegen

S13 Halmans, S. (2014). *Process innovation, innovation structure and project portfolio management within 'S13'; a diagnosis.* **(confidential)** MSc-thesis, Business Administration, Radboud University, Nijmegen

S14 Nijman, G. (2014). Harvesting the fruits of organizational research. Research of the organizational and control structure of Munckhof BV. MSc-thesis, Business Administration, Radboud University, Nijmegen

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A European Perspective on Innovation Management a Semi-structured Model for the Corporate Innovation System (CIS)

Merih Pasin, Mehmet N. Aydin, and Ceyda Ovaci

Abstract The new paradigm of digitalization represents disruptive changes for organizations around the world. Companies are facing with highly intense competition. In order to survive and achieve sustainable competition advantage, strategic innovation management becomes essential. In this regard, one of the most significant issues is to design and apply a model that includes a clear roadmap to implement innovation principles and activities to ensure innovation capability and performance of businesses. The first part of the chapter presents state-of-the-art literature on existing innovation management terminologies and models. The other parts provide a semi-structured corporate innovation system (CIS) model and its dimensions. The proposed semi-structured CIS model is articulated in terms of the model dimensions and their instantiations along the rich associated experiences gained via best practices of the successful nationwide innovation program. The proposed CIS is a holistic model that creates value by establishing strategic, cultural, and organizational infrastructure for innovation management. The CIS model provides a roadmap from initial evaluations of innovation performance and strategy formulation to implementation. Besides, the model enables us to customize the roadmap based on six dimensions and 20 key target indicators according to company needs and structure. It is a unique model as it aims to establish a system based on the requirements and readiness of organizations.

Keywords Innovation · Corporate innovation management · Management system

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1 Introduction

The ability of innovation is evaluated as a key success factor for profitable growth, sustainability of business, and competition for companies. Therefore, organizations need to adopt innovation systems that include different principles such as culture and strategic direction. Since there is no one-size-fits-all approach or model for successful innovation systems for organizations, various frameworks, models, and roadmaps have been proposed by scholars and implemented by practitioners. The contingency theory asserts that the best fit is possible by considering the specific needs of the organizations and customizing the model accordingly. In the context of corporate innovation systems (CIS), this is possible if a semi-structured CIS model is present and customized along the salient characteristics of the organization. Such customization is a matter of applying both science and art of the innovation management to the case at hand. The design and implementation of innovation systems require knowledge on appropriate models, toolsets, and industry experience.

Several nationwide initiatives, programs, and platforms are promoted to share this kind of valuable knowledge between practitioners. However, the literature on CIS, as shall be provided later, indicates there is a need for generic, yet adaptable innovation model taking into account organizations' needs and best practices accompanying customization of the model for effective CIS. This chapter aims to present a semi-structured CIS model that has been used to develop CIS for 129 organizations as part of a nationwide mentor-driven innovation program in Turkey (TIM İnosuit Programı, 2022). The proposed semi-structured CIS model is articulated in terms of the model dimensions and their targets which also include the rich experiences gained via best practices of the successful innovation program nationwide. This chapter demonstrates successful implementation of the proposed CIS model in 129 organizations on various sizes as part of the mentioned nationwide innovation-focused mentor program.

The developed CIS model, which encapsulates an innovation management workflow with 20 main targets and six dimensions to enhance innovation performance of firms is a comprehensive answer to the question of how to start innovation and manage it. Before going over that, it would be beneficial to summarize evolving models of innovation management from the literature. In the next two sections, we address key challenges with the implementation of Innovation Management, and elaborate evolving approaches to deal with them. In Sect. 4, we introduce a CIS model and its six dimensions in detail. Later on, implementation and impact of the proposed model are provided along the best practices gained. We conclude the chapter with the implications of the study for practitioners, innovation support policymakers, and researchers.

2 Key Challenges with the Implementation of Innovation Management

The development and spread of the technologies introduced with the new industrial revolution are faster than ever. The radical leap in digital technologies over the past decade has been a major concern for companies to adopt structural configurations, innovation strategies, and policies Nambisan et al., 2019, p. 1). Innovation is a core driver to achieve competitive advantage and economic growth in the changing global environment (Brem & Voigt, 2009, p. 351; Hidalgo & Albors, 2008, p. 113). Therefore, understanding the importance of innovation is crucial for businesses to manage it and survive in a compelling business environment (Tidd, 2001, p. 169–170). However, digital technologies have caused a paradigm shift in the innovation process and methodologies (Yoo et al., 2012, p. 1398).

The digital advancement in industries forces organizations to embrace novel innovation tools and techniques served for innovation management to build organizational resilience (Leonhardt et al., 2018, p. 2; Heinz et al., 2021). Companies struggle to design effective and sustainable governance structures and innovation processes due to the unique characteristics of firms. Besides, it is not possible to suggest a formula or recipe to succeed in innovation management, since organizational structures, industries, digital maturity, and market conditions vary (Dilan & Aydin, 2019, p. 8).

The exponential growth of the digital wave has brought many challenges and opportunities in the innovation field (Yoo et al., 2012, p. 1399; Levine & Prietula, 2013, p. 1). While companies enjoy the growing number of new product developments with the technological improvements, they also feel the intense competitive pressure due to short product and innovation life cycles as well as unpredictable competition. Thus, companies focus on establishing a systematic and holistic innovation management system that encompasses sustainability, agility, flexibility, resilience, and diversity (Niewöhner et al., 2019, p. 826–827). However, there is a definitional confusion and uncertainty surrounding innovation, which is a potential problem for companies in terms of creating a common understanding in the organization and creating a sufficient innovation culture. Furthermore, it is suggested to ensure that the company employees have coherent competencies to execute the requirements of the innovation process (Vey et al., 2017, p. 26).

The implementation of innovation management is sometimes hard to grasp for companies because the processes are iterative, uncertain, and interactive. In addition, companies are assumed to ensure organizational readiness for technology push innovations and change their approach toward innovation. They should adjust organizational culture, strategies, deployment of resources, decision making, interactions, and human resources in line with updated innovation strategies (Agostini et al., 2020, p. 3). Therefore, it might be necessary to start an internal transformation on corporate DNA and promote sufficient innovation in the organization (Vey et al., 2017, p. 25). As a growing number of companies restructure their innovation systems, digitalization provides platforms to enlarge value creation networks, ecosystems, and interdisciplinary communities that promote openness, affordances, and generativity (Nambisan et al., 2019, p. 3). Indeed, digital platforms turned into significant innovation enablers for companies to collaborate with external stakeholders and share knowledge for problem-solving, idea generation, and co-creation (Hossain & Lassen, 2017, p. 2–3).

3 Evolving Approaches of Innovation Management

The concept of innovation, which includes novelty and creativity in its essence, was first used by economist Schumpeter (1934) (Hidalgo & Albors, 2008; Trott, 2005). Schumpeter considered innovation as the main component of economic development and defined it as "making differences in economic life." Schumpeter's innovation theory enlightened the creation of value at a more macrolevel. In the following years, researchers carried out studies on the benefits that can be achieved with enterprises' innovation management at micro-level (Xu et al., 2006). Thus, several innovation management approaches that are illustrated by schematic flows in the literature began to emerge. Utterback (1971) introduced the first graphical innovation process model (Bagno et al., 2017, p. 638). Indeed, innovation models have evolved from simple linear models to complex collaborative ones due to rapid developments in technology and globalization. Du Preez and Louw (2008, p. 1) stated that existing models are not adequately comprehensive with different components and implementation areas. Thus, they introduced a roadmap generated by combining diversified innovation management concepts to guide small- and medium-sized enterprises to specifically enhance their open innovation practices. However, the fact that this proposed model is intended for SMEs prevents it from being a model with a wide application area. Nevertheless, it is assumed that there is still a gap of implementation-oriented corporate innovation system model design in the literature.

There is a considerable number of definitions for "innovation management" and combination of various terminologies and concepts in the literature. Hansen and Birkinshaw (2007) describe innovation management "as the active and conscious organisation, control and execution of activities that lead to innovation" (Eveleens, 2010, p. 3). According to Ojasalo (2008, p. 3), innovation management refers to "the management of the whole process of innovation from the idea generation stage through product or process development/adaption to launch in the market or start." Another definition emphasizes management functions, "a systematic planning and controlling process which includes all activities to develop and introduce new products and processes for the company*"* (Brem & Voigt, 2009, p. 352). Although most of the innovation management models involve different approaches, definitions emphasize designing a process that involves a pattern of similar steps or stages, such as idea generation and identification, conceptualization, evaluation, selection, and implementation (Du Preez and Louw, 2008, p. 2–5). In fact, this can be interpreted that innovation models and innovation process models are used interchangeably in some studies (Zartha et al., 2019, p. 188–189). The initial step of managing innovation is to conceive how the innovation process can be influenced and create the best practice model (Eveleens, 2010, p. 2–3). To sum up, what most definitions *do* agree on is the overall "improving the competitive position" through generating firm-specific, integrated, and collaborative innovation systems with cross-functional management activities.

As noted previously, many significant insights have been created into the innovation process with several models, but there is still a lack of comprehensive framework to lead management implementations (Tidd, 2001, p. 170). Moreover, innovation management models do not offer patterns that include a clear roadmap to initiate innovation practices and ensure sustainable innovation capacity and performance (Zartha et al., 2019, p. 188).

In order to build a common understanding of innovation management approaches, some fundamental considerations will be summarized here. The ultimate goal is to indicate changes in the models. It is possible to find many meta-analysis studies summarizing innovation models in the extensive literature (Verloop, 2004; Jacobs and Snijders, 2008 Eveleens, 2010; Lopes et al., 2012; Cortimiglia et al., 2015; Bagno et al., 2017; Zartha et al., 2019).

Rothwell (1994) five generations innovation model is one of the best-known examples of generation-based innovation management frameworks. He performed a historical overview of models from the 1960s onwards and focused on the evolutionary development of innovation strategies of companies (Bagno et al., 2017, p. 638.). Other major studies on the analysis of innovation models have a general tendency to work in the framework of Rothwell in five generation sequences (Kotsemir & Meissner, 2013, p. 5). Kotsemir and Meissner (2013, p. 10) claimed that Rothwell's framework is a universal and mandatory reference model, and that there is no proposal on the sixth generation of innovation management models. They explained the reason as follows: All the emerging trends in innovation such as networking and outsourcing can be classified under interactive innovation models, namely the fifth generation. However, in some studies, the sixth generation (Marinova & Phillimore, 2003; Barbieri & Álvares, 2016, p. 119) or even the seventh (Du Preez and Louw, 2008, p. 6) generation of innovation models was mentioned. Yet another study by Chiesa et al. (1996) put an emphasis on a technical innovation audit perspective, but its implementation with real-world cases appears to be limited (Table 1).

First-generation models focused heavily on the scientific knowledge produced by R&D. Innovation was driven by technology through a simple linear process. Second-generation models had recognized the market as a source of ideas that operated in R&D. Third-generation models tried to combine market and technology in order to trigger a process which was also linear design similar to the prior models. Fourth-generation models emphasized creating dynamic linkages and alliances and integrating activities and functions in house departments. Fifth-generation models regarded innovation as a continuous, integrated, and flexible process. System integration and extensive networking were the key features of this generation (Barbieri & Álvares, 2016, p. 119; Bagno et al., 2017, p. 638).

Table 1 Brief comparison of historic overview of innovation models

Generation	Rothwell framework (1994)	Key features	Marino and Philimore framework (2003)	Key features
First (1950s–First half of 1960s)	Technology push models	Simple linear R&D oriented Scientific discovery → technological development of product → selling of product on market	The black box model	Innovation is regarded as an economic activity No explanation of R&D characteristics
Second (Second half of 1960s–Early 1970s)	Market-pull models	Simple linear Market oriented Market need → development → manufacturing → sales	Linear models (Technology push and need pull)	New product developments through basic science discoveries Causes of innovation are existing demands
Third (Early 1970s–early 1980s)	Coupling model	Recognizing interaction between different elements and feedback loops between them Technological capabilities and market needs-oriented Interacting and interdependent stages	Interactive model (Coupling and integrated models)	Complex interactions between science, technology, and the market Iterative innovation process
Fourth (Early 1980s–Early 1990s)	Integrated innovation process models	Parallel integration and functional overlap in house departments Integration within the firm, upstream with key suppliers and downstream with demanding and active customers, emphasis on linkages and alliances	Systems model (Networking and national systems of innovation)	Dynamic, industrial, strategic innovation networks Interactions, inter-connectedness, and synergies

(continued)

Table 1 (continued)

Generation	Rothwell framework (1994)	Key features	Marino and Philimore framework (2003)	Key features
Fifth (Since Early 1990s–…)	Integrated interconnected parallel and flexible innovation process models	Joint R&D ventures/strategic alliances Collaborative precompetitive research Systems integration and extensive networking, flexible and customized Response, continuous innovation	Evolutionary model	External environment in which technologies developed Population perspective and variation Generation of variety Selection Reproduction and inheritance Fitness and adaptation
Sixth			Innovative milieu	Productive system Active territorial relationship Local collective learning process

Source Adapted from Tidd et al. (2005); Eveleens (2010); Kotsemir and Meissner (2013)

Even though there are several common features of classification according to Rothwell, Marina, and Phillimore framework, the evolution was divided into six generations in Marina and Phillimore study. Besides they analyzed the models through a macroeconomic perspective to provide an understanding of innovation for the whole economy. They argued that the first three models were sequential. Although the system and evolutionary models focused on the interaction between actors, the system model described the system of relationships and trigger factors behind it (Kotsemir and Meissner, 2013, p. 7–8). The proposed sixth generation focused on geographical locations and territorial organizations as an important factor for the innovation process. Although a time interval is defined for each model, these models are still used today, when needed.

Xu et al. (2006) proposed the total innovation management model, which is defined as an ecological system directed by strategy innovation. It is claimed that the TIM model penetrates time/space reference of a firm. Besides, the model emphasizes that all employees should be a part of innovation. However, the TIM did not take organizational differences into account. Moreover, it does not provide a roadmap that includes the objectives and dimensions of how innovation management should be realized. In addition, information regarding the implementation experiences of the TIM model was not shared. There are points that intersect with the model presented in this chapter such as the importance of organizational culture (Xu et al., 2006, p. 15–17).

To sum up, a range of models indicated that innovation includes a set of functions consisting of many different components to manage and assess in order to understand innovation capacity and performance. The key components of innovation management that contribute to organizational innovation capabilities are listed below (Björkdahl & Börjesson, 2012, p. 77–178; Igartua et al., 2010).

- The Strategy of Innovation: Comprehending the direction of innovation activities with strategy formation. Innovation strategies should be consistent with the company's mission, vision, and purposes.
- Prioritization of Innovation Portfolios: Organizations are recommended to prioritize innovation projects/ideas/problems/suggestions that generate value to satisfy the company's needs. Selecting and creating a portfolio is a dynamic process due to the constantly updated structure of innovation projects. Besides, it is noted that prioritization should be in line with innovation strategies.
- Idea and Project Management: Innovation ideas should be managed under a systematic management roof to overcome risks and uncertainties that they inherently have. Thus, it would be easier to follow, assess, and implement the value created by innovative ideas.
- Leadership and Organizational Culture: Leaders should promote and support innovation in the organizations to encourage employees to be part of the process. Also, management support is a significant ingredient for establishing and spreading innovation culture within the organization. For the in-house diffusion of innovation, it must create an innovation climate where failure is tolerated.

- Human Resources: Innovation movements should be integrated into human resource policies of the organization. Human resources are the key element of successful implementation of innovation strategies. Therefore, motivation, recruitment, rewarding of individuals are essential enablers of innovation performance.
- External Relations: Innovation is a critical success factor not to be left to the responsibility of just one person or a department. Thus, collaborations, interactions, or strategic alliances are tools for the creation of mutual benefit through sharing knowledge for innovation outside the company as well as within.
- Organizational Design: Organizational infrastructure should reflect the purpose and strategies of innovation in the organization. Therefore, it would be necessary to redesign the organizational structure and diffuse innovation authority within the organization for interaction.
- Implementation: The implementation phase should be structured to enable an efficient and effective flow. The innovation process, which should be designed as an iterative process, should be open to continuous improvements. In order to transform ideas into value, a properly designed implementation system is needed.
- Knowledge and Intellectual Property Management: All activities related to innovation in the organization must be protected within the framework of the principles determined in the directives. Especially knowledge management is an important part of innovation.
- Technology: Technology is a fundamental ingredient of innovation. Technological trends and emerging technologies should be scanned. Organizations prepare themselves for changes by anticipating the effects of technologies on their business with the roadmaps they generate.

As it is widely appreciated, innovation management is one of the fundamental functions for many businesses. In addition, the ability to renew the organization and provide continuous innovation performance in a rapidly changing environment is another challenge for companies (Steiber & Alange, 2013, p. 243–244). In some studies, innovation and sustainability have been associated with innovation outputs such as reducing raw material or energy costs, preventing negative influence on the environment, and so on (Shin et al., 2018, p. 2). Within the scope of the proposed model in this study, sustainability indicates the continuity of corporate innovation performance. What is meant by the sustainability of the corporate innovation system is that the current structure is a set of processes that offer innovation in all changing conditions.

To summarize, the model proposed in this study differs in three aspects from the existing ones: (i) targets of the model; (ii) scope of the model dimensions; and (iii) implementation of the model. The targets suggested in the model are related to dimensions. The dimensions of the model are more comprehensive and explanatory. The dimensions and objectives of the model provide a roadmap that will enable companies to reflect their original structures. Existing models are inadequate for establishing a roadmap for organizations that will consist of targets and various phases. However, in this model, an area is recognized that allows institutions to develop original methods by which they can reflect their own business style and corporate culture in achieving the proposed dimensions and goals. In addition, academicians who are experts in innovation management act as mentors in the field implementation of the model. In this context, mentors, presented in the semi-structured model, are incorporated into companies in a unique way with their knowledge and experience.

The semi-structured corporate innovation model proposal will be explained in the following sections. This model has been implemented in 129 different companies successfully nationwide in Turkey (TIM Inosuit Programı, 2022). The compatibility of six dimensions and 20 targets used in the model was confirmed with qualitative and quantitative data collected from the companies which attended the program.

4 Corporate Innovation System Model (CIS)-Six Dimensions of the CIS Model

The proposed CIS model consists of six dimensions and an additional element to ensure the sustainability of the corporation innovation system adopted. Figure 1 demonstrates each dimension as a facet of the innovation cube to put an emphasis on its holistic characteristics. In the following section, we shall discuss the model with its dimensions in terms of underlying concepts and their operationalization with fine-grained elements that need to be instantiated as an organization-specific model. Furthermore, the proposed model is articulated with a set of key targets to achieve along with its implementation.

Innovation Strategy

This dimension aims to establish the foundation of strategic elements for an organization including innovation strategy, its alignment with the strategy at the corporate

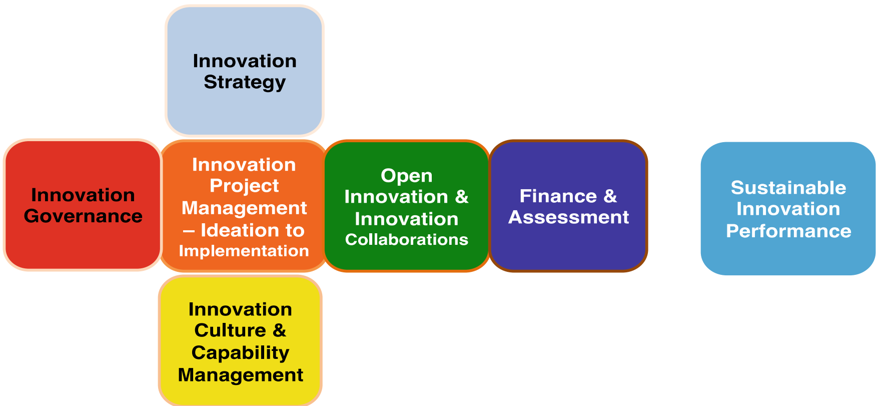

Fig. 1 Dimensions of corporate innovation system model

level, and other relevant units, including R&D. Furthermore, there is a need for the generation of strategic insights associated with innovation strategic options and effective planning that incorporate innovation portfolios and roadmaps (product, technology, etc.). One can consider well-known innovation strategy options such as the type of innovation (product, process, business model, etc.), degree of openness, and the scope of innovation (Dilan & Aydin, 2019). Innovation strategy should incorporate both the dynamics and structural aspects of an organization. Also, it can be employed as part of a strategic thrust. Its dynamic nature indicates temporal scenarios (short, mid-, long terms); and its structural element exhibits organization position as a leader with close followers in certain venues. Its uniqueness is inevitable and reflects intriguing and novel thinking embedded in its formulation.

Innovation Governance

The very idea of governance refers to an appropriate decision-making process and organizational configurations that fit an organizational situation. Interactions and communications among various parties in the organization require both the structural and dynamic aspects of innovation governance. The principles governing the structure and dynamics are particularly essential to develop and adapt to the organizing logic instantiated in terms of managerial and operational activities. One can consider such organizational arrangements as innovation board and committee. The former indicates an advisory role to achieve an executive commitment, whereas the committee can signify an intermediary role in coordinating and monitoring innovation endeavors in an organization. Company-wide representativeness of involved parties is essential to ensure innovation acceptance at different levels and across departments in an organization.

Innovation Culture

The cultural dimension is a common ground to attain a shared understanding, values, and rules underpinning *Weltanschauung* (a way of viewing the world, way of thinking about innovation). Naturally, the language that frames shared understanding of innovation is essential to constitute the worldview toward innovation. As such, its epistemological and ontological foundation, depending on its appropriateness, enables or prevents the progress of innovation in an organization. The former indicates how knowledge is accumulated and embraced at the individual and group levels, whereas the latter is concerned with meanings of basic terms (semantics) and organizational semiotics, and organizational culture (Stamper et al., 2000). The establishment of appropriate innovation culture is a long-term quest and subject to social embeddedness, a degree of unitedness, and other matters that cannot be easily codified.

Management of Innovation Projects-Ideation to Implementation

This dimension includes managerial and operational end-to-end activities from ideation to implementation. Managerial activities are concerned with monitoring transitions from one state of innovation progress to another state. One can adopt stage-gate models to design an overall innovation process and descriptions of fine-grained activities, tools, and techniques needed. Noticeably, the process starts with a set of promising ideas collected from various channels and may require idea management practice and tools. Turning ideation into potential innovation projects and eventually leading to successful outcomes is not guaranteed as the process naturally involves various risks. This dimension does not prescribe any particular roles, responsibilities at different stages of the process, but depending on the types of innovation, one can design specific process route maps to facilitate its implementation.

Open Innovation and Innovation Collaborations

The idea of collaborations in the innovation context is applicable to both intra- and inter-organizational scope. The degree of openness and its scope is a matter of strategic choice, but its realization necessitates not only basic interactions and interoperability among relevant actors, but also a unity around shared understanding and sustainable progress. As shall be discussed further later on, in many cases, collaborations are temporal in nature as a specific project and how to extend it to complex and dynamic relations since creating network-based ones is a challenging endeavor. A degree of openness is, on the one hand, a strategic choice, and requires networking capability in intra- and inter-organizational settings. On the other hand, it is a matter of collaboration between individuals, teams, and other organizational arrangements.

Finance and Assessment

This dimension is concerned with appropriate performance indicators to measure progress and the tangible outcomes for each innovation projects, and the overall the innovation system. The proposed model assumes varying degrees of innovation readiness for organizations and requires situation-specific targets per time windows such as monthly and yearly ones. The model aims to achieve 20 targets and addresses the challenge of limited resource availability in an organization. Nevertheless, one needs to monitor its process and outcome progress and strive for its sustainability for the long term.

In the following section, we shall explain the implementation of the proposed model and discuss the associations between the model dimensions and 20 targets. We further elaborate on the implications of the model implementation with exemplary cases.

5 Implementation and Impact of the CIS Model

This model considers the multidimensional and multi-functional nature of the innovation process and its implementation in companies in the form of corporate innovation system (CIS). It is vital to adapt the implementation of the model to the company's needs because the implementation roadmap varies with the size and the readiness–innovation maturity, as well as other organizational characteristics such as corporate culture, and tolerance to failures, which strongly affects the innovation performance.

The variation among the companies with respect to readiness to implement innovation management system is accounted for the semi-structured approach of the program. This approach enables a customized roadmap. Therefore, innovation model starts with a holistic evaluation of the company with respect to the corporate innovation system, which has six dimensions (Fig. 1), and related 20 targets (Table 2).

Evaluation aims to provide a roadmap to achieve the innovation management system. The CIS provides general guidance and targets to achieve; however, this road map is customized for the company needs based on the initial evaluations. Hence, the model is characterized as a semi-structured innovation management program.

Table 2 20 targets for CIS linked to six dimensions

Target 1	Evaluation of innovation capacity and performance
Target 2	Designing an organization-specific corporate innovation system
Target 3	Preparation and implementation of the internal and external communication plan for corporate innovation system
Target 4	Determining innovation strategies
Target 5	Preparation of the institution's technology road map and capability road map
Target 6	Creating innovation project portfolio
Target 7	Preparation of the innovation governance infrastructure
Target 8	Preparation of corporate innovation management directive
Target 9	Designing an idea and suggestion-sharing system
Target 10	Creating the appreciation and rewarding system
Target 11	Integration of innovation to HR applications of the organizations
Target 12	Corporate knowledge and know-how management system
Target 13	Providing innovation management internal trainings and building competence
Target 14	Forming innovation project teams
Target 15	Systematic management of innovation projects
Target 16	Designing open innovation processes and external stakeholders collaborations
Target 17	Designing intellectual property rights procedures
Target 18	Designing R&D projects based on university-industry cooperation
Target 19	Utilizing external finance sources and funds for innovation
Target 20	Evaluation of the effectiveness of the corporate innovation system

An academic in the innovation management field facilitates and guides the process of forming, and later implementing the customized roadmap for the company with the help of evaluation tools developed for this program.

There are a number of methods to assess the innovation maturity level of a company. Initially, the method proposed by AT Kearney was used. Subsequently, we developed our own tool "Corporate Innovation System and Network Analysis Tool"–CISNAT for this evaluation. CISNAT further ensures the compatibility of the analysis tool with the Corporate Innovation System that aims to establish the model in the company.

Such evaluation tools as AT Kearney or others are a set of questionnaires, filled by the management team with the facilitation of the innovation leader. Hence, it provides the evaluation of a company from the management perspective. However, employee perspective, which is also important for the innovation performance, is left out. Therefore, in addition to the CISNAT evaluation, which is a top-down perspective for innovation management, this method also incorporates a bottom-up perspective, which comes from employees. This is accomplished with a developed tool called innovation perception assessment tool (IPAT). IPAT evaluation is similarly linked to six dimensions and corresponding 20 targets and uniquely provides the employees' take on the innovativeness of the company.

The results from these two tools are combined to finalize the roadmap to achieve the 20 targets, which are the foundation for an effective innovation system. The following section provides an example for this evaluation:

Dimensional Analysis

An example for dimensional analysis is given in Fig. 2. It shows that for this particular company, the lowest score is 70%, which is "Innovation Strategy." On the other hand, high scores on "Innovation Culture and Capability Management" and "Innovation Governance" indicate that the company has solid fundamentals for innovation management.

Fig. 2 CISNAT dimensional results

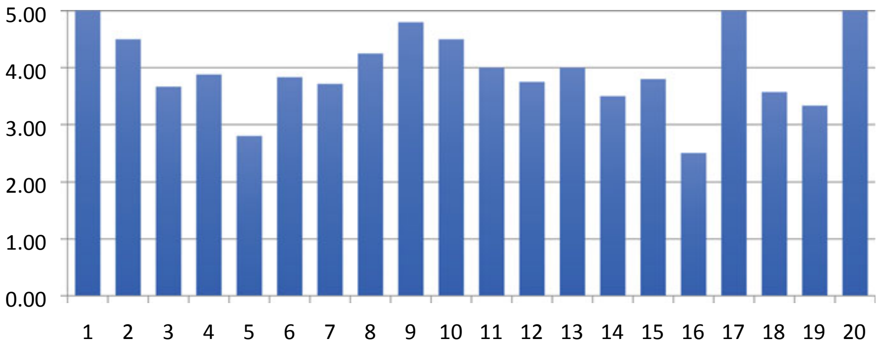

Fig. 3 CISNAT 20 target results

Outcomes from each dimension are further detailed in 20 targets, as shown in Fig. 3. For each dimension, there are several targets. Continuing with the same example, it is concluded that the low score for "Innovation Strategy" dimension mainly comes from the low scores of Targets 3 and 5.

Action plans are prepared for each target in order to complete the CIS implementation roadmap. Target 5 and the corresponding questions in CISNAT are given below:

T3: Preparation of Technology Roadmap and Capability Roadmap

17	Short-mid-long-term customer needs have been determined	4	2.80
18	Product and services necessary to develop in order to meet these needs have been determined	4	
19	Key technologies and capabilities to develop these products and services have been determined	2	
20	Strategies to acquire these technologies and capabilities have been determined	2	
21	Technology roadmap has been prepared, using all internally and externally available sources	2	

Based on these evaluations, one of the actions is to organize a work meeting to determine the key technology and capabilities to support future products and services to meet the customer trends. Also, innovation perception of the company among its employees is analyzed with IPAT, as shown in Fig. 4.

Results from CISNAT and IPAT are compared to show the differences between management and employee views, regarding the innovativeness of the company (Fig. 5).

Based on the evaluations from CISNAT and IPAT, the roadmap for innovation management is finalized. After the roadmap is finalized, the model is implemented. The implementation phases are shown in Fig. 6.

Detailed implementation for a specific company is generated using the above guidelines, together with CISNAT and IPAT results, based on the semi-structured approach of the program.

Last but not least, we also monitor the progress during the use of the model with 20 targets. The following scoring is used for each target: 1: Not started, 2: Limited completion, 3: Partial completion 4: About to be completed, 5: Completed. Posterior analysis of 57 implementation cases is carried out, and the result is published as the Model Impact Report. Descriptive statistical results can also be found in

Fig. 4 IPAT dimensional results

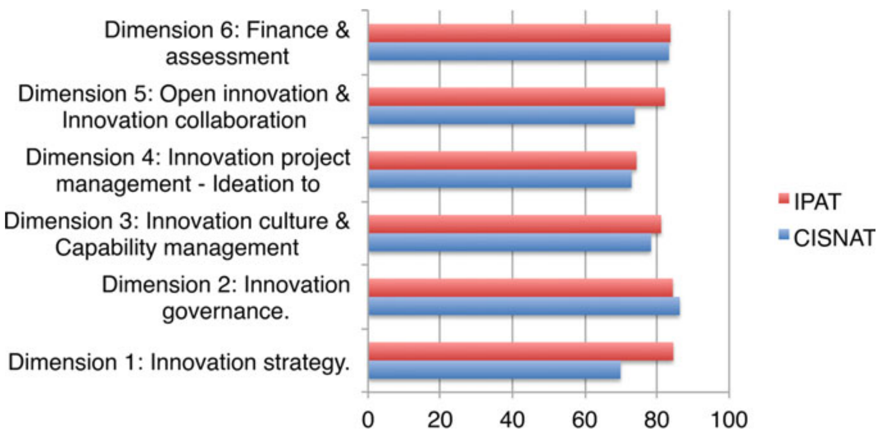

Fig. 5 CISNAT-IPAT dimensional result comparison

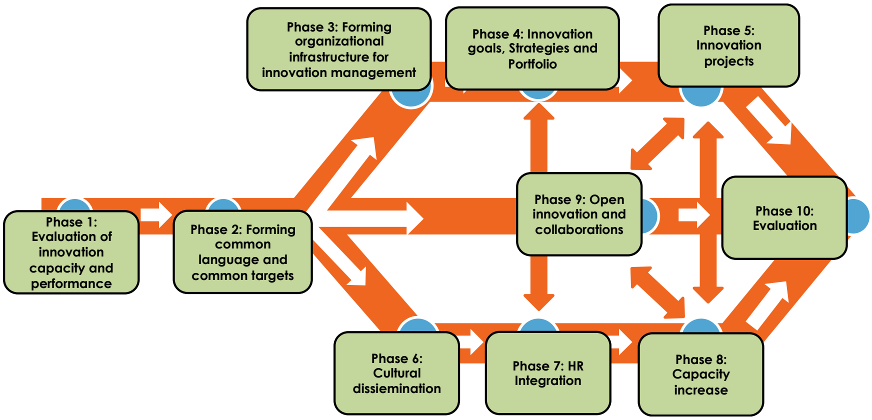

Fig. 6 CIS implementation phases

the published report (İnosuit Program Etki Analizi, 2020). The overall results from the participants show that in terms of the 20 targets, an overall 80% completion is achieved among the companies of the program. Other findings related to each target require further discussions, but since the focus of this chapter is on the CIS model description, we shall provide worthwhile results. Target number 2, which is "Designing an organization-specific corporate innovation system," has the highest score (4.63 out of 5) with a minimum standard deviation (0.616), whereas the lowest score (3.67) is found to be target number 11 (Integration of Innovation to HR Applications of the Organizations). The second highest score (4.74) is "Designing an Idea and Suggestion Sharing System," and whereas the second lowest score (3.75) is Designing Intellectual Property Rights Procedures. The other lower score targets are Utilizing External Finance Sources and Funds for Innovation, Designing Open Innovation Processes and External Stakeholders Collaborations, and Preparation of the Institution's Technology Roadmap and Capability Roadmap. Additionally, the Kaiser–Meyer–Olkin (KMO) and Bartlett tests were performed. The association of the six dimensions of the model and the 20 targets is analyzed with respect to model accuracy. The accuracy of the model was further confirmed by showing that its explanatory power was high at 0.74.

6 Conclusion

Innovation management requires a holistic approach that involves interactive, strategy-oriented, sustainable processes and structure. Corporate innovation systems that allow the reflection of organizational differences are paramount to benefit from the value created through innovation in the rapidly increasing competition environment. While innovation management models in the literature do not provide a roadmap to establish a corporate innovation system, we propose a semi-structured model and its elements with a roadmap to develop and improve innovation systems for businesses. In addition, the proposed model incorporates both top-down and bottom-up perspective evaluations to provide a complete analysis of the company, resulting in a better-suited roadmap for innovation management.

The semistructure corporate innovation system model provides some unique features that ensure forming a sustainable innovation performance within the company by having the following features:

- *Capacity and perception measurement* that allows us to organize, plan, and make decisions
- *Cultural development* through enhancing the ability to manage group dynamics and communication
- *Integrated system* that allows managing uncertainties and conflicts
- *Semi-structured approach* that provides flexibility
- *Custom-made implementation*
- *Talent and capacity development* by focusing on creativity, critical thinking, and a design mindset
- *Learning organization* by promoting the ability to transfer knowledge, sharing, and continuous learning
- *Multidimensional approach* that includes compliance and cooperative dimensions
- *Strategic link* that provides conceptual mapping between innovation and platform strategy, technology roadmap, and critical competences.

This model has been successfully implemented in 129 companies as part of a nationwide innovation program. The fact that participating companies came in various sizes demonstrates the robustness of the model. Companies that have successfully finished the nationwide program were responsible for completing the processes of the proposed model for a certain period under the supervision of a mentor. In addition, the impact analysis performed for 57 of these companies shows that the overall 80% completion is achieved based on the 20 targets specified in the model.

The model provides a roadmap for companies to establish a corporate innovation system that will ensure the spread of innovation climate in the organizations. Besides, the model sheds light on the practitioners as to where and how to start innovation management in institutions and which functions should be integrated. Therefore, it is thought that the model, which gives guidance on which targets should be achieved to create a successful innovation system, creates value for the practitioners.

Nonetheless, the study has limitations. The model has been applied to nationwide programs. However, some companies where the model was applied are multinational. This proves that the international differences of the model do not have a negative effect on the implementation of the model.

One of the important ideas for further research is to explore the network effect in the organization. Initial findings suggest that participating companies, following the same model, aiming at the same targets even though detailed planning may differ, create a common language. This forms a support network among the companies. This network is further enhanced by periodical meetings with the participants to share experiences and problems in order to develop the best solutions. One can consider applying the proposed model to other nationwide innovation-focused programs in other geographies. Further research is needed to articulate the proposed CIS model in a specific organizational context in which the characteristics of the organization can be a subject matter for adapting the model. For this purpose, the action research method will be suggested as an effective way of examining the rich context of the model adaptation.

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Innovating Executive Management in Self-Managed Organizations: A Radical Swedish Experience

Sofia Börjesson, Joakim Netz, and Fredrik Lagergren

We have fully decentralized decision-making processes.
No middle management, no CEO, and no executives.
-Qamcom

Abstract This chapter explores how new logic replaces power that associates with executive work in a managerial hierarchy. Following a collaborative research tradition, we conducted a case study of a Swedish company, Qamcom Research Technology, a 20-year-old firm within the Qamcom Group, which has a record of continuous growth through innovation. Results suggest that executive management itself can be innovated to enhance creativity and innovativeness of the firm. We explore the company's organizational model based on roles and self-organization, finding a novel logic that operates across four concepts—willingness to share power, a dynamic steering model, natural hierarchies, and true transparency. These concepts jointly extend innovation capability research and encourage rethinking the role that organizational democracy and hierarchy play in self-managed organizations to explain far-reaching self-management of executive work.

Keywords Executive work · Hierarchy · Openness · Innovation capability · Self-managed organization · Transparency

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1 Introduction

This chapter discusses the renewal and innovation of business management that create sustainable and innovative organizations, and it more specifically addresses how executive management can be innovated when new forms of organizations emerge in firms, often called self-management or self-managed organizations (Bernstein et al., 2016; Lee & Edmondson, 2017). Self-management has been used as an overarching term for several radical ideas, including holocracy, TEAL, and agile approaches (Laloux, 2014), that provide strategies for leading and organizing companies less hierarchically (Bernstein et al., 2016). When responding to frequent disruptions and social movements in society and at work, firms use self-management to create innovative, socially responsible organizations. Self-management breaks the traditional mode of organizational coordination of management by "eliminat[ing]…the reporting relationship between manager[s] and subordinate[s]" (Lee & Edmondson, 2017, p. 46), and it has increasingly received attention from researchers (Billinger & Workiewicz, 2019; Hamel & Zanini, 2020). In the form in which they appear in practice, self-managed organizations do not generally, however, eliminate managerial hierarchies entirely, with top management positions remaining unaltered (Child, 2019). Abandoning managerial hierarchies suggests that firms must innovate executive managers' responsibilities, particularly regarding information procedures and how to redistribute power during strategic decision-making, which represent far-reaching changes to power distribution. Innovating executive management might constitute a powerful, albeit radical and difficult, prerequisite to developing innovative organizations.

This chapter discusses results from a case study of a Swedish company, Qamcom Research and Technology, a 20-year-old firm within the Qamcom Group that developed a unique way of creating and developing innovation. Today, it comprises a group of companies in which Qamcom Research and Technology is the centerpiece. Qamcom Group's innovations resulted in more than 20 spin-off companies and joint developments, such as Aervivio, Airolit, Amparo, Hugin, Cetasol, Earin, Einride, ICX, and Librixer, that, as of 2023, are owned by Qamcom Group, together with investors and large international corporations.[1] These spin-offs all operate in high-tech domains, with products and solutions that include drones, airspace security, autonomous driving systems, and radar technologies. The innovations are originated from Qamcom Research and Technology, joint venture projects, and external inventors. Common to all of these growth cases is a history of being innovated by employees at Qamcom Research and Technology (hereafter, "Qamcom").

As an innovator, Qamcom radically rethought and practiced how redistribution of executive power can be accomplished, providing a rare example of innovating executive management through removal of an entire managerial hierarchy. Such an anomaly in Sweden is, however, unsurprising; decentralization, industrial democracy, management innovation, and self-organizing teams have, for decades, evolved as guiding principles during the design of Swedish companies' management

[1] For details, see qamcom.group.

(Hedberg & Jönsson, 1989; Normann, 1977; Rhenman, 1968), known as the Swedish Model for Management (Birkinshaw, 2002; Holmberg & Åkerblom, 2006). Historically, however, few Swedish companies have taken their decentralization as far as Qamcom has—to remove the entire hierarchy.

A few radical decentralization examples outside of Sweden have recently appeared in the literature, and some theories of the phenomenon have been developed (Child, 2019; Lee & Edmondson, 2017; Martela, 2019). Such research remains nascent, however, and how executive management is handled in self-managed organizations has received little attention in the literature. Examining self-management consequences for executive work and how self-management itself can be innovated thus broadens understanding of contemporary experimentation with new forms of self-managed organizations, since such new forms derive from a firm intent to be more prepared for innovation.

This chapter elucidates how executive management is innovated in the context of self-managed organizations, and we thus explore how execution rules can be reorganized in a radically different way. Using a collaborative research approach to both generate scientific knowledge and contribute to changes in studied organizations (Adler et al., 2004; Löwstedt & Stjernberg, 2006), we discuss analyses and conceptualizations of Qamcom's far-reaching, self-managed organization, in which new principles of executive management were developed. We find that executive management can be innovated by conventional managerial hierarchy being replaced with an alternative logic of a role-based structure, operating across four novel concepts—willingness to share power, a dynamic steering model, natural hierarchies, and true transparency. Findings contribute to both a small but growing body of knowledge on self-managed organizations and theory on innovation capability.

The next section discusses the theoretical background of the study, focusing on essential components regarding power redistribution, and a dimension that we argue is central to understanding how executive work is innovated in self-managed organizations. We then report on the research design and methods used. The case is then introduced and discussed further, concluding with implications for research and practice.

2 Theoretical Background

2.1 An Innovation Capability Perspective on New Organizational Forms

A capability perspective of organizations was applied to capture the complexity of innovation and self-managed organizations, a perspective that emphasizes the systemic character of innovation work that suggests that innovation depends on mutually dependent organizational aspects, such as structure, processes, mindsets, decision-making, ideation, management cognition, and others (Assink, 2006;

Börjesson & Elmquist, 2011; Börjesson et al., 2014; Danneels, 2002; Lawson & Samson, 2001; O'Connor, 2008; O'Connor & DeMartino, 2006). Innovation capability thus constitutes an organization's prerequisites for innovation, and it is not limited to technological features (e.g., products), but includes management processes (e.g., Birkinshaw et al., 2008). Development of innovation capabilities often means organizational change and resistance, and the ability to innovate means that obstacles related to a changing organization and its procedures and routines must be considered (Schreyögg & Kliesch-Eberl, 2007). Research suggests that executive managers are paramount when building an organization's innovation capability, both in terms of sanctioning and enabling innovation work, and regarding their own understanding and mindset as strategic decision-makers (Börjesson et al., 2014; Danneels, 2011; Helfat et al., 2007). It is therefore important to understand how experimentation with executive managers and their work responsibility, task allocation, and information flows (Puranam et al., 2014) constitute additional means for an organization's capability to innovate new organizational forms (Daft & Lewin, 1993).

2.2 Executive Work, Hierarchy, and Self-Management

2.2.1 Executive Work

Theories about top management have long converged on the functions of executives and their behaviors and how they evolve in changing environments (Barnard, 1938; Carlson, 1951; Hambrick & Mason, 1984). Executive work is characterized by decision-making related to a CEO and executive team, commonly treated as a firm's top management team (Hambrick, 2007). Executive decisions typically concern major intended and emergent initiatives taken by a CEO on behalf of owners and shareholders, and they involve use of resources that enhances firm performance in the external environment in which a company operates (Nag et al., 2007). Early studies suggest that information and planning underpin executives' decision-making to avoid misfits between the firm and external environment (Mintzberg, 1973). These activities have increased in significance since the 1990s (Tengblad, 2006), since information and communication technologies have led to a "profound shift in the economy from power derived from possession of tangible assets and inputs to power derived from possession of knowledge and information" (Child & McGrath, 2001, p. 1140; Boisot, 1995; Ciborra, 1996). Such tasks are central to executive work and the power that associates with it.

Research on executive work suggests the importance and persistence of managerial hierarchies across organizational layers, and coordination among them. The design of information control and exchanges among top, middle, and operational management teams represents a locus for continuously renewing the strategic direction of a firm because it enables development of new knowledge and firm capabilities (Floyd & Lane, 2000; Hambrick, 2007; Raes et al., 2011). Research also recognizes that information intensity and the digitalization of organizations produce new organizational forms and the need for open and transparent horizontal coordination, which, in turn, require new ways of experimenting with organizing, distributing power, and innovation-oriented roles (Splitter et al., 2022). Hamel and Zanini (2020) argue that "building natural, dynamic hierarchies" (p. 152) reduces influences from an organization's conventional hierarchy. During changes that result in new organizational forms, organizations are challenged by "new power asymmetries"—those between managerial agents and employees—and by the communities in which they operate (Child & McGrath, 2001, p. 1140). However, even new, radically decentralized and inclusive organizational forms that are emerging in companies, such as self-managed organizations, commonly must depend on corporate governance that is rooted in bureaucratic assumptions (Hautz et al., 2017). Organizations are thus often radically less hierarchical, but not non-hierarchical. In such cases, the bottom-line matters and shareholders remain the most influential stakeholders at the top of the managerial hierarchy.

2.2.2 Hierarchy

Management literature consensus suggests that hierarchy is the logic that resolves problems with organizing executive work. Child (2019) defines hierarchy as:

> A system in which the members of an organization or society are ranked according to their status or authority. Hierarchical differences create unequal relationships between individuals and groups of people. In a general sense, any relationship in which one party is subordinated to the other may be described as hierarchical. (p. 1)

Hierarchies can, for example, resolve efficiency problems associated with innovation work through differentiation of organizational units and integration of them using responsible unit managers who report to a corporate manager, thus representing an organizational layer. Hierarchies also facilitate innovation-related cooperation between firms because their respective managerial levels can be paired to mutual challenges (Chandler, 1962; Lawrence & Lorsch, 1967). Such vertical and horizontal relationships within hierarchies jointly make an organizational system more open to innovation, both within and beyond a firm (Berglund & Sandström, 2013; Chesbrough, 2003), particularly if responsibilities and roles throughout a hierarchy are adapted to appropriate managerial control (Floyd & Lane, 2000). Numerous cases exemplify the positive influences that managerial hierarchies have on firm innovation. Hierarchies can simultaneously be problematic to innovation work. Even if a hierarchy translates power into action, unequal rewards and statuses might produce social tensions, becoming a potential political problem (Burns & Stalker, 1961).

In contemporary society, it is increasingly important for firms to cope with such problems for two reasons. First, social movements in Europe and elsewhere have raised political concerns regarding hierarchies, with targets of such movements being not only politicians, but firms. Firms are increasingly subject to social demands, such as employee well-being and integration of social responsibility into corporate purpose

(Margolis & Walsh, 2003). Although managerial hierarchy has expanded to include various stakeholders and their interests in governance, shareholders remain the dominant stakeholders, who judge whether a firm has met their demands for return on investment (Hillman & Keim, 2001). Second, frequent disruptions highlight the need for decentralized hierarchies for information exchanges and knowledge to allow firms to adapt rapidly and continuously (Child & McGrath, 2001; Ciborra, 1996). Europe is not an exception; the continent has the most salient disruptive challenges, including supply chain dependencies, extreme migration complexities, industry crises, and labor issues. Despite a need for decentralization, knowledge acquisitions are both generally and specifically, from a capability perspective, understood as an executive choice at the top of the managerial hierarchy (Teece, 2007). The two trends—social movements and disruptions—thus challenge hierarchies and suggest a need to rethink and encourage (current) executives to organize their power differently.

2.2.3 Self-Management

Small but growing literature on self-managed organizations suggests that firms are motivated to address challenges of disruptions and social well-being, and they do so by organizing according to principles different from those of a hierarchy (Bernstein et al., 2016; Billinger & Workiewicz, 2019; Laloux, 2014; Lee & Edmondson, 2017). The literature further suggests that differentiation or division of labor does not occur top-down but bottom-up, emerging through interactions among employees. Reward distribution follows division of labor and is both peer-based and intrinsic, rather than supervised. Further, transparency guides all essential information flows among employees when they make decisions and act responsibly for the entire organization. In organizations with a single top management layer remaining, work integration instead depends on constant, IT-intensive communications within and between teams (Martela, 2019). Such radical efforts to organize less hierarchically eliminate traditional reporting relationships between managers and subordinates. Interesting, however, is that self-managed organizations, though intended to produce greater innovations, do not appear to experiment with top managers, perhaps because self-management in large organizations innovates operational effectiveness (Birkinshaw et al., 2008), while the scale of start-ups operates through growth trajectories (e.g., Greiner, 1972; Vaara et al., 2021), before self-executive management is possible.

How top management can be innovated in self-managed organizations has received little attention in the literature. Innovating management, particularly at the executive level, remains unexplored as a means of increasing innovativeness. From an innovation capability perspective regarding new organizational forms, there is thus reason to seek more knowledge about experimenting with new execution logics.

3 Research Design and Method

3.1 Research Approach and Case Selection

This study develops theory and principle understanding; it does not test theory. We thus used a collaborative research tradition, an approach during which issues emerge in collaboration with practitioners, and researchers and practitioners jointly create knowledge about a phenomenon. Knowledge is elucidated through language and models as input for action in organizations, contributing to theory simultaneously (Van de Ven, 2007). The design falls within a framework of phenomenon-based research (von Krogh et al., 2012), a problem-oriented, idea-driven, interpretive approach that describes and conceptualizes a new observed phenomenon (Schwarz & Stensaker, 2016). A qualitative design means that no single theoretical model is used as a starting point. Instead, intermediate theories created during collaboration drive the research, and combined, existing theories and established practices base the creation of knowledge (Starkey & Madan, 2001).

This collaborative approach is consistent with action research, which both generates scientific knowledge and contributes to change in an organization (Adler et al., 2004; Löwstedt & Stjernberg, 2006). One distinct feature is the emerging nature of research, during which research problems are not formulated fully in advance—they emerge instead. Since the phenomenon emerges, a longitudinal qualitative approach with a single-case design was used. This approach is appropriate methodologically in nascent fields because the theoretical knowledge of what is being studied is limited (Edmondson & McManus, 2007).

The research reported in this chapter is based on a collaboration, ongoing since 2019, between our research group and the case company. The Qamcom case was selected based on results from a pilot study among 14 Swedish firms conducted in 2018 and 2019. The pilot study included firms that elaborated on organizational and management forms, some of which also experimented with executive management. One firm, Qamcom, stood out in terms of more extreme intentions than the others, pursuing a far-reaching experiment with self-management. The company was selected for this case study because of its extreme characteristics, especially its intent to eliminate managerial hierarchy. Such cases are useful during research because their extreme character includes activities and mechanisms that reveal new knowledge (Flyvbjerg, 2006).

3.2 Data Collection

The study at Qamcom initially involved two data collection strategies—qualitative interviews and internal company files—conducted in parallel to achieve thorough understanding of radical self-management. Data were collected using 15 open, unstructured interviews, or knowledge-seeking conversations, with two respondents who had strategic and historical knowledge of the radical experiment with self-management. One respondent was one of three founders, and the second was a senior executive officer; thus, the interviewees represented key informants (Marshall, 1996). Most interviews were conducted with the founder. Lasting approximately two hours, the interviews were conducted between early 2019 and mid-2021, and each of the three researchers took systematic field notes (Van Maanen, 1988). We also had access to Qamcom's extensive documentation of decision-making and other internal documents.[2]

3.3 Data Analysis

The researchers analyzed each interview or conversation individually, identifying issues that were discussed and clustered, and thus coded during the search for relevant concepts. We reflected continuously on intermediate findings from one respondent (i.e., the founder), thus using an insider–outsider research approach (Bartunek & Louis, 1996), which encouraged co-creation of knowledge (Adler & Shani, 2001; Adler et al., 2004; Argyris, 1995; Börjesson, 2011) that allowed both data to be contextualized through ongoing dialogue with an insider researcher and in-depth understanding of phenomena.

Analysis followed an abductive approach of applying theoretical ideas and principles to structure empirical findings (Alvesson & Sköldberg, 2007; Dubois & Gadde, 2002). Theorizing or developing concepts and language to capture a phenomenon under study was conducted using continuous, iterative analyses and re-reflection of interview and document data. Intermediate theories (Adler & Shani, 2001) were thus created that could be developed and simultaneously validated by practitioners.

4 Qamcom's Experimentation with Executive Management

4.1 Background

Qamcom, a precursor and firm within the Qamcom Group, is a small, innovative, high-tech development company based in Gothenburg, Sweden. It develops software and hardware solutions for the telecom and other industries that work with communications, sensors, and advanced electronics. Qamcom was founded in 2001 as a spin-off of Chalmers University of Technology in Gothenburg, at which the founders researched physics and antennas. A patent together with a technology that solved

[2] During 2022, data collection continued in a broader research project for another study, which presented an opportunity to validate the conceptualization in the first study reported in the present chapter. We collected member-checking data (Lincoln & Guba, 1985) at numerous meetings with the two respondents, and at two workshops among a sample of Qamcom's employees ($n = 31$).

a major business problem for a large telecom equipment provider formed the basis of Qamcom's founding. With a contract signed with the first customer, the founders acquired a large bank loan to start the business, and since then, the company has evolved and broadened its scope, moving into several technology fields. Qamcom has five areas of competence—AI, wireless connectivity, autonomous systems, radar systems, and industrial IoT—and its clients operate within a broad range of industries, including aerospace, automotive, manufacturing, medical technology, smart cities, and telecoms. It creates value through two business models—high-tech development organized as projects, and consulting services at clients' R&D organizations. It owns several patents and earns income from licensing fees. Another way of developing new innovation at Qamcom is using its great expertise in-kind with other firms and jointly developing their partners' internal product projects to pivot new ventures and spin-offs.

In 2020, the Qamcom Group's turnover was 381 MSEK (~35MEUR) with 280 employees, and Qamcom comprises more than 50%, making it the centerpiece of the group. Since its founding, Qamcom has experienced rapid growth, both in terms of turnover and number of employees (see Fig. 1).

Three core philosophies for the company's way of operating were formulated—a close connection to academic research, a deep, core-technology competence, and, most important to this study, an intent from the start of the company to run the organization in a new way. The last is the focus of our study. Development of Qamcom's organization is detailed in the next two sections, with Fig. 2 showing an overview.

4.2 The Early Phases of Experimenting

During its early years (2001–2009), the company grew quickly, from 8 to 20 employees. During this phase, Qamcom had an informal organization, maintaining the open and free spirit atmosphere of a start-up, with most decisions made after open discussions. There was no time or any perceived need to add hierarchical levels, aside from a CEO, who, during the early stages, was one of the two founders. The Qamcom way of organizing internally was characterized by anarchy, partly as a joke and partly a description of the company's free spirit and non-hierarchical, informal way of working. An attempt during 2008 was made to expand the managerial hierarchy, but it ended poorly, so the anarchistic structure continued under the supervision of one of the two founders.

A few years later during 2010, the first self-reflection and critical rethinking of the organization began. When the number of employees increased from 20 to 40, the anarchistic organization and lack of management structure eventually hindered work. Growing frustrations were evident over the inefficiency of work, and in response, the company initiated a conventional hierarchical structure, with teams, units, and managers across roles. During that year, Qamcom was restructured and what today is Qamcom Research and Technology (QRT) was established, with a new, external CEO hired to lead QRT. Early during the reorganization, dissent grew regarding

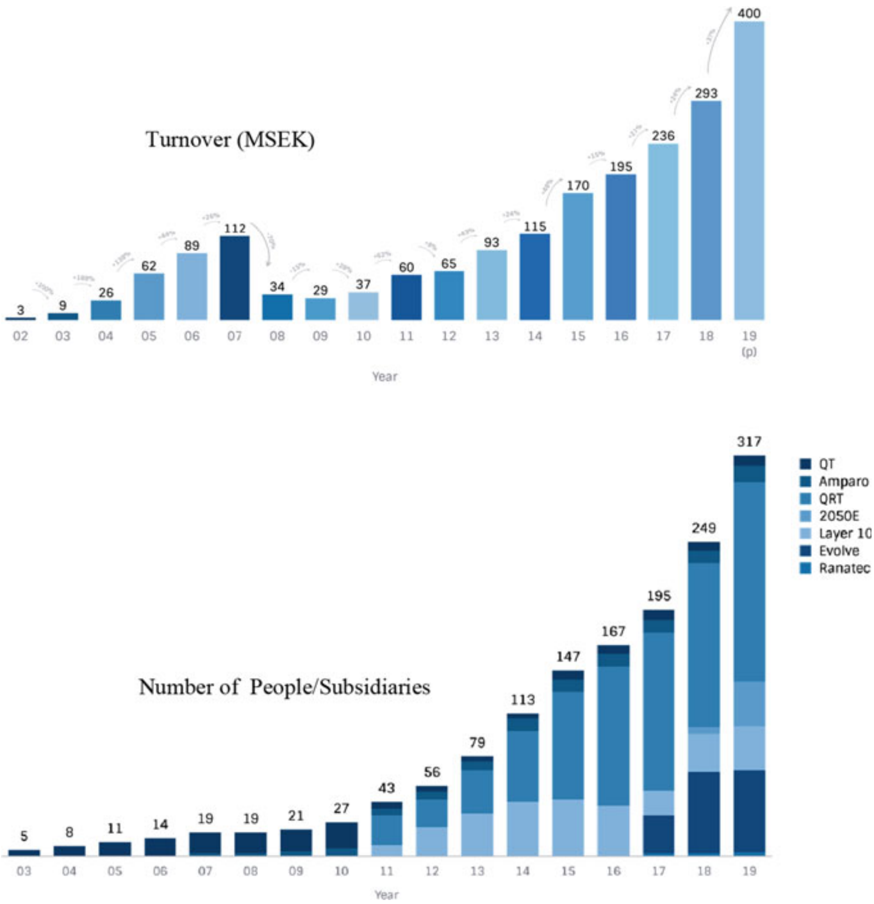

Fig. 1 Qamcom's growth

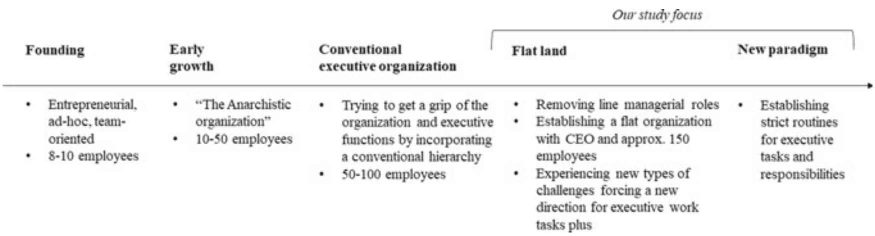

Fig. 2 Qamcom's development while becoming a self-managed organization

the idea of going hierarchical. People had become accustomed to working side-by-side as colleagues, with only the founder as leader, but in the new emerging (hierarchical) structure, suddenly they started to position themselves in a hierarchy. They questioned who should become the boss of a former colleague, and why that person and not another. There was also concern about potential loss of creativity and innovativeness when growing and becoming more bureaucratic, in comparison to the previous anarchic way of working. The organization eventually broke down during 2018, as the next section explains.

4.3 Rethinking Predominant Beliefs

4.3.1 In Search of New Logic for Execution

During 2018, many discussions took place regarding flat organizations, and the founders, together with a group of employees, searched for an organization that fit with the ideas and philosophies specific to Qamcom. There was clear conviction that it would be possible to run the business in a new way, without hierarchies, in which the most central principles were employee involvement, commitment, and responsibility for the entire business. The primary idea was that everyone had the opportunity to contribute to the company's success through competence and personal development, rather than position or managerial power—underlying beliefs that required major requestioning of conventional hierarchical principles for management and organizational design. One of the founders was inspired broadly by new organizational ideas, such as TEAL, agile, holocracy, and other self-managed organizational practices.

> There were a lot of discussions about flat organizations, TEAL, etc. In 2018, people began to think about the organization. There was no structure in the organization, a CEO and more than 100 people. The CEO built an organization but did not have the strength to exceed resistance. He had 100+ direct reports; it did not work. There was an anarchist atmosphere in the company. (Informant 2)

The underlying objective during the rethinking of the organizational principles was twofold: (1) achieving an organization that was a "better place to work at" because it was more democratic and transparent, and (2) becoming an organization that was more "effective", with increased innovativeness (i.e., prepared to innovate) and adaptability (i.e., able to deal with uncertainty).

4.3.2 Mapping Work Related to Common Functions

One critical insight was the need to radically rethink how work, including both common and, to some extent, executive tasks, was distributed among employees. At the time, most employees were assigned to projects according to two business models—technology development and client consultancy. Tasks related to projects were not a problem, but there were many tasks and duties within common functions of the company that needed to be addressed. The company thus decided to identify, isolate, and formulate each part of work related to common functions, describing it as a role or notion that became critical. Roles were defined and assigned to one or more individuals who spent a portion of their total work time on the roles. The overall idea for roles regarding common and strategic work was derived from the original idea of rethinking organization, a conviction that it was possible to run the business in a new way, during which the most central principles were employee involvement, commitment, and responsibility for the entire business, and during which the business was constantly evolving. Role definition and allocation resulted in all individuals being allocated to carry out both project and role work, and thus administrative and executive tasks. Initially, role experimentation worked well, but over time, several undefined, common work duties developed and ended up on one role's desk. Non-core issues, such as who was entitled to a parking space or should be granted travel privileges, increased over time. People increasingly sought advice from the CEO, and they continuously brought new, unsolved questions to him. Accordingly, the CEO's workload and responsibilities grew.

> We noticed this clearly. All questions came to the CEO when we only had one position. The organization felt passive and turned to the CEO…if you do not now break up that position. (Informant 1)

During 2018, the CEO was struggling with the fact that everyone was equipped with a proper mandate and the means to navigate processes and make decisions, and yet they were reticent to take responsibility and did not act. In a hierarchy, one person decides on issues and has the corresponding responsibility, and all questions can be directed to the person who handles them. Qamcom realized that even a single hierarchical level and position were sufficient to create a flow of issues directed to that position, making the remainder of the organization passive. That person, the CEO in Qamcom's case, must deal with many kinds of questions, including strategic business decisions and rules regarding, for example, parking spaces, thus contradicting the ambition of sharing responsibilities across all work tasks.

4.3.3 Removing the CEO

During late 2018, a decision was made to change the organizational structure and implement a new organization—a role-based one. Consequently, the external CEO was removed. The idea behind the change was to allow the organization to operate without a CEO. This, in turn, was a response to the organizational difficulties that Qamcom experienced when trying to allocate administrative and executive work and roles and was intended to enable employee involvement in, commitment to, and responsibility for the entire business.

> Qamcom has taken the final step towards a fully flat organization and removed the only remaining hierarchical position in the company, that of the CEO. (Corporate press release, 27 May 2019)

Removal of the CEO required the board's acceptance. A board is tasked with the legal responsibilities required to run a company, but all other executive tasks and responsibilities had to be resolved, which required a new way to organize a company—a flat organization without hierarchy. Internally, the new organization was called Flatland because managerial hierarchies no longer existed, reflecting Edwin Abbot's (1838–1926) notion in *Flatlands* (Abbott, 1991). The former CEO began to work alongside other employees on recruitment and customer issues, and new business.

4.3.4 A New Steering Model

One dilemma was how the board's responsibilities would change when the power and responsibilities associated with steering the organization, delegated previously to the CEO, were reassigned. The board questioned whether power should instead (vaguely) be given to the organization, but the board did not delegate that power. Instead, it accepted the idea of delegating responsibility for steering proposed by the organization. A new steering model for operating Qamcom was created and introduced, characterized by involvement, transparency, and optional participation.

> The board actually delegated all higher tasks in the company to the entire business, which may break them down and work with them. However, if the business wants to change any of the main processes, it is a board issue. You must not do that. (Informant 1)

The steering model was grounded in a few overarching rules, combined with dynamic decision forums, all approved by the board. The model consisted of three components.

(1) Existing defined tasks and roles, role descriptions for all work tasks, and project work tasks and both administrative and executive tasks.

(2) Three forums open to all employees, and each led by a facilitator and held regularly. How many and which employees participate vary.

    A role definition forum. A biweekly forum opens to all employees, during which roles are defined and redefined when a new task requires a new role or a role's capacity needs to be increased. This managerial task is executed and decided through this forum.

    A role allocation forum. A biweekly meeting to which all employees are invited, during which assignments are decided and given to a role. A new task that emerges does not always fall naturally within an existing role domain. Participants must agree to which role a task should be assigned.

    A compensation forum. This forum determines compensation and salaries for all employees. Any changes to roles played in the role definition or allocation forums are considered in this forum. Roles vary in scope and extent; some require full-time attention, such as financial control, others require only a few hours per week, and still others require several days each week. The number of roles changes over time, but in 2020, 55 roles involved some type of executive management task.

(3) Communication platform using tensions. Qamcom's intranet represents a platform for multidirectional communication and continuous exchanges of information, allowing both broadcasting of information and constant interactions among employees. Work and internal documents are developed and stored on the platform. One essential function relates to the forums, that is, ways of working and organizing issues. At Qamcom, the notion of tension is used:

> Ordinary tensions are how we handle…roles are evaluated, roles evaluate, for example, patent coordination. Unusual tension? When we override the board's decision. Tensions are about responsibility, power. (Informant 1)

A tension is a description of something that needs to be discussed and that anyone in the organization can formulate; it is written documentation of an issue, directed to one of the three forums and discussed online prior to the forum in a co-creating, open dialogue. During discussions, a tension can be expanded, compressed, and developed and eventually raised during one of the forums. Both deviations from desired states and developments that someone wants to achieve at Qamcom are treated as tensions, and thus, tensions concern roles and responsibilities. Tensions are largely handled in role definition and role allocation forums. They are seldom addressed at the compensation forum, but such tensions are much more sensitive. The notion of tensions was not Qamcom's own invention, but adopted by its organizational members, inspired by the broader movement of self-management (e.g., TEAL, holocracy). At Qamcom, tensions were intended to express both risks and opportunities (i.e., both deviations from a desired state and opportunities for improvements) that lead to more desirable states. In other words, use of tensions is a language that captures positive and negative aspects when developing a technology business and its organization.

Most frequent tensions regard responsibilities and to which roles should be assigned. Other frequent tensions involve the relevance of a role, when new roles were needed, and to whom such roles should be assigned. All tensions are commented on and documented on the internal communication platform. A tension proposed to a forum is archived, as are subsequent recorded discussions, serving as organizational memory. Recruits are commonly directed to read previous conversations to understand the underpinnings of roles and responsibilities, and thus, the language and activities related to tensions represent an essential component of continuous learning.

5 Empirical Analysis—Innovating Executive Management

5.1 Four Themes that Describe Far-Reaching Self-Management

For more than 15 years, Qamcom has consistently sought radical principles for its organization and management, and its experimentation has since been rooted in dual but bundled objectives. The first is improving efficiency, including several dimensions

Table 1 Conceptualization of redistributed power during executive work

Concept	Empirical phenomena
Willingness to share power	Consider alternative ways to organize decisions related to executive work, such as reorganizations, new job design, strategic planning, and capability procurement; remove line managers' roles; remove executive role (i.e., CEO)
Dynamic steering model	Forums for processing ideas and issues toward roles and action; disciplined deadlines for written information as preparation; communication platform for documentation and follow-up
Natural hierarchies	Organizational members' values and competences to lead; participation in discussions across knowledge domains; continuously shifting roles
True transparency	Meetings open for everyone to participate; documentation open for everyone to access (online); handle relational issues that are challenging employees; open about abilities and anxieties concerning tasks

such as creativity, innovativeness, and flexibility.[3] The second is improving quality of working life, including increasing resilience, sustainable organizations, well-being, and democracy. The focus was to achieve increased innovativeness, typical in a technology development firm such as Qamcom, and simultaneously achieve smarter ways of working, based on the idea that the organization should, as its ultimate purpose, reach beyond an exclusively economic rationale to be a better place at which to work. These two objectives grounded radical rethinking of executive management—rethinking the rules and principles regarding the way execution is organized. Norms for how firms are, and should be, organized and managed were questioned and eventually replaced with a new, role-based logic for organization, in which executive work was also distributed. Essential to this was introduction of a new steering model.

This study, and subsequent emerging understanding and conceptualizations, was driven by intermediate theories—extant theories and established practices combined initiating creation of new knowledge (Starkey & Madan, 2001). Such co-created knowledge provided the researchers with knowledge of the Qamcom experiment, from which we applied theoretical ideas and principles abductively to structure empirical findings (c.f. Alvesson & Sköldberg, 2007; Dubois & Gadde, 2002). Analyses and subsequent conceptualizations of Qamcom's new ways of working with the executive task resulted in four concepts—willingness to share power, a dynamic steering model, natural hierarchies, and true transparency. These concepts together constitute a new structure for handling execution, shown in Table 1.

[3] Interestingly, productivity was deliberately excluded from improvement. An underlying principle at Qamcom was, and still is, that profits should be sufficient, but there is no self-fulfillment in maximizing profit. This principle accords with capability theory, which addresses a learning perspective (Lavie, 2006; Winter, 2000).

5.1.1 Willingness to Share Power

A necessary, though insufficient, prerequisite for succeeding with far-reaching self-management is a willingness to share and distribute power. This addresses a willingness to share power generally, but it includes a willingness among top executives to share and (re)distribute their own executive power. By executive power, we mean decisions related to executive work, such as reorganization, new job design, strategic planning, and capability procurement. The origin of such new thinking was the founder's idea to rethink his own executive task, which presumes a conviction to practice involvement and responsibility, and the idea that people perform best when they are empowered to influence and are given proper responsibilities. This, in turn, requires entrepreneurial leadership through explorative actions and inquiry, with trust in both the company's vision and coworkers.

> As a previous founder and CEO of the company, my presence influenced others in the company, so, for example, I never participated in the role allocation forum. (Informant 1)

Thus, the founder, together with the board, decided to remove the executive role, and the externally recruited CEO was removed. This decision was long rooted in the founder's conviction of sharing power, including a willingness to share his own.

5.1.2 A Dynamic Steering Model

At Qamcom, the true intent to share power and resignation from the CEO authority were clear, though based simultaneously on a belief that even were there no managers, both management and control are needed; removal of the executive role required an alternative model for steering. The model applied at Qamcom, with its three forums and everyone being involved, was a solution premised on dynamism; it could change easily due to perceived changes needed and/or new knowledge. The agenda for a forum, for example, was open for weeks for everyone to add tensions and develop existing ones, which allowed continuous development of what was to be discussed during the forum. To avoid late introduction of information, to which others would not have time to react, the iteration closed 48 h before the start of a meeting.

> It becomes realpolitik where most organizational members share our system as ideology but can debate factual issues and submit comments on underlying proposals. (Informant 1)

Unsurprisingly, the founder commonly used democracy metaphorically to describe the process, and the steering model was based on people's involvement and engagement in decision-making. Only about 10% of employees chose to participate, and even so, it served as a vehicle for changing the way of working, breaking with the hierarchical logic of steering and creating spaces, in which people could explore if they wanted to take on executive power. The steering model thus became a powerful tool to change organizational behavior and people's attitudes. One prominent challenge with the steering model was risks associated with the fact that the model urged the organization to become text-based. Each tension was documented, and all activities related to reported tensions were subjected to documentation for action and evaluation of outcomes. The model thus depended on people's ability to communicate, especially to write; the primary portion of discussions took place in written form and on the communication platform.

5.1.3 Natural Hierarchies

> I have thought that natural hierarchy is a better word [than the opposite of hierarchy] because then you have to relate to the fact that there are things that are important around you. However, you also have to interpret what 'natural' means, which in my world means that people need to look up slightly and realize that [natural] hierarchies are strongly context dependent. It matters what it is we are discussing and when our problem changes. Someone in the organization has some form of mastery, they become more relevant to the organization's current position. (Informant 1)

Qamcom eliminated the conventional vertical hierarchy, but it did not become a hierarchical void. Instead, natural hierarchies, rooted in organizational members' values and competences, have developed. Natural hierarchies matched with the dynamic steering model and its forum meetings. Who participated in what tensions during forum meetings changed continuously according to the character of the problem and the competences of a person or group of people. The steering model thus allowed for a situation in which the person who was, at the moment, best suited for a role and responsibility was also the one who had an understanding superior to that of other organizational members. In a knowledge-intensive firm such as Qamcom, innovating and operating in the technology development industry, the logic of natural hierarchies related to the steering model enabled an organization of competences throughout and across operating parts. Natural hierarchies facilitated employees' vertical development. By continuously shifting roles and opportunities to allow people to participate in discussions across knowledge domains, employees increasingly gained holistic competence.

> A holistic competence, paired with domain competence, is an enabler for innovation on all levels in the company. (Informant 1)

5.1.4 True Transparency

A prerequisite for the new organization was transparency. At Qamcom, transparency was considered essential to continuously develop, or reinvent, the organization and its management. All meetings and documentation are open to everyone:

> The intranet has been the center of discussions. A lot of information is there, even sensitive information. (Informant 2)

Transparency is not novel, particularly in self-managed organizations (Martela, 2019), but as executive powers are redistributed, the meaning of transparency expands. Executive work implies handling relational issues that are challenging employees. An example is an employee who does not conform to the values that are essential to the firm, and another is the extent to which organizational members have the courage to make strategic decisions that will have profound consequences for colleagues. Redistribution of executive power during self-management that produces a new organizational form creates sensitive situations that require transparency beyond information-sharing. Individuals must also be transparent about their own abilities and anxieties concerning tasks.

> [If a] consultant on an assignment does not thrive, [t]he person should be able to take responsibility for himself or herself and say that he or she is not happy. However, it does not happen. One solution would have been for the person to talk to his or her receptor / on-call friend. However, that did not work. This is a shortcoming. How do we obtain a better idea of well-being? Everyone should have a receptor. However, there are good sides too. If we all become self-leading, we will also get the best organization. (Informant 2)

Qamcom treated transparency as an important notion, especially regarding the new logic for steering. Without it, the dynamic steering model would have become meaningless, or at least not a democratic alternative to a hierarchy, in which power follows from information exchange, which is both an open and closed activity. Transparency and the functionality of the steering model were mutually dependent. Without full transparency enabled by a communication platform, the steering model would have failed, and without the steering model, full transparency would also have been meaningless. The same is true of its underpinning—a willingness to share the power of information and natural hierarchies. Analogous to democracy development, the organizational landscape shifted from democratic influence within a hierarchy to democratic, or self-managed, responsibility of each organizational member for the purpose of both collective well-being and individual growth.

5.2 A Renewed Logic for Handling Executive Work

Combined, the four concepts discussed above constitute a new organizational system of handling executive work. For Qamcom, an organization with a sincere intent to run the firm differently and one that has searched for new ways of organizing execution for more than a decade, it was not until the company decided to remove the CEO and introduce a role-based organization that a radical shift appeared. By removing the CEO, all conventional hierarchies were eliminated, which, in turn, forced the company to develop a new logic to deal differently with executive tasks and power—the alternative steering model with roles and forums. These two actions linked closely, but could not themselves be productive without new perspectives and concepts. The notion of natural hierarchies, both conceptually and as a way of working, was equally important. Hierarchy was thus not eliminated; only conventional hierarchies were eliminated in favor of a type that allowed authority to change continuously.

6 Discussion—Innovating Executive Management in Self-Managed Organizations

This chapter explored how executive management was innovated in Qamcom by replacing the conventional managerial hierarchy with an alternative structure—a role-based one—here characterized as a far-reaching self-managed organization. We specifically explored how the ways rules of execution are conducted can be reorganized in a radically different way, when a conventional hierarchy is being replaced with an alternative logic of a role-based structure, operating across four novel concepts—willingness to share power, a dynamic steering model, natural hierarchies, and true transparency. This study thus contributes to explaining executive work in self-management and self-managed organizations as a novel innovation capability, discussed further below.

6.1 Far-Reaching Democracy in Self-Managed Organizations

The compelling democratic characteristics observed at Qamcom demonstrate what researchers during the 1960s recognized as an important alternative organizational form—firm democracy (Rhenman, 1968). At Qamcom, removal of the CEO position and its subsequent required redistribution of executive power demonstrated that the firm's democratic dimension was not necessarily limited to lower levels and simple strategic problems, as discussed in extant self-management literature. Lee and Edmondson (2017) argue that organizational democracy literature represents a source of understanding less-hierarchical organizational forms, such as self-managed organizations, but the democratic dimension is limited to employee committees that are empowered to make some operational decisions, while managers still make most operational and strategic decisions. They suggest that democracy is not a term that truly characterizes self-management, and it should be revised based on the findings reported in the current study. Based on this study of Qamcom, we point to broader implementations of democracy rather than lower-level forums alone, such as committees, to encompass involvement and employee responsibilities for strategic decisions. It is thus possible to create democracy as an impactful dimension of self-management that is significantly more far-reaching than that evident in extant literature.

6.2 Self-Managed Organizations and Innovation Capabilities

It appears important to consider the innovation dimension when understanding self-management and self-managed organizations. Qamcom's self-management history (see the Fig. 2) suggests that the firm experienced times both with and without hierarchies, and various degrees of democracy. Child (2019) argues that as long as conventional hierarchical relationships coexist with democratic structures in an organization, democracy is limited, and so it was at Qamcom. Once conventional hierarchies were replaced, the firm embraced democracy differently. A combination of a new steering model and use of natural hierarchies at Qamcom constituted a dynamic and temporary hierarchy with less negative influences on democracy. In other words, the steering model and its associated concepts (see the Table 1) at Qamcom formed an innovation capability.

With the steering model's forums, democracy was not limited to only a portion of operations, but extended to cover strategic issues. This corroborates what Puranam et al. (2014) suggest are the overarching problems of new organizational forms (e.g., self-managed organizations)—task division, task allocation, reward distribution, and information flows. Thus, the new way of organizing executive work observed at Qamcom not only contributes to a changed understanding of democracy in organizations, but better understanding of the role of conventional hierarchy—and non-conventional hierarchy—when identifying and developing innovation capabilities.

6.3 Innovating Executive Management

Even if most organizational members are not shareholders, a firm's bottom-line performance is likely influenced more strongly by members' ownership of their roles as dominant stakeholders. Difficulties with implementing self-management might, therefore, be explained by difficulties when communicating an alternative managerial hierarchy, which alters shareholder governance found in self-managed organizational forms. We argue that there is a lack of language that describes these forms of self-management when executive management work is innovated and the executive power is redistributed. The conceptualizations and wording we use here contribute to understanding what "executive self-management" is and how it can be practiced throughout an organization (see the Table 1). Self-management literature is predominantly influenced by notions of conventional hierarchical order, including terms such as *organizations without managers*, *fewer hierarchical levels*, *involving employees in decisions*, and *delegating decisions*. These terms imply dichotomous reactions that hinder researchers and practitioners from seeing what lies at the core (e.g., Farjoun, 2010)—alternative ways of organizing rules for how execution can be organized. The Qamcom case suggests that new organizational and managerial logics exist that have the capacity to create, express, and implement new ways of working with executive tasks' responsibilities. Conventional hierarchical language preserves and thus inhibits people from thinking outside of existing frames (e.g., Beer, 2001; Sandberg & Tsoukas, 2011). New words and concepts, other than those rooted in conventional hierarchies, are thus needed. Executive work still exists in far-reaching self-managed organizations, but it is undertaken differently, and the Qamcom case with its innovation of the executive work demonstrates how it can happen.

In far-reaching, self-managed organizations, we argue that natural hierarchies replace conventional ones, suggesting a dynamic authority based on expertise (e.g., French & Raven, 1959), not positional power. Hamel and Zanini (2020) argue that "building natural, dynamic hierarchies" (p. 152) reduces influence from an organization's conventional hierarchy. Our findings corroborate this argument by suggesting that natural hierarchies are substitutes for conventional ones. Removing the CEO position is crucial to radically changing the redistribution of all types of power, including executive power, which is the outspoken intent of self-managed organizations. However, this is difficult (e.g., Child & McGrath, 2001). To do so, a willingness to share power in a democratic mode, which we argue is inherent in natural hierarchies, must be accompanied through true transparency. Considering these concepts as prerequisites and their systematic character as an innovation capability provides a new and better understanding of not only how, but also why, far-reaching self-management occurs in organizations.

7 Concluding Remarks

Most firms still use conventional hierarchies as a principle of organizing. Therefore, shareholder interests based on hierarchical logic dominate when seeking to develop organizational forms, in general and for innovation purposes, or developing executive work remains untouched. In contrast, the Qamcom case demonstrates a radical and far-reaching effort to use a democratic organizational form that simultaneously increases preparedness for innovation. At Qamcom, executive work, including the role and responsibilities of the CEO, is redistributed to employees, an unusual and bold innovative experimentation. Until now, most self-management attempts have excluded the executive dimension from experimentation. Our findings contribute to self-management research because it includes executive work and subsequent responsibilities to self-management. From an innovation capability perspective, this similarly is new. Literature on innovation capabilities, exploring firms' efforts to become more innovative (i.e., actions conducted to build innovation capabilities), has thus far excluded executive managers' experimentation with their own work. Thus, a new order for executive work has not yet been considered a potential component to capability building. We point to the power of rethinking executive principles for organization and management, particularly executive management, in emerging contemporary attempts at new organizational forms. Such attempts might not only lead to increased democracy and quality of working life, but form an additional building block for a firm's innovation capability.

The self-management movement has thus far been limited, but new organizational experiments embedded in the movement in Sweden and elsewhere appear to be critically new sources of renewing preserved hierarchical thinking, particularly since social movements in societies and frequent disruptions must be met ahead of time. More research is needed to explore and elaborate on theories of self-managed organizations and their nature, boundary conditions, and long-term innovation effects. Future research and practice should develop language, terms, and concepts of self-management to open executive work up to further knowledge exploration.

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Toward a Research Instrument for Firm Behaviour in the Dichotomy Dynamic Versus Myopic National Innovation Systems: Reflections from a Systems Perspective

Rob Dekkers, L. J. Lekkerkerk, and Peiran Su

Abstract Whereas Patel and Pavitt's (Econ Innov New Technol 3:77–95, 1994a) work has been modestly cited, its postulation of two archetypes for national innovation systems, i.e. dynamic and myopic national innovation systems, has hardly been used to advance insight in firm behaviour; in this chapter we explore this dichotomy and build a novel research instrument for characterising this behaviour with regard to technological activities (although we equate their original terminology with innovation). An exploration of the underlying postulations, background and domain assumptions leads to the development of elements for the instrument. At the same time, it demonstrates that firm behaviour has limitedly been discussed in the context of national innovation systems. Therefore, suggestions for research, including the use of research methods, build on the deliberations on this chapter. Furthermore, the thoughts on how to use the research instrument informed by systems theories indicate the multiple levels of analysis: decision making on and monitoring of innovation processes in firms and innovation networks, sectoral innovation systems, regional innovation systems and national innovation systems. In addition, decision making on and monitoring of innovation processes in firms and innovation networks is related in this chapter to two models derived from systems theories: the model for the dynamic adaptation capability and the model for management of innovation and organisational structures. Particularly, we advocate that data for using the research instruments to position firm behaviour in the continuum of dynamic and myopic national innovation systems can be aggregated to compare firms across sectoral, regional and

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national innovation systems; this will lead to answering the question whether firms' perspectives on innovation are an expression of its individual approach to innovation management or whether they share traits related to managing innovation with other firms in an industrial sector, regional innovation system or national innovation system.

Keywords Innovation management · Dynamics capabilities · Model for dynamic adaptation capability · Model for innovation and organisation structure · National innovation systems · Systems theories

1 Introduction

Even though Patel and Pavitt's (1994a) paper making the case for national innovation systems has received ample attention, the conceptualisation of a dichotomy (ibid, pp. 90–92) and its potential implications for innovative firms seems to have been largely overlooked. Most likely, this interest in national systems of innovation sprung about by the success of Japanese firms and the related interactions in the Japanese economy, exemplified by studies, such as Freeman (1988), comparative studies, for instance, Patel and Pavitt (1987) comparing Western Europe with Japan and the United States, and more generically, the recognition that institutional settings (for example, Lundvall, 1988) may play a role beyond the market as learning process. In these deliberations, firms are seen as playing a crucial role, something that has not changed, even within more contemporary notions, such as the triple helix model (Leydesdorff & Etzkowitz, 1996, 1998), quadruple helix model (Carayannis & Campbell, 2009, p. 206 ff.) and national innovation ecosystem (Fukuda & Watanabe, 2008). Firms in these writings and models not only invest in R&D but also engage with universities and research institutes for innovation. Moreover, they are seen as instrumental to commercialising ideas, inventions, patents and other forms of knowledge. Given the role of firms within national innovation systems, as recipients of knowledge transfer, generators of innovation and actors commercialisation, the question is how individual firms decided on undertaking such technological activities within the context of national systems of innovation, particularly within Patel and Pavitt's (1994a, pp. 90–92) dichotomy.

1.1 Background and Objectives of Chapter

The objective of this chapter is to consider how national systems of innovation form a context for technological activities of firms. Whereas in earlier writings about national innovation systems, firms played a central role, notably Schumpeter (1911), the emphasis in later publications has moved to institutional settings and how firms are actors in an innovation network; Freeman (1995) and Nelson (1993) are early cases in point. However, to understand how firms contribute to national innovation systems, their modus operandi for innovation should be understood. This is often a separate strand of research that links poorly to studies on national innovation systems. Examples of these separate studies in which national innovation systems form merely context for the investigation are Eom and Lee (2010) and Motohashi (2008). Furthermore, there is lack of evidence that the thoughts on myopic and dynamic national innovation systems by Patel and Pavitt (1994a, pp. 90–92) has not been scrutinised on its postulations and underlying assumptions. Our research approach bridges the two distinct strands of literature by developing a research instrument that builds on the assumptions embedded in the dichotomy.

The purpose of this novel research instrument is to position firms' activities in the context of national innovation systems, specifically Patel and Pavitt's (1994a, pp. 90–92) dichotomy. Although efforts are made to capture firms' behaviour, they are typically oriented at how firms act within a specific context rather than linking behaviour and actions to the characteristics of a national innovation system. An example of the more traditional approach is found in Wagner and Kreuter (1998) when they compare innovative and less innovative firms as case studies in Germany, Japan and the United States of America (USA); they (ibid., pp. 39–40) find that soft factors such as communication play a larger role in more innovative firms than hard factors such as organisational structures, with Japanese firms emphasising them more than their counterparts in Germany and the USA. Moreover, national innovation systems are often compared in studies, without considering the stratum of firms. Instances are Intarakumnerd et al. (2002), and Marxt and Brunner (2013). Thus, our purpose is to connect how firms' innovative and technological activities are co-determined by characteristics of national innovation systems.

1.2 Scope and Outline of Chapter

Besides offering a fresh perspective on a particular classification, i.e. dynamic and myopic national innovation systems, this chapter aims at making three scholarly contributions. The first contribution is that we examine the postulations of this dichotomy in detail. Other scholars can build on these assumptions and consider how their studies either use them or challenge them for validity in specific conditions and institutional settings. A second contribution of the chapter is a novel research instrument that is developed in this chapter. Again, this can be used by others to measure the orientation of firms in the context of the dichotomy. A final contribution are the deliberations on how systems theories can inform investigating national innovation systems. All three contributions to scholarly knowledge aim at better understanding firms and their technological activities in the context of national innovation systems.

This chapter starts by looking at the dichotomy for national innovation systems proposed by Patel and Pavitt (1994a, pp. 90–92) in the second section. This includes investigating its underlying assumptions, commensurate with Alvesson and Sandberg's (2011, p. 258) position for articulating and developing alternative assumptions.

In contrast to their approach, in the third section, we use these assumptions for the dichotomy to develop a novel research instrument to position firms in the continuum presented by the two archetypes of the dichotomy. The instrument is further developed for the inclusion of networked innovation. Additionally, its use for different research methods is discussed. In the fourth section, the research instrument is placed in the context of systems approaches. This allows us to extend the instrument from a holistic perspective. In the fifth section, a research agenda is presented, building on the novel research instrument and challenging the assumptions of the dichotomy. Implications for research and managerial practices are discussed in the final section.

2 Scrutinising Dichotomy Dynamic Versus Myopic National Innovation Systems

When introducing the concept of dynamic and myopic national innovation systems, Patel and Pavitt (1994a, pp. 90–92) presented these as contrasting notions. The use of the word ‘spectrum’ (ibid., p. 91) and ‘dynamic national systems, on the other hand, …’ suggest so. Moreover, in their treaty of ‘incentive failures’ and ‘competency failures’, they refer mostly to Germany and France as representing dynamic national innovation systems, and to the United Kingdom (UK) and USA as typifying myopic national innovation systems. The proposition for this classification emerged during an epoch in which thinking shifted from vertically integrated firms to networked innovation (link with large firms). For instance, Tidd (1995, p. 321) concludes that European firms in home automation tend to be more narrowly focused when engaging in networks for innovation and new product development compared to American and Japanese firms, thus not taking full advantage of open networks [this precedes the coining of ‘open innovation’ (Chesbrough, 2003) by almost a decade]. Additionally, the emergence of networks is evidenced by the trend towards outsourcing at the time; for example, see Dekkers et al., (2020, p. 12), although observed by them for innovation in the period 2007–2011. This means that Patel and Pavitt’s (1994a) writing did not consider the impact of networked innovation and outsourcing on their considerations since these topics played a lesser role at the time. A final remark is that Patel and Pavitt (1994a) do not consider multinational corporations, probably because their focus is on national innovation systems. Keeping in mind that their proposition for the two distinct national innovation systems does not account for networked innovation and multinational corporations, for the development of the research instrument, we will consider it a dichotomy, reflecting on this in Sect. 3.2 and the concluding section.

2.1 Relevance of Dichotomy

Mostly, the work of Patel and Pavitt (1994a) appears in the context of studies into national innovation systems. Although this work is taken as starting point here, the distinction between dynamic and myopic national innovation systems already appeared in earlier writings by them, notably Pavitt and Patel (1988, p. 52), albeit in a more rudimentary manner. Also, in the same year for the work of reference they published another paper in which the dichotomy (Patel & Pavitt, 1994b, p. 782) appears in an abridged description. Returning to how Patel and Pavitt's (1994a) publication is used, an example of works studying national innovation systems is Watkins et al. (2015), who investigate the role of industry associations, referring several times to Patel and Pavitt (1994a). A similar study is the one by Neely et al. (2001) into the role of policy makers to enable firms to become more competitive. Others refer to the innovation capabilities of national innovation systems, such as Schlaile et al., (2017, p. 2253/3) in the context of sustainability. This quest into actors and innovation capabilities using Patel and Pavitt's (1994a) paper is complemented by studies into national policies for innovation, for instance, Smith (2000, p. 17) citing their observation on patterns of R&D expenditures, patenting and scientific publications demonstrating specialised technological capabilities embedded in national innovation systems. Another related theme is the impact of globalisation of technological activities, particularly by multinational firms, on national technological competitiveness, e.g. Archibugi and Michie (1997), who reflect on the changing role of the nation state, and Radice (1998, p. 278), who casually refers to Pavitt and Patel (1988) but in the remainder of the essay sets off the Anglo-Saxon context to the Rhenish and Japanese contexts. Other implications of their thinking are reflected in studies on the composition of the workforce, by way of illustration, Lavoie and Finnie (1998), and Patrinos and Lavoie (1995). Sometimes, the work of Patel and Pavitt (1994a) is merely used for its description or definitions of innovation, with Hidalgo and Albors (2008, p. 115), and Landry et al. (2002, p. 683) being cases in point. Setting aside casual citations and the definition from Patel and Pavitt (1994a), their work has informed studies of national innovation systems in many ways, such studies drawing in their reasoning and design of research methodology on different fragments and aspects (the latter in the sense of systems theories, see Dekkers, 2017, pp. 29–32).

When firms are studied using Patel and Pavitt's (1994a, pp. 90–92) dichotomy, with Pavitt and Patel (1988, p. 52) being a precursor of their later conceptualisation, this is mostly done by considering myopic behaviour when making decisions. For example, Mueller and Yun (1998) look into investment strategies implicitly by considering measures for long-term and short-run decision making, referring to myopic and dynamic perspectives (ibid., p. 349), albeit relating to Patel and Pavitt's (1994b, pp. 781–782) related description of the dichotomy while citing-in-text incorrectly; curiously, Mueller and Yun (1998) do not reflect on it in their findings and conclusions. In the study of Dekkers et al., (2019, p. 215) the approach to collaboration for innovation by Scottish firms is linked to myopic behaviour in the context of Patel and Pavitt (1994a, 1994b). However, some studies have questioned how the dichotomy should be applied. Whereas Patel and Pavitt (1994a, pp. 90–92) present it as a contrast, Feldman and Ronzio (2001, pp. 7–8) note that some behaviours of organisations may be myopic and others dynamic, citing Turney's (2001, p. 37) interpretation of Patel and Pavitt's thinking. Mueller and Yun (1998, p. 349) hint at the same. Therefore, the few studies using the dichotomy are fragmented, focusing on specific aspects and topics, with little precedence for firms as constituent parts of national innovation systems; in addition to a scrutiny of the dichotomy missing, there are also hints that actual firms' behaviour may be a blend of traits associated with either myopic or dynamic national innovation systems.

2.2 Looking at its Assumptions

Since no other work has yet considered the postulations and assumptions, we scrutinise the dichotomy of dynamic and myopic for national innovation systems by Patel and Pavitt (1994a, pp. 90–92). Their preceding work (Pavitt & Patel, 1988, p. 52) also captures the dichotomy but is less extensive and more related to the background and domain assumptions that will follow later. The identified postulations in Patel and Pavitt (1994a, pp. 90–92) are captured in Table 1; in their writing, they posit different arguments for the differentiation between dynamic and myopic national innovation systems, making their reasoning somewhat incomplete. To articulate the postulations, we distinguish four facets of these systems. The first facet is how technological activities are viewed by actors in the system, which includes firms. In a myopic national innovation system, technological activity is undertaken as a response to a well-defined market demand and evaluated as a traditional investment, in which risk and duration are considered. This means that actors approach these activities as yielding new products, services and processes, all tangible outcomes; for the purpose of our quest—the development of a research instrument—the intricate relationships between these three types of innovation are set aside. These outcomes should produce benefits, the second facet; in the context of myopic national innovation systems, there is stronger emphasis on financial outcomes and on the (relatively) short-term for obtaining these benefits. According to Table 1, the third facet is how capturing technological opportunities is left to divisional organisational structures that respond poorly to new and longer-term technological trajectories, particularly noted as a challenge in the context of the myopic national innovation system. In this respect, a well-educated workforce will not directly result in tangible outcomes, the fourth facet. This notion for the myopic national innovation system contrasts with the assumption for the dynamic national innovation system, which relies on the development of competencies and places performance in a longer-term perspective. Note that Patel and Pavitt do not directly address how organisations in the dynamic system are organised with regard to capturing technological opportunities (the third facet); however, it can be interpreted that they imply that top management (ibid., p. 91) plays a more prominent role in this context. These four facets are exemplified by countries; the institutional settings of the UK and USA are seen as representing the myopic national innovation systems, and Germany and Japan as typical for dynamic ones. This association of specific countries with these two archetypes is partly derived from empirical evidence presented in their paper. Nevertheless, the delineation of the two extreme types on the four facets—perspective on technological activities, horizon for performance measurement, organisational structure and education of the workforce—creates a theoretical base for further research.

Following Gouldner's (1971, pp. 29–35) thoughts on background assumptions underpinning postulations, five can be discerned from Patel and Pavitt's (1994a, pp. 90–92). The first background assumption is that technological activities act as 'drivers' for innovation. This is a somewhat restricted interpretation of Schumpeter's (1911, 1934) notion of innovation and current views that focus more on innovation as 'doing things differently', with managerial innovation being a case in point. The second background assumption is that technological activities yield both tangible outcomes, i.e. product, service and process innovation and intangible ones, such as market, technological and organisation knowledge. The accumulation of knowledge is expected to lead to both later identifying opportunities for product, service and process innovation, and providing context for and (integral) implications of such decisions. The term innovation used here includes commercialisation whether as process or outcome; we do not want to wade into a discussion on appropriate definitions, as

Table 1 Postulations for myopic and dynamic national innovation systems

Facet	Myopic national innovation system	Dynamic national innovation system
Decision making on technological activities	Technological activities viewed as 'traditional investment' for tangible outcomes (process, product, service): • Well-defined market demand • Discounted risk • Limited horizon	Technological activities yielding tangible outcomes (process, product, service) and intangible benefits: • Accumulation of intangible assets through market, technological and organisation learning • Building of competencies
Performance measurement	Short-term financial performance	Longer-term performance
Organisational structure	• Decentralised through delegation of responsibility and accountability • Unable to capture new and longer-term technological opportunities	–
Education of workforce	Lesser of well-trained workforce	Reliance on rigorous vocational education

Source Patel and Pavitt (1994a, pp. 91–92)

Baregheh et al. (2009), Kogabayev and Maziliauskas (2017) and others do, with the danger of throwing another definition in the ring. Returning to the accumulation of knowledge, a potential complication is that this knowledge may play an implicit role in decision making even if a particular decision could be considered myopic. The third background assumption is that national innovation systems provide context for how technological activities are decided on and monitored. This must be interpreted as actors within a national innovation system exhibiting a collective set of traits that differs from similar actors in another national innovation system. This background assumption was challenged in the preceding subsection when referring to assertions by Feldman and Ronzio (2001, pp. 7–8), and Mueller and Yun (1998, p. 349). Another tentative challenge to this background assumption is that it may be bound by industrial sectors in a nation, with the difference innovation systems between the Dutch agricultural sector and process industry being a case in point. The fourth assumption is that top management is better suited to capture new and longer-term technological developments compared to decentralised divisional structures. However, there are studies into behaviour of CEOs that indicate that such behaviour can only be achieved if their contracts include incentives related to long-term performance, such as the discussion paper by Francis et al. (2011), although the simulation by Levesque et al. (2014) points towards other factors, including duration of tenure, playing a role; that the longer a CEO has been in position may reduce R&D investments is also found in the investigation of US firms by Peng (2017). For our quest, these studies only confirm that differences in a firm's behaviour and decision making by top managers may occur with respect to the time horizon; consequently, this influences how technological activities are managed and monitored. The fifth background assumption is that the education of the workforce, i.e. vocational training and higher education, determines competencies for technological activities. These five background assumptions and how they are related to existing literature confirm that they are not merely assumptions but also have been observed; they also affirm that the dichotomy may be rooted in realistic assumptions, although actual behaviour of firms may have to be rated on a scale, i.e. a continuum within the context of dynamic and myopic national innovation systems as extremes.

The five background assumptions identified in the work of Patel and Pavitt (1994a, pp. 90–92) are rooted in five domain assumptions, again based on Gouldner (1971, pp. 29–35). The first domain assumption is that it is possible to discern between tangible and intangible benefits as outcomes of innovation processes. Tangible outcomes concern new or improved products, services and (primary) processes, where the latter could also be constituting control processes and structures (following the thoughts of systems theories and sociotechnical design of organisations), whereas intangible benefits are technological, market and organisational knowledge. Related to the first domain assumption, the second domain assumption is that intangible benefits of technological activities take longer to be converted into tangible benefits. The third domain assumption is that intangible benefits are more difficult to measure but a necessity for building competencies and capabilities. The fourth domain assumption is that top management in firms combines better long-term vision, insight into potential markets and implications of technological activities than divisional structures.

The fifth domain assumption is that the dichotomy is evidenced by the 'behaviour' of large firms that they see as normative for national innovation systems. This latter assumption is more appropriate for the aggregated behaviour of actors in a national innovation system and, for this reason, may have to be set aside for developing a research instrument. However, when aggregating firms' behaviour with regard to initiating and undertaking technological activities in the context of a national innovation system, it could be that the behaviour of large firms will be a determinant of the behaviour of such a system. Thus, the five domain assumptions presented here underpin the thoughts for the five background assumptions, which formed the foundation for the postulations.

The postulations, background and domain assumptions derived from them are shown in Fig. 1, which also introduces their interrelations and some points not yet addressed. The first point is that a domain assumption is introduced, labelled DA-0, which states that the technological activities are observable, related to the background assumption that technological activities are the driver for innovation. Keeping mind that Patel and Pavitt's (1994a) performed mostly economic analysis of nation states, the rationale is that technological activities can be noticed by R&D expenditures, patents, etc., which makes sense for their analysis; there are studies that point out the R&D expenditures are not necessarily linked to innovativeness of firms, with Jaruzelski et al. (2006) being a case in point. Also, Patel and Pavitt (1994a, p. 91) express reservations about patents as measure for codified knowledge since it poorly reflects actual innovation, which they call innovation leads. In this vein, on the same page, they also refer to technological, market and organisational learning; the nature of learning and its accumulation is more difficult to observe and not directly by expenditures, etc. This is somewhat a contradiction in the figure, as indicated by the dashed line. Another potential inconsistency is the contradiction between top management as decisive decision makers (fourth background assumption) and the education of the workforce for building competencies (fifth background assumption). If there is a higher level of education in the workforce, then top management can not only be better informed for decision making but may also be challenged in its decision making. This can be straining if there is a cultural difference between engineers and top managers; see Schein (1996) for a treaty of this matter. In this sense, evidence provided by studies, such as Alderman et al. (2022), Çelikyurt and Dönmez (2017) and Daellenbach et al. (1999), seems to suggest that firms with top management teams or CEOs with engineering and scientific backgrounds fare better. Setting these potential inconsistencies aside, the assumptions will serve as base for deliberations and the development of the research instrument.

2.3 *Implications of Conceptualisation*

From the identification of postulations, background assumptions for the postulations and domain assumptions (Fig. 1), it emerges that aspects of decision making on technological activities and trajectories are covered by the dichotomy of dynamic

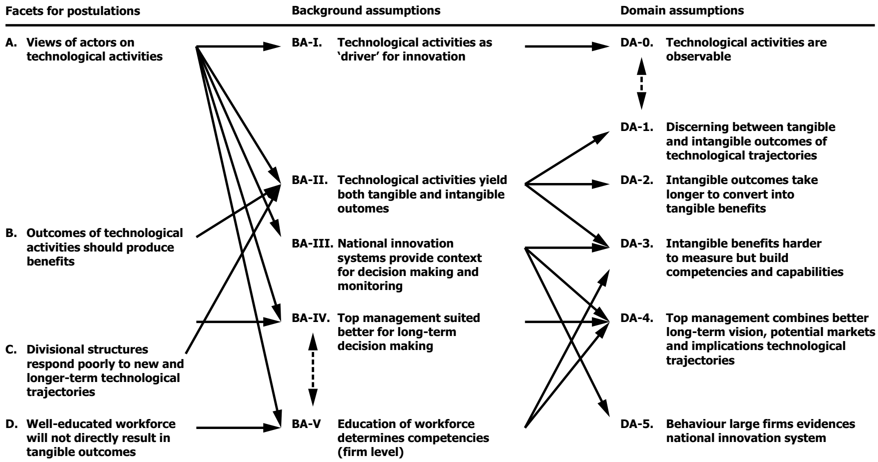

Fig. 1 Overview of facets for postulations and assumptions for the dichotomy dynamic and myopic national innovation systems

and myopic national innovation systems. This implies that it is probable that decision making can be captured by a framework that is valid for a broader range of national settings than the ones seen by Patel and Pavitt (1994a) as exemplary. Such decision making extends to firms as actors in national innovation systems. However, it was noted earlier that actual decision making by specific firms could be a blend of points noted for myopic and dynamic national innovation systems. This implies that the framework for postulations and assumptions presented in Fig. 1 can serve as a guide, but that further research is necessary, since elements of the framework are investigated by studies but not the holistic characterisation with regard to decision making in the context of dynamic and myopic national innovation systems that has been brought to the fore here; also, to where firms' decision making on technological activities and trajectories is found in the continuum presented by the two archetypes is lacking.

When interpreting the dichotomy of dynamic and myopic national innovation systems, the context for its emergence should be kept in mind. Setting aside emerging interest in national innovation systems, perhaps spurred by an interest in the success of Japanese firms and how they were supported by policies and developmental agencies as intimated in the introductory section of this chapter, in the era of Patel and Pavitt's (1994a) writing and its preceding work (Pavitt and Patel, 1988), there was much attention to organisational learning. Exemplary works are Dodgson (1993), Kim (1993) and Senge (1992). Hence, the linkage of market, organisational and technological learning to dynamic national innovation systems may be a product of that era. In the same period, thinking by academics and firms was shifting from monolithic firms to networked structures, partly caused by the popularity of outsourcing; see Dekkers et al. (2020) for an overview of this trend and its possible origins. There is also a potential influence from the interest in Japanese keiretsu structures, see

Bennett and Dekkers (2009, p. 15 ff.). Consequently, networked structures for technological activities and trajectories also gained more prominence, as evidenced by Pittaway et al.'s (2004) review. Thus, when forming a research instrument to position decision making in firms within the context of the dichotomy, contemporary settings should be accounted for, too.

3 Forming Research Instrument for Firm Behaviour

Looking at the domain assumptions, it becomes possible to design a research instrument. The identified domain assumptions can be treated as a combination of 'technological rules' (van Aken, 2004, p. 227) and tentative theory akin to Popper's (1966, pp. 52–55) hypothetico-deductive research cycle, although his thoughts are rooted in Selz's (1913, p. 97) thinking. This also means that the suitability of the domain assumptions for use in research instruments needs to be evaluated.

3.1 Key Elements of the Research Instrument

The first identified domain assumption can be tested by unearthing evidence that its distinction between tangible and intangible benefits as innovation outcomes is valid. Such can be evaluated by using empirical evidence that firms are actually considering benefits beyond product, service and process innovation that are driven by market demands that manifested or customer requirements (for example, for business-to-business) when initiating technological activities or monitoring these activities. This will also prove whether the second background assumption of Patel and Pavitt (1994a) is true. Conversely, this also leads to a technological rule that if intangible benefits have been identified, they will be used at one point for informing technological activities; the assessment of intangible benefits is part of technological, market and organisational learning. The latter statement can be integrated into the research instrument for positioning firms on the dichotomy.

The second domain assumption can also be integrated into the research instrument. This assumption stating that intangible benefits of technological activities take longer to be converted into tangible benefits implies that these outcomes of technological activities cannot be used directly. If true, it means that not only the identification of technological opportunities and well-defined market demands are used for initiating technological activities but also outcomes of market, technological and organisational learning from preceding projects. Conversely, completed projects should lead to market, technological and organisational learning, which are used by later projects. To achieve learning, it should be expected that firms either discuss intangible benefits in a formal or informal manner within the organisation or with collaborators. Thus, captured intangible benefits can be observed through learning expressed in meetings, discussions and decision making and initiation of technological activities where there is no direct (explicit) market opportunity or recording these in a formal repository.

The third domain assumption poses some challenges with regard to its validity and use for research instruments. Where it is possibly true that the intangible benefits are more difficult to capture, a lack of measurement by firms does not necessarily indicate that these benefits are not used for competence building and enhancement of organisational capabilities. Conversely, competence building and enhancement of organisational learning are not directly a result of measurement, too. However, it supposes second-order and deutero learning by organisations, for which mechanisms can be identified in firms. These indirect mechanisms could be part of a research instrument, akin to the point raised for the second domain assumption.

The fourth domain assumption is that top management in firms has long-term visions, insight into potential markets and a grasp on implications of technological developments; this can only be indirectly measured, unless aptitude tests are considered. Indirect evidence could include what is considered during strategic processes, and which methods and tools are used to support decision making, such as technology road mapping, for example, the methodology proposed by Groenveld (2007). Additionally, time horizons for strategy and planning relative to the business cycle of industrial sectors and firms form part of the evidence for initiating and managing technological activities. Thus, the fourth assumption is that indirect measures exist.

The fifth domain assumption—the dichotomy is evidenced by 'behaviour' of large firms that they see as normative for national innovation systems—can only be evaluated by aggregated evidence from studies. To this end, points raised for the four preceding domain assumptions should be sufficiently evidenced by empirical studies into the behaviour of firms, their decision making about technological activities and their monitoring of these activities, taking into account their size. Either through comparison of larger and smaller firms on these points, supported by aggregating evidence through protocol-driven literature reviews, or by considering evidence from firms in the specific context of national innovation systems, also through aggregating evidence in protocol-driven literature reviews. However, this point is uncertain, and therefore, cannot yet be included in the research instrument; this also points to a potential limitation of the research instruments, i.e. some of its measures are derived from larger firms, and perhaps, not suitable for applying it to smaller firms until evidence appears to this purpose.

Putting the points about the domain assumption raised here together results in the proposed research instrument; see Table 2. Principally, the items derived from the domain assumption imply that to what extent long-term considerations and learning play a role determines the position on the continuum of firms' behaviour in the context of dynamics and myopic national innovation systems. A further point is that Patel and Pavitt (1994a, p. 91) emphasise the premise that top management should have competence in decision making for the long run. However, they have formulated this as 'the relatively greater power and prestige given to financial (as opposed to technical) competence is more likely to lead to incentive and control mechanisms based on short-term financial performance, and to decentralised divisional structures insensitive to new and longer-term technological opportunities that top management is not competent to evaluate', although ascribing this to two sources. The first of these sources, Hayes and Abernathy (1980), is an opinion piece on the future of the US economy with regard to dominating management principles, while in the background comparing these with those of European and Japanese counterparts; they (ibid., p. 77) express the view that only senior executives can reconcile differences between functional areas of management. In addition, they posit that an emphasis on short-term results, particularly financial ones, combined with less informed managers or those that consider less long-term implications will gravitate decisions towards less innovative alternatives and favour efficiency-oriented paths. This has been followed by some research into the myopia of top management, which affirms some of the points raised here. For example, indirectly for innovation, in the study of Agnihotri & Bhattacharya, 2021, p. 154) seen as part of output orientation, the negative impact of myopic behaviour in the context of narcissism is found. And, Lee et al., (2017, p. 657) find that backgrounds of top managers in science and engineering lead to a firm undertaking more explorative R&D projects in a statistical analysis of patents and traits of managers. Such evidence supports the notion that there are differences in how top managers view and evaluate technological activities, and thus, gives weight to the premise of Patel and Pavitt (1994a, 1994b, p. 91) albeit they formulated it in a slightly different manner. The second source, Lawrence's (1980) monograph, describes the 'German style of management', contrasting this with the approaches in the UK, other European countries and the US, with a particular focus on manufacturing. This seems to be followed by publications on German 'hidden champions', perhaps best described as dominant firms serving niche markets, with Simon (1990) an early publication, Venohr and Meyer (2007) a later study and Schenkenhofer (2022) an extensive literature review. However, Simon (1996) points out that this type of firm also exists in other national settings, although it seems to be most abundant in Germany; for instance, Witt (2015), in her publicly unavailable doctoral thesis, has set the number of UK 'hidden champions' at 50 compared to approximately 1300 in Germany. The success of hidden champions indicates that perhaps understanding technological implications comes along with knowledge about specific customers. This interest in a German style of management underpins Patel and Pavitt's (1994a, 1994b, p. 91) thinking but does not provide evidence for it. Nevertheless, these signals indicate that perhaps the measurement of the capabilities of top management should be approached with caution, whereas the other dimensions are possibly more reliable in terms of the dichotomy.

3.2 Extension to Innovation in Networks

Given that firms are often seen as (or may be?) a constituent and important part of national innovation systems, the way they are embedded (strength of ties) may influence their innovation practices and performance. In particular, it could be reasoned that firms may have preferences towards specific actors in an innovation system for innovation projects. This can be induced by prior experience, for example, as

Table 2 Foundational items for research instrument

Domain assumptions	Item
Distinction between tangible and intangible benefits	• Product, service and process innovation as tangible benefits • Technological, market and organisational learning as intangible benefits
Intangible benefits take longer to be converted into tangible benefits	• Learning from preceding projects to inform new technological activities • Informal and formal capturing of learning
Intangible benefits more difficult to capture	• Building of organisational capabilities • Expressed in competitive advantages
Long-term visions, insight and implications of technological activities	• Decision making by top management • Involvement of business units, departments

mentioned by Hewitt-Dundas et al., (2019, p. 1319) for university-industry collaborations and Sampson (2005, p. 1027) noting that benefits of prior experience diminish over time for alliances. Alternatively, preferences can be related to the nature of an innovation project, with van Beers and Zand (2014, p. 308) pointing to radical versus incremental innovation and manufacturing versus services. Notwithstanding this preference, typically, each project may comprise a different set of collaborators. This leads to a situation in which a firm's practices and performance may vary over time, depending on its actual interactions with collaborators. Consequently, the instrument should account for collaboration but can only provide a snapshot, since prior experiences influence the outcomes of innovation processes but less when time goes by.

The way collaboration in networks takes place is another factor impacting how decisions are made. An example is collaboration with suppliers. Whether or not these suppliers are part of the same sectoral, regional or national innovation system, such collaborative efforts can be viewed as networked innovation. The trend of outsourcing work to suppliers has led to greater attention to early supplier involvement in product innovation. The form and intensity of collaboration with suppliers for innovation and new product development can be characterised as white, grey and black boxes (Petersen et al., 2005, p. 379), each representing a higher degree of supplier integration. Le Dain et al., (2010, p. 79) extend this model to five types of supplier involvement related to development risk and autonomy of suppliers. This means that collaboration is not just a matter of whether collaborators are involved but also how. When being embedded in networks, industrial sectors and supply networks, innovation as a process of interactions between actors and resources cannot be studied fruitfully at one level, irrespective of whether the study takes place at the level of specific projects, firms or national innovation systems. This implies the need for a research instrument that can address an integrative, multilevel perspective.

3.3 Positioning Research Instrument

Thus, by considering aggregation of individual firms' behaviour, there are two sources for contingencies within the context of our quest. The first is national innovation systems; this has been the mainstay of the discourse in this chapter. The second source for contingencies are industrial sectors. It could be that behaviour by firms and managers in specific sectors is gravitating towards being myopic rather than dynamic; this can be related to product life-cycles, strategic planning horizons, shareholders pressures and perceptions of how a business should be managed. It also means that firm behaviour in the context of a national innovation system can be influenced by the industrial sectors that it is part of; thus, there is a likely link between the characteristics of sectors triggering specific decision making on technological activities and the institutional settings of national innovation systems.

In addition to the contingencies related to national innovation systems and industrial sectors, the research instrument also captures stakeholder engagement, albeit in an indirect manner. For stakeholder engagement, often a distinction is made between the Anglo-Saxon model and the Nippon-Rhineland model; see Table 3. In the Nippon-Rhineland model, a firm represents a work community that can exist only when value is permanently added. Required capital comes mainly from private investors, institutional investors such as pension funds and financial service providers with knowledge of the economic sectors in which they operate. In the model there is a high degree of organised collaboration between trade unions and firms, sometimes mediated by governmental representatives or institutions. In the Anglo-Saxon model, firms receive working capital through the stock exchange and investors. In this model, a rising share price or value of the firm is seen as key to success. Cost savings, mergers and acquisitions, and repurchase of shares are steps to increase earnings for shareholders. These models correspond to some degree with dynamic national innovation systems respectively myopic national innovation systems, last but not least because of the differentiation between long-term outcomes versus short-term earnings. Additionally, the prime countries associated with these models correspond in both views. Notwithstanding the similarities between the dichotomy of dynamic versus myopic national innovation systems and the characterisation of the Anglo-Saxon versus the Nippon-Rhineland model, there seems to be a lack of studies taking the latter as a point of departure. For example, Dekkers et al., (2014, p. 14) make reference to the Anglo-Saxon and Nippon-Rhineland model in the context of Joseph Schumpeter's influence on thinking about innovation. In addition, Tidd and Brocklehurst (1999, pp. 240–241) provide a brief overview of the debate, associating the Anglo-Saxon and Nippon-Rhineland model with different national innovation systems. This means that the association of the Anglo-Saxon versus Nippon-Rhineland model with the myopic versus dynamic national innovation system is conceptual and that the impact of the related socioeconomic setting is yet to be established.

Table 3 Characteristics of Anglo-Saxon and Nippon-Rhineland model as ideal types

	Anglo-Saxon model	Nippon-Rhineland model
Social-economic perspective	Shareholders value	Stakeholders value
	Focus on market	Consensus between labour and capital
Responsibility	Individual responsibility	Collective responsibility
Legal system	Case, common law	Civil law
Employees	Labour as resource	Active role of trade unions and employees
	Hierarchical	Self-management
	Earnings	Quality of work-life
Managerial incentives	Financial targets and bonuses	Development of firms, incorporating views of multiple stakeholders
Role of government	Free market	Market regulation
	Laissez-faire	Actor and involved in societal development

3.4 *Relating the Research Instrument to Research Methods*

The resulting instrument incorporating the extensions is outlined in Table 4; the tabulation also includes suggestions for measurement of the items. It includes measurements that can be indirectly observed in addition to those that can be either directly observed or measured. An example of a direct measurement is the projects that do not directly lead to product, service or process innovation. The measurements in the tabulation have been informed by the preceding discourse about the dichotomy and literature. One of these sources is the OECD report (1997), which focuses on knowledge and information flows in national innovation systems. In our case, interactions between firms, universities and public research institutes can be formal, i.e. projects are undertaken with a specific purpose, and informal, i.e. knowledge exchange, meetings, conferences, and seminar attendance, etc. A further source for measurement in the research instrument is the innovation funnel by Stevens and Burley (1997), which indicates that there should be projects in different stages, with the early stages populated more than later stages. Firms that tend to be myopic will be more likely to have projects positioned in the final stages of the innovation funnel, whereas firms that fit better with a dynamic perspective on national innovation systems will be involved with projects in earlier stages. This may also be manifested in the collaborations, whether they are including projects aiming at technological, market and organisational learning rather than having projects and technological activities with short-term benefits. Such should be supported by formal evaluation of technological activities, use of knowledge repositories and interactions in intraorganisational networks (see, e.g. Carnabuci & Operti, 2013; Tsai, 2001) to enhance technological, market and organisational learning. This also leads to considering the reconfiguring of resources and technological knowledge for innovation, as demonstrated by the study of Carnabuci and Operti (2013). This aligns with the thoughts of Sirmon et al. (2011) on resource orchestration and the notion of dynamic capabilities (for instance, Teece et al., 1997). Another source of measurements is the work by Pittaway et al., (2004, p. 145) when they refer to (informal) networking among firms to enhance access to knowledge and to contribute to diffusion of innovation.

The proposed research instrument for positioning firms in the continuum of dynamic and myopic national innovation systems in Table 4 can be used for diverse research methods. A proposed set of questions for qualitative studies is listed in Table 5. The set can be used for case studies, which have the advantage that they advance insight in how the individual components and measurements in the research instrument are related. Dekkers and Hicks (2019) add to this that case studies should undertake analysis at multiple levels, since understanding a phenomenon in its context is a key feature of the case study methodology; here the levels of analysis are technological activities, organisational level (firm), in some case perhaps the network a firm participates in, the regional or national innovation system (or for the latter, alternatively, industrial sector). Further qualitative methods that may be used are interviews and focus groups; for generic guidance, see Kidd and Parshall (2000) and Kitzinger (1994). Following Woodside's (2016, pp. 6–7) thoughts qualitative studies should precede quantitative studies, such as surveys (questionnaires), mathematical modelling and simulation studies. Using quantitative methods will lead to defining constructs into more precisely formulated variables, which leads to loss of accuracy in terms of the proposed research instrument. Also, mixed-methods studies—see Johnson and Onwuegbuzie (2004), and Schoonenboom and Johnson (2017) for how to design these—can be supported by the research instrument; an example would be to conduct multiple case studies in a nation, i.e. analysis at firm level, in addition to a survey at national level, thus combining insight from two levels of analysis. Finally, aggregation of studies in the form of systematic reviews with mixed-methods synthesis, particularly those that are of an integrated design (see Dekkers et al., 2022, pp. 423–31) could then lead to synthesised findings of studies using the research instrument. Therefore, the research instrument can be used in a variety of study designs with different purposes which allows to build a body of scholarly knowledge about the dichotomy of dynamic and myopic national innovation systems and its relation to firm behaviour towards technological activities.

Another strand of research using the proposed research instrument are studies into aspects or elements of it. For example, the decision making by firms and their CEOs could be studied in the context of the continuum represented by the two archetypes of national innovation systems. Studies that have looked at behaviour of CEOs and innovation are Alderman et al. (2022), Çelikyurt and Dönmez (2017), and Francis et al. (2011). Although they study their behaviour in settings, the reflection on the influence of national innovation systems is missing here, a link explicitly made by Patel and Pavitt (1994a, p. 91). A similar topic of study would be the decision making in innovation networks. Another set of studies could look into firms interact with universities and public research institutes.

Table 4 Research instrument with extensions (firm level)

Domain assumptions	Item	Measurement
Distinction between tangible and intangible benefits	• Product, service and process innovation as tangible benefits • Technological, market and organisational learning as intangible benefits	• Number of projects that are explorative versus those that are aiming at specific product, process and service innovation • Innovation funnel (how many projects in which stages) • Interactions with knowledge institutes (universities, public research institutes, private research organisations), knowledge intermediaries, firms (including suppliers and downstream organisations), special interest groups, trade organisations
Intangible benefits take longer to be converted into tangible benefits	• Learning from preceding projects to inform new technological activities • Informal and formal capturing of learning	• Formal evaluation of projects and recording of evaluation • Knowledge repositories and informal intraorganisational networks for knowledge exchange (multifunctional) • Initiation of projects, both for commercialisation and exploration, informed by knowledge sharing and repositories
Intangible benefits more difficult to capture	• Building of organisational capabilities • Expressed in competitive advantages	• Resource allocation and orchestration related to moving frontier for competitive advantages • Distinct organisational capabilities related to competitive advantages
Long-term visions, insight and implications of technological activities	• Decision making by top management • Involvement of business units, departments	• Structures and processes for decision making on technological activities • Involvement of business units, departments in decision making on technological activities

(continued)

Table 4 (continued)

Domain assumptions	Item	Measurement
Networks	• Engagement with suppliers, customers beyond technological activities for products and services aiming at commercialisation • Building of organisational capabilities with suppliers, customers	• Exploratory activities not yet related to specific product, process and service innovation • Seeking for external resources to complement existing organisational capabilities • Modes for supplier involvement (grey and white boxes)

4 Providing Holistic Context from a Systems Perspective

The research instrument in the context of innovation management can be related to perspectives on dynamic capabilities. Whereas the link between innovation and dynamic capabilities has been established in literature, with Babelytė-Labanauskė and Nedzinskas (2017) being studies in point, how this can be modelled remains relatively vague. Often, studies into innovation management (e.g. Breznik et al., 2014, p. 375; Fallon-Byrne & Harney, 2017, p. 23) refer to the model of Teece's (2007, p. 1322 ff.) decomposition of dynamics capabilities into three processes: (1) to sense and shape opportunities and threats, (2) to seize opportunities, and (3) to reconfigure resources and capabilities to maintain competitiveness. However, such a coarse model does little justice to the inclusion of market, technological, and organisational learning in a holistic model. To this end, exploring systems perspectives enables the creation of more holistic and inclusive models that build on the research instrument.

4.1 National Innovation Systems from a Systems Theory Perspective

That national innovation systems can be approached from a systems theory perspective has been recognised as instrumental to their clarification. For example, Carayannis et al., (2016, pp. 17/5–10) provide discourse on the advantages of viewing national innovation systems (and regional innovation systems) from notions derived from systems theories. Also, Bergek et al., (2008, p. 408 ff.) dwell on the implications of thinking in systems, albeit they stress processes in technological innovation systems, as do Colapinto & Poriezza (2012, pp. 346–7) for systems theories as an alternative perspective on knowledge creation. Others that have looked at innovation systems in terms of systems theories include Reale (2019, p. 101174/2 ff.), although his claim that a systems perspective is missing seems contradicted by the works cited

Table 5 Set of sample questions for qualitative studies (firm level)

Domain assumptions	Measurement
Distinction between tangible and intangible benefits	• Are there projects on-going or have been conducted in the past five years that do not have a direct financial benefit or a commercial opportunity linked to it? • What is the estimated ratio of these projects versus ones that are having a direct financial benefit or a commercial opportunity linked to it? • Are there projects in ideation stages? • What interactions do you have with knowledge institutes (universities, public research institutes, private research organisations), knowledge intermediaries, firms (including suppliers and downstream organisations), special interest groups, trade organisations? • And, how regular are these interactions? Or, do they only occur when an opportunity arises?
Intangible benefits take longer to be converted into tangible benefits	• How are projects and ideas for new product and service development evaluated? • Are these evaluations entered in a repository? • How are these evaluations of projects and shared? And, who are involved in sharing? • How are projects that are initiated by knowledge sharing and repositories?
Intangible benefits more difficult to capture	• What are the firm's distinct organisational capabilities that sets it apart from competitors • How are resources for ideas and projects identified? Both internal and external. How are these resources related to competitive advantages? • How are these resources coordinated?
Long-term visions, insight and implications of technological activities	• Which processes and structures are in place for decision making on technological activities? Who provides input for decision making in which stages? • Who (individuals, teams, departments, business units) are involvement in decision making on technological activities?

(continued)

Table 5 (continued)

Domain assumptions	Measurement
Networks	• Beyond existing products and services (also in development), are there exploratory activities not yet related to specific product, process and service innovation that involve knowledge providers, customers and suppliers? • Which activities are undertaken to identify external resources to complement existing organisational capabilities? • Which modes for supplier involvement are commonly used during product and service development (grey and white boxes)?

in his writing. In these works, institutions, universities, research institutes and firms are commonly seen as elements (sometimes called actors). There is also recognition of multiple levels of analysis when using systems perspectives, for instance, national innovation systems and regional systems. Also, industrial sectors are seen as level of analysis. However, the recursive system theorem holds limitedly because firms, among other entities, appear as elements at all levels. Furthermore, Bergek et al., (2008, p. 408 ff.) propose that national innovation systems should be seen as constituting of dynamic processes; in terms of systems theories, those are adaptive processes (see Dekkers, 2017, pp. 122–3) and lead to the creation of new products, services and processes at national, regional and sectoral level in the context of the quest here. All this should take into account that conceptualisations for national and regional innovation systems may vary, as implicitly expressed by Baskaran and Muchie (2008), when they attempt to present a unified model for innovation systems. Notwithstanding that different descriptions are abound, viewing national innovation systems from a systems theory perspective is common ground.

This raises the question of what benefits viewing national (and regional) systems of innovation as systems brings to studies into firms in the context of national innovation systems. The application of systems theories to national innovation systems (and their subsystems) provides a lens for modelling the interactions between their actors and could lead to a more intricate understanding of how national innovation systems respond to interventions, policies, actions by their constituent actors and changes in their environments. Thus, it leads to multiple levels of study, including national economies, regional economies, clusters and industrial sectors. At lower levels of aggregation for national innovation systems it can be found how firms, universities, institutions, economic development agencies and governmental agencies undertake actions to strengthen their capabilities, and take advantage of technological opportunities and collaboration (directly and indirectly). These actors (or agents) can be viewed as the constituent elements of national and regional innovation systems from which actions, interventions and collaboration lead to increased collective capabilities. Conversely, the settings of national innovation systems also determine actions, interventions and collaboration. Viewing these systems from a systems perspective allows to develop coherent insights into the interactions. For this purpose, systems theories offer a consistent use of subject terms and modelling of these interactions to determine the effects of actions, interventions and policies, and to assess the impact of changes in the environment and structures (i.e. internal and external structures) relevant to the aspects studied.

4.2 Three Systems Approaches to Capturing Viability of Firms

For firms as constituent elements of national innovation systems, innovation is seen as vital for organisational viability, as it is the way organisations adapt to changes and (technological) developments in their environment. This view follows the ideas of Schumpeter (1911) about firms creating new ways of working and Sombart's notion of creative destruction (see, Reinert & Reinert, 2006 for an explanation) amalgamated in the seminal work by Schumpeter (1934) for innovation. Complementing the ideas about innovation, Ashby (1956) pioneered the idea that any system able to adapt, and hence, survive had to have four basic functions. Its transformation to convert inputs into output—the first basic function—valued by stakeholders needs operational regulation—the second basic function. The setting, monitoring and adapting goals Ashby named 'control'—the third basic function—, and adapting the system to new goals or to solve persistent problems he labelled 'regulation by design'—the fourth basic function—(Ashby, 1956, as cited in Achterbergh & Vriens, 2009, pp. 52–7). Building on Ashby, the viable model was developed by Beer (1972, pp. 213–82). Along two different lines of thought, i.e. an analogy with the functioning of the brain and principles for control, he arrived at this model with five subsystems and their interrelationships. When these subsystems are fulfilled in an organisation, a 'necessary and sufficient' condition for viability is met (Beer, 1994; 2000). This model has been developed with the diagnosis and design of organisations in mind as becomes clear during a discussion with Stafford Beer (Kybernetes' Editorial Team, 2000, pp. 562–3). For more detailed studies, functions may be divided into related processes at a lower level of aggregation. For example, 'control' includes setting initial goals, monitoring progress towards them, evaluating progress, scanning the environment for market opportunities, technological advantages, competitive pressures and changes in the institutional environment, and eventually, this leads to modifying the set of goals and adjusting the desired values of the goals (deployed in a set of essential variables and desired values for each). Since Ashby's 'regulation by design' adapts the system's infrastructure, i.e. grouping of processes, implementing adequate control structures and enhancing capabilities it can be regarded as the innovation process, taken as adapting to changes from within the organisation and its environment.

To study the innovation process as an adaptive process, diagnostic models derived from these thoughts on systems theories have been developed, providing more detail on processes in organisations and their relationship. Dekkers (2005, p. 313) developed a 'model for the dynamic adaptation capability', inspired by (theoretical) evolutionary theories. This model adapted here using a modification (ibid., p. 378), see Fig. 2, incorporates learning processes in a structured process model for achieving breakthroughs. The latter can be anything in Schumpeterian thought that represents new combinations of resources and ways for executing recurrent processes. The complementary thoughts about processes for organisational learning are commensurate with learning, as expressed in Patel and Pavitt (1994a, p. 91). In addition, Lekkerkerk (2012, p. 296) constructed the 'model innovation and organisational structures'. He builds on Beer's (1972, pp. 213–282) viable system model and inherits his claim of 'necessary and sufficient' subsystems and relations, thus turning it into a normative, diagnostic framework useful for systematically describing the (innovation) structure of any organisation and for comparative case studies., this model incorporates organisational learning, although borrowed from March's (1991) dichotomy on exploration and exploitation. Both models seek to move away from the relatively simplistic approach of the 'sense-seize-managing threats and reconfiguration' model presented in Teece (2007) to a more intricate capture of processes and interactions.

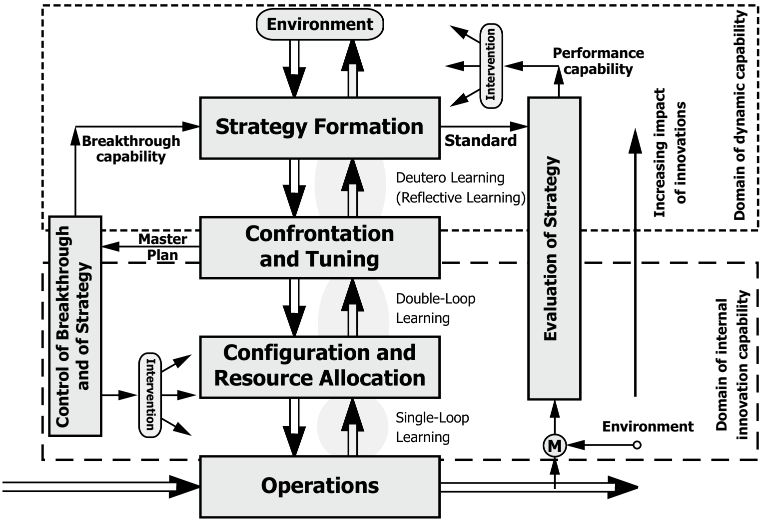

Fig. 2 Model for the dynamic adaptation capability (Dekkers, 2005, pp. 313, 378)

4.3 Implications for Research Instrument

When studying firms, their innovation efforts, and their position in a national innovation system, it is necessary to map the network in this system of which the organisation under study is part of, i.e. which actors a firm interacts with, what the nature of these ties are and how strong such ties within the national innovation system are. When searching for differences in the approach to innovation that firms may have, one could look at their innovation-related practices. However, this would neglect the influence of the organisational structure, in which innovation efforts (as captured in descriptions used in practice) are divided along organisational units, and coordinated and managed between these units. For example, the ‘practice’ of making wooden furniture is identical for both a carpenter and a large furniture manufacturer: sawing pieces, painting them and assembling the table, chair and so on. Obviously, the carpenter performs all these steps alone. In a factory, many design alternatives for the division of labour are possible: activity-based (units for sawing, painting, assembling), product-based (all steps in separate units for chairs, tables, etc.) or market-based (furniture for Europe, Asia, etc.) organisational structures. Therefore, to determine whatever handovers of work (here, innovation work) between organisational units occur, both a practice and a structure lens are needed; the model for the dynamic adaptation capability and model for innovation and organisation structures can be used in combination to do precisely such.

The multilevel approach to the research instrument is supported by the recursive nature of both models. For organisations, they can be used to systematically describe how the processes and functions embedded in the model are assigned to individual positions, teams, business units, divisions, committees and C-suite executives, and how these are linked through organisational structure and processes within and between units. Depicting links with external actors to an organisation can support coordinating and managing mechanisms necessary to integrate these with internal processes and functions, including analysis and design. In the same vein, at one higher level of recursion, supply and distribution networks of organisations can also be described, building on the links found with the individual firms. At the same network level, the innovation network of the organisation can also be positioned. This partly overlaps with its supply network through supplier involvement in innovation projects, with additional knowledge partners that are also part of the national innovation system. It should be mentioned that these supply and innovation networks of firms are dynamic. For supply, they last as long as the product life cycle or the contract period. For innovation, the project-related set of actors exists as a network for the duration of the project, while noting that there could also be collaborative agreements beyond specific projects, particularly for key components and knowledge. During the commercialisation of an innovation a part of the innovation network may continue as supply network. Knowledge partners may have more loosely-linked relationships with organisations and their networks, until a new project opportunity for closer collaboration comes along. It seems to be useful for research to view the national (or regional) innovation system as a level above the level of supply and innovation networks; then, this level describes the total set of actors and their interactions, where the relations have several characteristics. When considering these three levels, in practice, there are both more permanent ties between organisational members at various hierarchical levels that meet at regular intervals at events to maintain contacts and establish knowledge transfer in addition to innovation projects and long-term supply chain partnerships. Such ties and interactions add a layer of complexity to modelling innovation processes and functions at the three levels distinguished here. All this means that the dynamic adaptation and model for innovation and organisation structure form the foundation for analysing and designing adaptive processes and structures, and embedding these structures at the level of innovation and supply networks, and the level of the national innovation system.

5 Setting Research Agenda

After these deliberations, the question arises how the proposed research instrument can be used for studies in addition to suggestions and remarks made so far. So far in this chapter, the use of the research instrument has been outlined as capturing the decision making for technological activities, as core activity for achieving innovation. Aggregating data about the behaviour of firms on this point, then results in positioning regional, sectoral or national innovation systems on the continuum dynamic versus myopic innovation systems; this is the perspective offered here. However, this comes along with some additional considerations for research that will be presented now.

5.1 Further Research into the Continuum Dynamic Versus Myopic National Innovation Systems

The first point here is that no proof for the existence of the two extremes for firms embedded in the dichotomy has been observed. The writings by Patel and Pavitt (1987, 1994a) indirectly derive these points from their observations at macro-economic level and conjectures by others; see Sect. 3.1 for the latter. And, in their proposition of distinguishing dynamic and myopic national innovation systems (Patel and Pavitt (1994a, pp. 90–92) only examples of which nations are associated with the classification; see Sect. 2.2. There are no studies that have confirmed this classification, although generally it seems to be accepted in literature that refers to it. This points to undertaking research how other nations are positioned on the continuum; only then it can become clear whether there is a continuum between two extremes or there are archetypes, which include the dynamic and myopic national innovation systems; given the lack of precedence in this chapter this distinction between dichotomy and archetypes has been treated loosely, but it is a fine line that warrants further studies.

Another related topic for further investigations is how regional or sectoral innovation systems fit within the dichotomy. The question is whether the position of national innovation systems in the dichotomy are reflected in regional or sectoral innovation systems, or perhaps, to what extent. The position of a national innovation system as an aggregate may be in-between positions of regional or sectoral innovation systems as its constituent elements. In such a perspective, the contribution of a regional or sectoral innovation system to the overall innovation system may play a role. Thus, the question is whether a national innovation system is an average or weighted average of regional innovation systems or expressing an alignment that is reflected in regional and sectoral innovation systems based on the dichotomy of dynamic and myopic national innovation systems.

Finally, an implication of the dichotomy is that the performance of a national innovation system may depend on where the system is positioned on the continuum. It is possible that the system's performance is mediocre when it is either dynamic or myopic. Or may the performance of an innovation system improve when there it is a combination of dynamic and myopic national innovation systems. There could also be an inverted-U shaped relationship between the performance of national innovation system and the extent to which it is dynamic or myopic. In this case, the optimal performance thus indicates a balance between aspects of dynamic and myopic national innovation systems that depends on multiple factors, such as R&D intensity, knowledge transfer between universities and firms and innovation networks. And does the balance affect the innovation barrier? Does this mean that nations can only keep improving the performance of their national innovation systems by combining different levels and aspects of dynamic and myopic national innovation systems? Only further research can tell.

5.2 Using the Research Instruments for Studies

The research instrument can also be used to look at specific firms or sectors. This not only follows from our thinking in this chapter, but also aligns with Woodside's (2016, pp. 6–7); he advocates that qualitative studies, particularly here, case studies, should be conducted before statistical empirical studies involving larger samples of firms are undertaken. Of particular interest is to undertake qualitative comparative analysis, a method advocated by Ragin (1999) in general. Such studies should be variance-based as outlined by Elsahn et al., (2020, p. 320), following theoretical replication (Dekkers & Hicks, 2019; Eisenhardt, 1989, p. 537)—though called theoretical sampling by her—since the research instrument is an outcome of conceptualisation and selecting the appropriate number of case studies for a specific research objective following guidance from Dekkers and Hicks (2019). The purpose of outcomes of case studies and other qualitative research methods such as focus groups, guidance found in Kitzinger (1994) and Kidd and Parshall (2000), is to ensure that surveys and questionnaires reflect sufficiently accurately the reality and are not merely mathematical exercises. The use of the research instrument for qualitative studies could result in further enhancements or amendments, depending on institutional settings at regional or national level, or sectors. Thus, it would be most appropriate to conduct qualitative case studies or other studies using qualitative research methods first.

Once evidence has been built by deploying the research instrument as part of qualitative empirical studies, then quantitative studies can follow. These allow then consider statistical power by aggregating results from surveys into data at sectoral, regional or national level. Having these samples could lead to comparative studies, aiming at identifying similarities and differences between sectoral, regional and national innovation systems. Another possibility is mixed-methods research, for generic guidance see, for example, Johnson and Onwuegbuzie (2004), and Schoonenboom and Johnson (2017), where the analysis at the level could be statistical and at the level of firms qualitative. The approach of mixed-methods studies reflects the nature of studies into innovation management, i.e. multilevel analysis, the latter intimated by Elsahn et al., (2020, p. 320); also, Dekkers and Hicks (2019) see the analysis for case studies taking place at multiple levels, depending on the unit of analysis. Thus, the research instrument may spur quantitative studies and mixed-methods studies using the typical approach to research into innovation management accounting for multiple levels of analysis.

A further point for research is the link made between the research instrument and models for describing internal processes for innovation management. This is reflected in the models presented in Figs. 2 and 3: the model for the dynamic adaptation capability and the model innovation and organisational structures. Both models share similar thoughts by building on systems theories and how organisations manage innovation processes. Aspects of the research instrument, such as decision making and interaction in networks for technological activities, can be related to how processed in the models are conducted. Thus, this can enhance insight in the effectiveness of processes, decision making, monitoring of technological activities, and how these are bound and enabled by the context of national innovation systems; both models serve a structured understanding for advancing scholarly knowledge, and analysis for enhancing performance of firms and innovation networks.

5.3 Challenging Dichotomy Dynamic Versus Myopic National Innovation Systems

Further research may also result from looking into the assumptions for the dichotomy dynamic versus myopic national innovation systems. Our analysis in this chapter points to a number of background and domain assumptions that warrant further investigation; particularly, those that are not directly evident or the ones where it is more difficult to relate them to literature. One approach would be to discover under which conditions these assumptions hold. Identified contingencies could be feed into

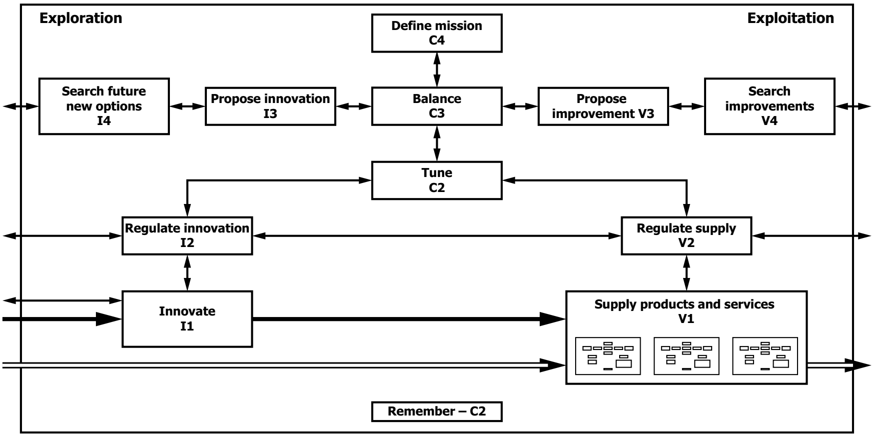

Fig. 3 Model innovation and organisational structure (Lekkerkerk, 2012, p. 296)

further modifications of the postulations for the dichotomy. A potential complication could be that technological activities are diverse and can be undertaken by a broad range of actors in a national innovation system. However, such broad variety of potential factors related to the background and domain assumptions can stimulate further research.

6 Concluding Remarks

This brings us to what the study in this chapter brings to the table. First, the analysis of the classification of dynamic and myopic national innovation systems has yielded its postulations and how they are related to background and domain assumptions. This evaluation was particularly directed at firms, which is commensurate with how Patel and Pavitt (1994a) described their dichotomy, i.e. having a focus on firms. Second, the appraisal of the two archetypes is reflected in the proposed research instrument; see Sects. 3.1, 3.4 and Table 4. It includes extensions to the dichotomy discussed in Sect. 3.2. Although this instrument is primarily developed for capturing firms' behaviour in the context of national innovation systems, aggregation of firm data can lead to inferences and findings on sectoral, regional and national level for positioning national innovation systems in the dichotomy. Third, the chapter makes a case to use models for innovation processes based on systems theories to study innovation management by firms. These models can be used to support diagnosis of organisations and design research for innovation management, a strand of research described by Auernhammer (2020). Examples are the use of the model for the dynamic adaptation capability in Dekkers (2009) and five case studies in Lekkerkerk (2012). The deliberations on these contributions to knowledge have set out a research agenda for how firms consider and manage technological activities, particularly how firms take decisions and how they interact with others in this context.

In addition to these three contributions to scholarly knowledge, two more points for research came to the fore. Well, the chapter has highlighted that the classification into dynamic and myopic national innovation systems put forward by Patel and Pavitt (1994a, pp. 90–92) may still hold, even when accounting for changing perspectives on innovation management, including the networked nature of innovation and its processes. The dichotomy has been used by few studies, but it potentially offers insight for different levels of analysis for studies into innovation economics and management. Moreover, the contributions to scholarly knowledge have implications for research, practice and economic development policy, what will be discussed now in more detail.

6.1 Implications for Research

In this chapter, we have often referred to technological activities rather than talking about innovation. One reason to do so has been that the original writing of Patel and Pavitt (1994a) mention it throughout their publication. Moreover, when considering the subject term 'innovation', it points to an idea, invention or intervention reaching a product-market combination or put into practice for improvements to recurrent processes and how they are managed, whereas a technological activity is not directly seen as yielding an outcome that can be monetised or put to use in a product, service or process; rather, a technological activity produces knowledge. Consequently, following the thoughts of innovation funnels (e.g. Stevens & Burley, 1997), not all technological activities are successfully resulting in product, service or process innovation. Furthermore, the discerning of technological activities implies that it encompasses more than R&D budgets and resources. Thus, this brief exposé provides the reasons why we followed the original terminology of Patel and Pavitt (1994a), and retained a distinction between technological activities and innovation as a potential outcome; this also means that probably without reservations the dichotomy can be applied to innovation management and economics, something that has most likely resounded in our writing.

Inherent to writing by Patel and Pavitt (1994a) and their focus, innovation refers to technological activities, wording that we have used throughout with the purpose of not diverting from their thinking. Following the spirit of what is seen now as innovation, their thinking could well extend to organisational innovation and other forms. Most likely, for process, product and service innovation to happen enabling organisational and administrative innovation is necessary. van de Ven et al. (1999, p. 9) stress that 'most innovation involves technological and administrative components'. Similarly, Wheelwright and Clark (1992, p. 92) suggest that the extent of change in product and in process must match in order for innovation to be successful. However, it may be more cumbersome to delineate outcomes of the administrative type of innovation process, since they are probably yielding more intangible benefits and associated learning. Therefore, the research instrument may have to be adapted to fit better with other types of innovation.

Alluded to in this chapter at various points, there could also be an argument that innovation systems are not only nation-specific, but within nations specific to sectors, or perhaps even regions. Balzat & Hausch (2004, pp. 207–8) point also to this avenue for further research, although they direct their argument to nations and bias caused by emphasis on highly industrialised countries. However, this is a tentative notion that could be explored with the research instrument. It implies that evidence collected by using the research instruments, it should be aggregated not only within nations and across nations but also across sectors and regions. This would lead to identifying whether the conceptualisation of dynamic and myopic national innovation systems applies to which aggregation strata and classifications for technological activity.

6.2 Managerial Implications

In addition to implications for further research, a consequence for practitioners is the question whether views associated with dynamic and myopic national innovation systems call for different set of resources. If so, the (re)allocation of resources will require managers' attention. It could be that there are constraints in terms of availability of resources. Then, this raises a further question, being how limited resources in the firm can be used to meet requirements for technological, market and organisational learning, which is relevant to the implications of the dynamic perspective on national innovation systems and related firms' behaviour. Perhaps, these resources should be coordinated and managed in different ways. Hence, the first implication for managerial practice following from the dichotomy would be that to achieve a dynamic innovation system at firm level, activities related to long-term objectives and learning should be organised in a less formal way, with more emphasis on supporting interactions in the firm and its networks.

A second managerial implication is how collaborative partnerships, strategic alliances, mergers and acquisitions should be considered. If a firm does not have necessary resources to compete or contribute to the sectoral, regional or national innovation system, it can form partnerships, alliances and consider mergers and acquisitions. Then seeking a balance between dynamic and myopic perspectives on technological activities and innovation processes will not be found within an organisation but between organisations or within an industrial sector. This requires understanding private and common benefits, following Khanna et al.'s (1998) generic thoughts for organisational learning in alliances and Larsson et al., (1998, p. 290) conceptualisation that managing interorganisational learning is a delicate balance that could easily divert into disgruntled views by partners. Thus, forming collaborative partnerships, strategic alliances, mergers and acquisitions requires thinking beyond the capabilities and resources of an individual firm and place decision making in the context of these networks in addition to managing these relationships, perhaps in a more supportive manner than following a tightly-controlled approach.

6.3 Implications for Economic Development Policy

Complementing the two managerial implications is that economic development policy, often having a long-term view, fits better with dynamic national innovation systems. In the perspective of the myopic national innovation system, the benefits of collaborations and interactions, particularly monetary benefits, should manifest themselves in a relatively short period of time. The technological activities from the perspective of a dynamic national innovation system do not necessarily have direct benefits but should contribute to interorganisational and intraorganisational learning to advance insight in implications for markets, technology and organisations. Whenever, these learnings coincide an opportunity for commercialisation of technological knowledge may happen under the condition that market opportunities for products, services and processes were identified. Moreover, it is not settled yet, how the inclinations in sectoral and regional innovation systems differ from national innovation systems in the context of the dichotomy. And, if there is a balance between dynamic and myopic perspectives across organisations and sectors in a national innovation system, then should economic development policy be diverse to be effective, i.e. incorporating both incentives and identifying opportunities for commercialisation of outcomes from technological activities and long-term visions combined initiating learning actives aiming at developing knowledge without direct short-term benefits; a challenging dilemma for policy makers.

A second implication for economic development policy may be about whether a bottom-up or top-down approach to the development of a national innovation system is more effective. The bottom-up approach relies on initiatives and technological activities by firms and other actors in a national innovation system. The top-down approach focuses on the implementation of policy, expecting that firms and other organisations in a national innovation system will follow suit. However, this question was one of the starting points for Patel and Pavitt's (1987, 1994a, 1994b) quest; given that research has been inconclusive towards this point, it seems that different economic policies suit different national innovation systems in the context of the dichotomy, but it would be worth to evaluate these policies based on its postulations and assumptions presented here.

6.4 A Final Thought

Although the work by Patel and Pavitt (1994a) has been cited moderately, it seems that less attention has been paid to its potential implications and underpinning postulations and principles. However, looking at what was uncovered there are more implications than recognised in literature. Perhaps, it has been overlooked because the emphasis is on how measurement of national innovation systems should take place to make comparisons. In this sense, our quest focuses more on how decisions by firms, and potentially, other actors are made and what is considered during the decision making processes. Hopefully, the outcomes of the analysis here may initiate further research, building on the classification into dynamic and myopic national innovation systems and looking further into assumptions that drive these types of typologies.

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Technology Valorisation in Open Innovation Systems: A Two-Phase Empirical Study of the Scottish Medical Technology Sector

Julie Roberts

Abstract Open Innovation is a recognised management approach, and although many companies are aware of it, there is still a lack of clear understanding of the mechanisms, inside and outside of the organisation to gain value from it in practice. Open Innovation literature argues that it is not new, not yet making it clear how companies can capture value out of their Open Innovation process. Based on a two-tier research methodological approach, the concept of Technology Valorisation is explored, and this research builds upon research from a series of company interviews in the Scottish Medical Technology (Med-Tech) sector, exploring their Open Innovation practices in action. This chapter reveals that companies are too tied up with their daily activities and are not actively engaging in Technology Valorisation. Theories associated with Open Innovation are commonplace; however, they are not considered applicable theory for companies to deliver on the value of Open Innovation in practice. Companies in the Med-Tech sector are operating Open Innovation practices to a varying degree; however, this research signals the need for a new framework for practice which is necessary to guide companies through the Open Innovation processes more effectively with Technology Valorisation embedded, which can enable organisations to capture fuller value from their innovation processes.

Keywords Open innovation · Technology valorisation · Medical technology · Collaboration · Value

1 Introduction

The concept of Open Innovation was popularised by Chesbrough (2003) with over 5 million hits on Google Scholar since its inception. This large influx of published research (e.g. Dodgson et al., 2006; Gassmann et al., 2010; Laursen & Salter, 2006;

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West et al., 2014; Tuckerman et al., 2022) has given the approach of looking outside of your organisation for useful sources of knowledge, skills and technology a name and a focus for improving practice. One might argue that the need for Open Innovation approaches in more recent years has accelerated, with heightened global competition and more sophisticated convergence in technologies. However, as Wang et al. (2021 p. 255) identify, there is still a gap in research on the practice of Open Innovation inside a company.

'Open Innovation Systems' as described by Chesbrough, 2003 (pp. 51–52) have been characterised as a flexible way for firms to coordinate many innovation projects. Chesbrough argues that in dynamic markets, the value of a portfolio of innovation projects is difficult to assess and, subsequently, that the value of patents—as a specific means to 'secure' an invention's value—is very uncertain. Hence, the concept of Open Innovation aspires to reduce that uncertainty through mechanisms of collaboration and partnerships. In the context of Open Innovation Systems, most attention is paid to whether companies collaborate with universities (e.g. Perkmann & Walsh, 2007; Harryson et al., 2008; López et al., 2015), competitors or other companies (e.g. Gassman & Enkel, 2004; Lichtenthaler, 2009) and to the role of IP for the purpose of technology development and commercialisation (e.g. West & Gallagher, 2006; Keupp & Gassmann, 2009). However, the core of commercialisation of technology is not just Intellectual Property (IP), as advocated by many, but how to create value in its widest sense. For example, Lichtenthaler (2005, p. 248) writes: '*…there are no empirical studies that go considerably beyond measuring the financial returns, such as licensing revenues, and try to capture the strategic dimensions of external knowledge exploitation. Nearly all publications—academic and managerial—focus exclusively on the monetary effects of externally leveraging knowledge assets. This neglects a variety of strategic effects that may even exceed the positive financial impact of external exploitation …*'. This proposition is supported in the writings of both Andriessen (2005) and Dekkers (2005) and to a certain extent by Gassman and Enkel (2004) who introduce three archetypes for acquiring external knowledge and external commercialisation of internally generated potential innovation. Hence, the question remains to be answered as to how to create value out of knowledge, whether it concerns inventions, knowledge or patents in the context of Open Innovation practices and this chapter makes a step towards answering this.

Although the era of Open Innovation was heralded as an impetus to innovation management, models for the external commercialisation of technology still need further expansion (Gassmann, 2006, p. 225; Chebo & Wubatie, 2021, p. 424). Lichtenthaler (2005, p. 249) called this a severe research deficit when pointing out the lack of empirical research for the external commercialisation of technology and not much has followed since. Therefore, this chapter explores 'commercial value' in the context of Open Innovation. Specifically, the research presented seeks to address the mechanisms that assist in creating value out of knowledge, inventions and patents in the context of Open Innovation systems. So far, this has been ambiguously dealt with by academic literature. For example, Herstad et al., (2008, p. 68) point out that they have excluded external technology commercialisation from the survey, although they denote it as a critical dimension. Additionally, it seems that Lichtenthaler (2008) and Lichtenthaler and Ernst (2007) attempt to define strategic approaches but do so by quantitative analysis. Quantitative research is a common research practice for studying Open Innovation (for example, Chesbrough, 2006, p. 4; West & Gallagher, 2006, p. 6). However, according to Shah and Corley (2006, p. 1831), quantitative studies tend to lack accuracy and need to be complemented with studies that go into more detail and Hoskisson et al. (1999, p. 447) add that the use of quantitative-based tools is not applicable to all research questions. Following this reasoning, a study into excavating mechanisms for acquisition of external knowledge and external technology commercialisation should ultimately be one based on qualitative research methods.

This explorative study investigates practices for acquisition of knowledge and technology commercialisation by conducting qualitative research with Med-Tech companies. This chapter firstly provides a review of the literature on Open Innovation and Technology Valorisation leading onto a deliberation on the novelty of Open Innovation. A section on the research methodology follows which explains the two-tier approach for the research; the first step in the empirical research is being a questionnaire as a scoping study. The results of this questionnaire give some direction for a literature review that is more in-depth and that adds perspectives on the concept of Open Innovation. The review of literature provided a theoretical framework for interviews with representatives of Scottish companies. The qualitative analysis of the interviews is presented, and a final section concludes on the key outcomes of this research and implications for research and practice.

2 Literature Review

This literature review begins by setting the context of the Med-Tech sector in Scotland before exploring the concept of Open Innovation. It then critically assesses the added value of the concept and addresses its focus. This focus leads to mechanisms that underpin the concept of Open Innovation in connection with the acquisition and external commercialisation of technology.

2.1 Med-Tech Sector in Scotland

The rationale for choosing the Med-Tech sector as a focus for this research is underpinned by trends in this sector towards technology convergence with a wide range of different disciplines coming together making it challenging to manage and difficult for all the expertises to be contained within one company. Enkel and Gassmann (2010, p. 256) describe the phenomenon of innovations created in a cross-industry context as a key Open Innovation approach. In addition, the rationale for this research area is associated with research on Open Innovation often being highly prescriptive, and based on case studies of leading practices in firms such as Lucent, Intel, 3 M, IBM and Procter and Gamble, with attention towards large, high-tech multinational enterprises (van de Vrande et al., 2009, p. 423), there has been little focus made on the Med-Tech sector companies. In addition, Chesbrough's case studies focus on large companies neglecting to look at small-to-medium enterprises and the impact of Open Innovation practices on their innovation processes despite there are being more small-to-medium enterprises than large companies. However, Teirlinck and Spithoven (2008, p. 692) discuss that large firms embrace the model of Open Innovation to a greater degree than smaller ones who sometimes lack a critical mass of absorptive capacity and, especially in the case of knowledge intensive firms, are less likely to be open to outside partners. However, there is growing interest in looking at Open Innovation in SMEs (Van de Vrande et al., 2009; Hervas-Oliver et al., 2021; Lee et al., 2010; Meng et al., 2021). Pavitt (1984) discussed in his seminal paper that firms can be differentiated according to their type and sector and hence have different constraints, opportunities, and challenges for managers. This therefore adds to the complexity of engaging in Open Innovation and the need to carry out research focused on each sector. It is believed that the knowledge generated here by focusing on the Med-Tech sector may be transferable to other high technology and knowledge-intensive sectors.

This research however provides a focus on Open Innovation in the Med-Tech sector, where technology convergence is seen across the areas of expertise from engineering, software, digital technology to life sciences and with the requirement for medical/clinical expertise to bring a product to market. For example, the rapid increases in computer processing power and the marriage of test tubes with microchips are transforming devices that aid in the diagnosis of human disease (Gottlieb, 2003; The Engineer, 2008). The implications of the convergence of different technologies are that the boundaries of previously distinct and relatively independent industries are blurring (Van De Ven, 1993). The emergence of an industrial complex implies that the opportunities for new business development will grow, and previously alien assets and skills are likely to become necessary to enable them to exploit these opportunities successfully (Pennings & Harianto, 1992, p. 356). Tidd (1995, p. 307) also wrote the challenges of developing novel products and the requirement for management across traditional product-division boundaries due to the breadth of competencies required in the increasingly complex product systems. This technology convergence, together with increased research costs and a shortening of product lifecycles associated with innovating in this sector, has increased the relevance of Open Innovation. With the move towards a digital medical future, the market opportunity created by a merging of the consumer electronics and healthcare industries is vast, but companies need to seek appropriate mechanisms to achieve this effectively. The global challenge of the Med-Tech sector is to reduce costs, improve quality of life and enable better healthcare outcomes, and a framework that will guide companies to meet these challenges more effectively will be of immense benefit to this sector. The Med-Tech industry is highly innovative, with hundreds of start-up companies and strong links with an exceptional engineering and science base. It is diversified and innovative, capturing a wide range of technological advances for application in the medical field. There is considerable potential for growth in this knowledge-intensive sector, and medical and technical advances are driving better health care (Gopal et al., 2019). This research focuses on the Med-Tech sector, where there has been relatively little written about in this context of Open Innovation and value capture to-date. Most notably, research carried out into Med-Tech innovation management by Geisler has focused research on the adoption and utilisation of information technology in health care and on digital transformation (Geisler et al., 2003; Gopal et al., 2019; Turchetti & Geisler, 2010), but in the academic literature management practices in Open Innovation systems are limited.

2.2 *Introducing Open Innovation*

The perceptions on models for the innovation processes have changed somewhat over the last three decades. The views have progressed from linear progression of inventions and markets (the first and second generations of innovation processes) to the ever more complex interactions found in the third, fourth and fifth generations of processes (Rothwell, 1994). Rothwell's fifth-generation innovation process indicates that the growing complexity and pace of industrial technological change forced firms to form new vertical and horizontal alliances. Extending Rothwell's earlier typology, a momentum has been built around a sixth-generation model where firms are less focused on internal ideas or close networks anymore but focus on opening up to the whole market. Marinova and Phillmore (2003) make reference to this generation as an innovation milieux, interactions based on proximity as a territorial localised phenomenon. In this spirit, the perspective of firms shifted: using external ideas as well as internal ideas to generate innovation, and internal and external paths to market to commercialise technology (Chesbrough, 2003). Similarly, in the same year, Linder et al. (2003) drew our attention towards a transactional approach for innovation and refer to sources of innovation as channels. A significant body of research has followed Chesbrough's writing, and Open Innovation has been one of the most debated topics in the literature on innovation management. It is this innovation milieux, the interplay of interactions between different actors and institutions, which Uzunidis et al. (2020) identify is now contributing to entrepreneurial innovative performance through the supply of scientific, technological and financial resources.

But what does the conceptual approach to Open Innovation offer? Chesbrough's (2003, p. 25) model of Open Innovation considers the boundary between the company and its surrounding environment as porous; enabling innovations or ideas to move more easily from outside of the organisation in or inside of the organisation out, known also as inbound or outbound innovation respectively (Lichtenthaler, 2009, p. 318). In this respect, Gassman and Enkel (2004, p. 6) denote that there are three Open Innovation process archetypes: (i) the outside-in process, (ii) the inside-out process, and (iii) the coupled process; the coupling process refers to linking the outside-in process to the inside-out process. The management of these three processes constitutes the domain of Open Innovation; this means that by looking outside the organisation, innovation management could become more effective in terms of cost

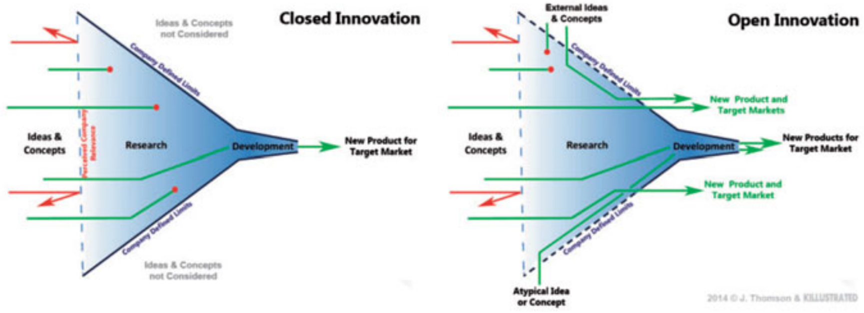

Fig. 1 Thomson et al. (2015, p. 929)

saving, lead-time reduction and risk management within the conceptual approach of Open Innovation. Chesborough's model was adapted further by Thomson et al., (2015, p. 929) to illustrate that there is the potential for more ideas to make it through the new 'product' funnel when combined with outside ideas and support (see Fig. 1). In addition, new markets can be created and new applications for products/services than the company can do so operation alone.

2.3 Open Innovation is Not 'New'

It has been argued that Chesbrough's concept of Open Innovation is merely a branded combination of traditional activities and that many of the characteristic features have been around for a long time (e.g. Teece, 1986; Tidd, 1995; West & Gallagher, 2004). It can also be seen that Tidd (1995) wrote about the challenges of developing novel products and the requirement for management across traditional product-division boundaries due to the breadth of competencies required in the increasingly complex product systems. All these authors make reference to 'open networks' as being more effective than 'closed networks' or alliances, well before Chesbrough. Other notable authors who have explored the role of external sources of technology and knowledge include Schumpeter (1934), Rosenberg and Nathan (1982), Pavitt (1984), von Hippel (1988), Cohen and Levinthal (1990), Freeman (1991), Langlois (2002) and Christensen et al. (2005); the roots of the Open Innovation model overlap with these contributions. Trott and Hartmann (2009, p. 715) have argued that the Open Innovation paradigm is representing '*little more than the repackaging and representation of concepts and findings present over the past forty years within the literature of innovation management*' and talks about Open Innovation being '*old wine in new bottles*'. In saying this, they are identifying that Open Innovation does no more than introduce and assign a name to a concept that has been in existence, but not necessarily practised by all firms that have R&D.

However, the advantages of collaborating are increasing in what has been called the Open Innovation era (Enkel et al., 2009a, 2009b, p. 311), especially in a changing world where innovating the business model (Chesbrough, 2006, p. 108) has become even more necessary. In the recent Covid-19 pandemic, examples are abundant of companies collaborating to develop solutions with a more rapid and timely response. For example, to meet the demands of the medical shortage of ventilators (Bernardo et al., 2021). Lichtenthaler (2009, p. 318) notes that inter-firm technology transfer has increased and van de Vrande et al. (2009, p. 434) discuss the growing popularity of Open Innovation practices in small and medium-sized enterprises. There is a broad awareness of the mechanisms of Open Innovation carried out by companies, but the real challenge associated with being successful at it in practice. The management of inter-firm alliances is often complex and not well-defined (Anand & Khanna, 2000, p. 296), and there is widespread recognition of the difficulty inherent in the process of value creation within an alliance. Le Pennec and Rauffle (2018, p. 817) have identified that researchers tend to focus on the identification of organisational motivations and on key success factors for collaboration. However, they note that it is both the nature and processes of value creation in inter-organisational collaboration that has yet to be examined. This implies that further research is needed to understand collaboration in the context of creating value as part of Open Innovation.

2.4 Creating and Capturing Value

Relating to creating value, Intellectual Property Rights (IPR) issues appear frequently in the literature on inter-firm collaboration (e.g. Teece, 2003, p. 44; Chesbrough, 2003, p. 156; West, 2005, p. 111; Adomako et al., 2021, p. 24)—but there appears to be little evidence (or even systematic thinking) on the relation between these fields. At the European Union funded INNO-grips workshop (INNO-grips, 2009), the common stance was that leveraging patents for in- or out-licencing provides opportunities for revenue enhancement and cost avoidance whilst building sustainable product differentiation (Pure-Insight Ltd, 2006). West (2005, p. 109) says that Open Innovation reflects the ability of firms to profitably access external sources of innovation and that this depends on IPR laws and highlights that certain types of Open Innovation are only possible through such IP protection. There are however other forms of IP protection, such as copyright, trade secrecy and trademarks. Nevertheless, there is however a gap in the innovation (and Open Innovation) literature: as it is focused on patents as a means of appropriating value (Lichtenthaler, 2005, p. 248) ignoring other mechanisms.

It might even be that the renewed call for Open Innovation and its emphasis on IPR is a continuation from efforts during the 1990s in relation to capturing Intellectual Capital. According to Azeem et al. (2021, p. 1), management is increasingly aware that knowledge resources are essential to innovation. Carneiro (2000, p. 94) states that the strategic choices for innovation that a company makes have a profound influence on the required knowledge. Literature has seen a vast amount of contributions about intellectual capital, especially driven by economists who attempted to move away from the traditional principles of business economics to guidelines for knowledge-intensive industries (e.g. Viedma Marti, 1998). Yet, this has hardly succeeded, mostly due to the intangible nature of innovation and its valuation (Johnson, 1999, p. 572). The Intellectual Capital of an organisation is the knowledge that can be converted to generate cash-flow and ultimately into profits (Harrison & Sullivan, 2000, p. 38); the Intellectual Capital represents the codified, tangible, or physical descriptions of specific knowledge to which the company can assert ownership rights. The literature surrounding Open Innovation and IP follows this reasoning present in literature on Intellectual Capital. Teece (2006, p. 1135) writes that embedded in the profiting from innovation framework is the recognition that IP might lubricate the market for know-how.

In the perspective of Open Innovation, the innovator must develop a business model consistent with both the value of IP and the value network. Literature has indicated the positive alignment with the value network which can leverage the value of a technology (Chesbrough & Rosenbloom, 2002, p. 535). In this sense, there is a range of Open Innovation strategies in relation to the IPR framework, which include sourcing innovation, shared innovation, licencing internal innovations and a hybrid of vertical integration and licencing; the following activities are incorporated into the strategy: incorporate effective partner screening, pre-partnership negotiations, partnership structuring activities, contract administration, monitoring of alliance partners after contract termination. However, many executives think of managing IP as being solely a means to extract value from a technology or a set of technologies (Chesbrough, 2006, p. 10). IP can be managed to help create value, not simply capture it; clearly, there must be other concepts important in linking Open Innovation to capturing value.

2.5 *Insufficient Mechanisms to Capture Value*

Despite the breadth of literature populating the domain of Open Innovation, a full understanding of how it can add value is still not apparent (Enkel et al., 2009a, 2009b, p. 311). Fast forward to 2018 and Chesbrough et al. (2018, p. 7) reflect that whilst the goal of economic activities is to generate value, the definitions of value creation and capture have not been sufficiently clarified in the Open Innovation literature. The focus has mainly been on the existence and operation of Open Innovation systems. Whilst Open Innovation requires collaboration, the authors identify that managers need to work towards the development of an Open Innovation capability, which comprises four value processes: value provision, value negotiation, value realisation and value partake. However, despite this, the mechanisms for developing this capability are still not apparent.

If value capture can be both financial and non-financial, an understanding of the mechanisms that take place is needed. Laursen and Salter (2020, p. 255) drill deeper to question where the value extraction occurs, in terms of by the company employees or the firm itself. In relation to mechanisms, a method that was developed to examine external alliances being used to meet internal needs is that of the four-stage 'Want, Find, Get and Manage' framework (Chatterji, 1996). However, this framework is focusing on looking outside of the firm for 'ideas', and most research has followed this outside-in process of Open Innovation (for example, Enkel et al., 2005, Dodgson et al., 2006, Van de Vrande et al., 2009), whilst the inside-out process remains less explored (as follows from Lichtenthaler's statement [2005, p. 248]). In this respect, six out of nine articles in a Special Issue of *R&D Management* on Open Innovation in 2006 focus on the inbound perspective, either user involvement and idea generation (Hienerth, 2006; von Krogh & von Hippel, 2006; Letti et al., 2006; Piller & Walcher, 2006; Prügl & Schreier, 2006) or governance models for technology sourcing (Van de Vrande et al., 2009). Lichtenthaler (2009, p. 317) examines moderating effects that derive from a firm's environmental context to conclude that the degree of technological turbulence, the transaction rate in technology markets and the competitive intensity in technology markets strengthen the positive effects of outbound Open Innovation on firm performance. However, most of all, these studies are directed exclusively at establishing sources of technological developments.

It has been suggested that industry has not established practices and that academic research insufficiently addresses frameworks to evaluate the value of technological developments. Hence, the concept of technology valorisation is a relevant concept to be explored further.

2.6 Technology Valorisation

This discussion should be positioned in the context of how to capture value from innovations. Traditionally, valorisation has been linked to Knowledge Valorisation across university–industry collaborations (PWC, 2006) and the Council of the European Union has adopted recommendations on the Guiding Principles for Knowledge Valorisation (Council of the European Union, 2022) focusing on getting value from knowledge and reusing knowledge to increase impact. They identify intellectual asset management as one of their areas of guidance. Dekkers (2005) and Andriessen (2005) proposed to extend the term Technology Valorisation from its use in university–industry knowledge transfer to intra-company relationships for commercialisation of technology. This builds on the argument that external commercialisation should be based on a value proposition rather than just purely monetary considerations. Thomson (2012, pp. 247–253) confirms that technology.

Valorisation is a complex process with many uncertainties; the author's findings reinforce the notion that capturing value from IP is a lengthy and cumbersome process, for which companies do not always allocate sufficient resources due to competitive pressures or viewing it as a supplemental process. Dekkers et al. (2019, p. 217) more recently stress the importance that firms who want to exploit Open Innovation should allocate resources to Technology Valorisation. However, their statements have not yet resulted in an understanding of the mechanisms for Technology Valorisation. In this context, it is worth mentioning that only two suggestions have been made for capturing value:

1. The use of technology roadmapping by Lichtenthaler (2008). It should be noted that technology roadmapping is not new at all (e.g. Groenveld, 2007 [a rewrite of his paper published in 1997]; Phaal et al., 2004, Kostoff & Schaller, 2001). Lichtenthaler (2008, pp. 81–82) claims to extend these by depicting internal commercialisation and external commercialisation separately. However, its novelty might be disputed.
2. The allocation of resources for the processes of Open Innovation in a separate organisational unit (Bianchi et al., 2009, pp. 464–465; Linder et al., 2003, p. 48); this could also be seen as an attempt in their case study to demonstrate that a separate unit has to prove its baseline. Hence, this solution does not substitute the search for mechanisms.

Although the only viable proposition so far, technology roadmapping (Lichtenthaler, 2008), might assist in capturing value from inventions, knowledge or IP it is neither comprehensive nor explanatory for Technology Valorisation in the context of Open Innovation nor was it discussed by any of the companies interviewed in this research (as it turns out).

However, before undertaking any further research steps, it is necessary to understand what is meant by Technology Valorisation. Andriessen (2005) points out that there is a fundamental difference between Technology Valuation and Technology Valorisation with the latter being a more encompassing concept. The term is also expanded by Dekkers (2005) who introduces an integral view of Technology Valorisation describing that it contributes to more effective management of innovations and says that this will lead to a higher degree of commercialisation of breakthroughs. Valorisation should be understood as the process to give or assign a value to something and could be linked to theory related to value innovation. For example, Park and Park (2004, p. 387) discuss that the economic value of technology is affected by various non-technical factors; and Matthyssens et al. (2006, p. 751) stress the importance of 'value innovation' in order to create/sustain competitive advantage. Value here is not only monetary value, which is largely studied, but also the advantages that can then lead to more successful commercialisation. Giessel & Boekholt (2005, p. 10) raise the concept of 'valorising patents' and discuss measuring the 'real value', which includes using non-financial value assessments. Additionally, particular relevance can be seen here with Johnson et al. (2008, p. 51) definition of a business model as being the structure of product, service and information flows and the roles of the participating parties. It is disputed here that Technology Valorisation is a different approach to business model innovation. Therefore, Technology Valorisation in the context of this research will be defined as the decisions that companies make and actions that they take in the context of Open Innovation processes to maximise value, both monetary and non-monetary, in achieving successful commercialisation; appreciation and assessment of the value of the technology developed is encapsulated in this process, which is the result of the interaction with one or more organisations and not the firm alone.

3 Methodology

3.1 A Two-Tiered Qualitative Study Design

There is no encompassing model for Technology Valorisation that makes it possible to understand its mechanisms in the context of Open Innovation. This position is strengthened by the outcomes of the initial literature review: an emphasis on IP and IPR rather than broader concepts of knowledge and ideas, an emphasis on monetary valuation, the relatively conceptual descriptions and technology roadmapping are not comprehensive enough. Therefore, the development of a model for Technology Valorisation needs to involve empirical analysis of the management of technological innovations:

- How are companies making appropriate decisions to achieve maximum value (monetary and non-monetary)?
- How are they managing the processes for Technology Valorisation?

The aim of this research has been to gain greater insight into how companies can improve their current processes for engagement in Open Innovation and to embed Technology Valorisation within processes for innovation management. Given that little is known about the implementation of Open Innovation and mechanisms for Technology Valorisation, the research presented here is exploratory in nature.

A grounded theory approach was adopted, and Allan (2003, p. 1) states, in principle, grounded theory which investigates actualities in the real world and analyses the data with no preconceived hypothesis. This could be interpreted as recommending that fieldwork can be carried out before the literature search. However, this can be considered a misconception of the original premise put forward by Glaser and Strauss (1967, p. 169) who encouraged researchers to ‘use any material bearing in the area’.

Thus, a two-tier qualitative research approach was conducted. First, to identify the research focus and the direction of the research, exploratory data was collected in the form of a scoping study amongst practitioners participating in a series of arranged innovation workshops (in the form of a descriptive questionnaire). Secondly, nine in-depth face-to-face interviews and one telephone interview were carried out with companies in the Scottish Med-Tech Industry. Both phases of the empirical research lay a base for understanding the mechanisms of Technology Valorisation in the context of Open Innovation. Each of these phases will now be discussed in the following subsections.

3.2 First Phase of the Research: Scoping Study Questionnaire

As mentioned, the first phase of this study involved a questionnaire and this involved engaging with practitioners about their awareness of Open Innovation and mechanisms for Technology Valorisation, to identify gaps and direct the research. The objectives of the questionnaire as a scoping study were two-fold. It represented an initial attempt to carry out exploratory analysis into the systematic practices of Open Innovation by analysing the current opinion of practitioners and individuals supporting companies working in innovation. Secondly, this questionnaire was aimed at identifying issues that require further exploratory research.

To identify issues for Open Innovation and Technology Valorisation, qualitative research was undertaken in the form of a semi-structured descriptive questionnaire. Comprehensive definitions were provided on the questionnaire to explain theory or 'stock phrases' used such as 'Open Innovation' and 'Radical and Incremental Innovations' thus ensuring that instructions to respondents were clear and unambiguous. Question sequencing was considered and the questions were arranged in a structured order to set the scene for the topic, but as the questionnaire proceeded, more thought provoking questions were provided as well as the questions appearing in a logical sequence. The respondents were encouraged to provide their thoughts and opinions; therefore, closed questions requiring a yes/no answer were not included and unstructured questions were presented. Guidance was given in the form of additional information, to provide some direction as well as to stimulate further responses. As the questionnaire was also being used to stimulate further research avenues, the questionnaire was not narrowly focused; however, all questions were deemed highly relevant in the context of the preceding literature review. A standardised answer was only requested in one of the questions to enable the level of importance of a particular issue to be assessed, and the respondent was also encouraged to provide additional comments to back up their selections (Gill & Johnson, 1997, p. 92).

The respondents to the questionnaires were participants in a series of ten innovation workshops held over a 2-month period. The participants were academics and innovation support providers which included consultants, business advisers and public sector bodies (e.g. Scottish Enterprise). Participant opinion was gathered from discussions, which took place during the workshops. In addition, 26 questionnaires were sent out to academics, practitioners and innovation support providers and this study is based on the nine completed questionnaires received back, thus giving a response rate of 35%. The findings of this scoping study are presented in Sect. 4.

3.3 *Second Phase of the Research: Exploratory In-depth Interviews*

This second phase followed with a more detailed explorative study, in this case ten in-depth qualitative interviews. As Kvale (1994, p. 170) states: '*Qualitative studies may be accepted as relevant in the first exploratory phases of research, but in a scientific investigation the preparatory qualitative steps should lead to more precise hypotheses and theory, which can be experimentally tested*'. By connecting the qualitative interviews to literature, justice can be done to the original premise put forward by Glaser and Strauss (1967, p. 169) who encouraged researchers to 'use any material bearing in the area'. This implies that the second phase should prelude by a literature review before conducting the interviews.

The face-to-face and telephone interviews were carried out with companies to investigate how they were managing their Open Innovation processes. A structure was needed to guide the research in the form of a theoretical framework (see Fig. 2). This was achieved through identifying the key theoretical concepts underpinning both Open Innovation and Technology Valorisation. Key literature was then identified for each of the concepts illustrated and critically analysed to generate a series of interview questions. The theoretical framework is acted as a foundational review of existing theories and is based on questions raised or gaps found during a wide literature search on the area of Open Innovation and theories related to the concept of Technology Valorisation. This framework became a roadmap for developing the arguments.

Following a review of the data obtained from the initial four face-to-face interviews, a more structured interview survey instrument was then developed before a further five interviews were carried out using the new more focused research design. Following further literature review critiquing and data analysis of the interviews, a selective process was used to reduce and rearrange the data, looking for emergent patterns and links between theories. The data collected from the interviews was then analysed against common themes, identified in the literature and used to develop generalisations about their meaning and relationship to one another. Here, the theory is informing the research.

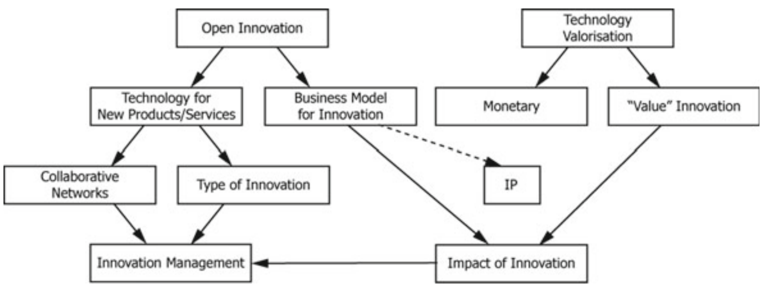

Fig. 2 Theoretical framework for interview questions

The companies interviewed operate in the Med-Tech sector and have research and development capabilities within their company. The companies were randomly selected from The Medical Devices in Scotland Capability Directory. It should be noted that company I and company J are companies supporting innovation and providing a service to the Med-Tech companies; therefore, some of the questions posed were not applicable to these companies. The interviews were semi-structured and were carried out with R&D/Innovation managers and at Director level. Primary data such as internal company newsletters on new product development and collaborative projects was also collected as well as a review of the company websites. An initial series of ten in-depth interviews (as shown in Table 1) were carried out.

Qualitative analysis interpretation methods have been employed in the form of a series of techniques for identifying themes in qualitative data generated from the interviews (Ryan & Bernard, 2003). Table 1 lists the companies interviewed with anonymity maintained to protect the identity of the company and confidential nature of the information discussed. Computer aided software (CAQDAS) and in particular NVIVO™, was used to more systematically carry out qualitative analysis. This has been used to aid in continuity and increase both transparency and methodological rigour to exhaustively as possible perform qualitative analysis of the data (Saunders et al., 2009, P. 514).

Ryan and Bernard (2003, p. 85) discuss that theme identification is a fundamental task in qualitative research. They present a range of techniques, which they have drawn across epistemological and disciplinary boundaries and spanning both observational and manipulative techniques. Each technique has its advantages and disadvantages, and some methods are more suited to rich, complex narratives, whilst others are more appropriate for short responses to open-ended questions. In addition, some techniques require more time and expertise to implement. Of the twelve techniques presented by Ryan and Bernard, this research draws upon five of them: (i) similarities and differences, (ii) cutting and sorting, (iii) missing data, (iv) repetitions and (v) word occurrence. With the use of NVivo software, an ideas log has been kept and saved as a journal document, which has also supplemented this technique by recording the researchers' ongoing thoughts. The NVivo secondary tool is useful to aid theme identification by uploading the interview transcripts, and each interview can be easily searched for particular word associations. In addition, theme identification was implemented during the literature review, to establish areas of innovation literature theory that would be relevant to the Open Innovation field and require exploration.

Table 1 List of companies interviewed

Company name	Size	Med-Tech area	Open Innovation example
Company A	Large	Develop medical devices in the areas of patient monitoring and connectivity, anaesthesia delivery and ventilation and diagnostic cardiology	Licenced algorithms from University of Dublin and MIT to feed into R&D process
Company B	SME	Develop, manufacture and licence products based on patented drug delivery technologies in the area of Women's Health	Licencing business model for commercialisation of their products
Company C	Large	Develop blood glucose monitoring systems for home and hospital use	Have an exclusive agreement with a company to develop a new device for their customers in the USA. The new device integrates with the collaborating companies existing technology
Company D	SME	Developed critical care real-time cardiac monitor	Purchased IP for original technology (sourced idea externally)
Company E	SME	Design, development and manufacturing centre providing a one-stop service to take technology from concept into production	Spin-out company, which has developed a hand-held device
Company F	Large	Design, manufacture and market vascular products for the treatment of cardiovascular disease	Work closely with surgeons and end users to develop new products. Collaborated with a company with expertise in textiles to help design one of their key products
Company G	SME	Design and develop high-tech prosthesis technology including a multi-articulating bionic hand	Spin out from the NHS. Continue to develop new IP through externally sourcing expertise not available in the company
Company H	SME	Develop technology for medical imaging and industrial non-destructive testing	Regularly work with universities to develop new technology
Company I	SME	Provide technology and innovation consultancy to the private and public sectors with Med-Tech expertise	Provide support to companies in the sector and encourage a collaborative approach
Company J	SME	European Patent and Trade Mark Attorneys with specialist area in Med-Tech	Encourage the protection of IP and gaining value from IP

4 The Results

4.1 Findings—First Phase: Questionnaire as Scoping Study

The analysis of the questionnaire responses has taken two forms. First, the responses given were compared to the other respondent's answers. A comparative method is used to discover empirical relationships among the variables identified and between the different company cases (Lijphart, 1971, p. 683). This case-orientated research method involves examining where each company case exhibits similar combinations of causal conditions and then examines the outcome (Ragin, 2007, p. 73). In addition, the opinions given or particular thoughts made are compared to the current literature and it is discussed and critically examined to determine whether there is an agreement or gap in the current literature in relation to this area of research and where a contribution to research in this area can be provided (Wallace & Wray, 2006, pp. 30–31). Each of the findings will now be discussed across four themes; the need for collaboration in the innovation process, multi-disciplinary approach to Open Innovation, challenges associated with performing Open Innovation and companies performing Open Innovation.

4.1.1 Need for Collaboration in the Innovation Process

A first finding from the scoping study was that there was a strong need for collaboration in the innovation process; one respondent labelled it as 'must haves' rather than 'nice to haves' in this age. The latter is congruent with literature on Open Innovation, for example, Docherty (2006, p. 64) explores the importance of collaboration. A second finding from the scoping study is the potential impact of sectors on mechanisms for technology valorisation. This is in keeping with a conference panel discussion on Open Innovation (Addison, 2010) where it was noted that having 'excess' innovation is not an issue in the food and drink sector. It is also important in the biotech sector where routes to market and manufacturing have been built over many decades, longer than many new innovative companies which have been in existence.

A reflection on the capabilities and the capacities of organisations to generate innovations resulted in some ambiguous statements about the role and advantages of collaboration (a third finding from the scoping study). Such an aspect mentioned by the respondents was the lack of resources, which some thought might warrant collaboration (consummate with literature like Gassmann & Reepmeyer [2005, p. 233]) and others postulated that it would hinder collaborations. The relative size of R&D was seen by some as not necessary unless being an R&D focused company; at the same time, some participants commented that if a technology does not fall within the remit of a core capability, collaboration should not be considered, but the focus should be on prioritised technologies/developments. However, the necessity for collaboration to be providing complementary sources was also recognised (also found in Teece, 1986, p. 285). It might also be that if a company could not support a technology (for example, financially), then it might better to concentrate on improving performance than on innovation.

In the context of strategy, the companies were questioned on whether they would get involved in licencing-in ideas rather than internally carrying out R&D based on their own idea generation. The respondents had experienced many examples of this, and it was noted that looking externally would extend the technological capability of the company innovating. A respondent commented that this happens in companies who are involved in the European Commission Research Projects under Framework Programmes. Collaborative innovation was seen as an attractive proposition for collaboration and in particular in the development of new equipment, gaining access to the generation of cash from assets before the final marketing of products. Collaboration in the innovation process where a firm's internal technological capability is weak was met with caution by the respondents who saw some limitation of this mechanism in practice. This data follows literature on the Partnering matrix (Harris et al., 1996), reviewed by Dekkers (2005), where companies must assess their internal technology capability to determine partnership constructs. It was also proposed that the company would still have to have some core competency along the route to market to enable effective collaboration (akin to theory on Absorptive Capacity; see Cohen & Levinthal, 1990). This was still seen as an attractive opportunity, as by doing this they may be able to develop their capability, whilst the individuals involved in the collaboration could learn from the partners.

4.1.2 Multi-disciplinary Approach to Open Innovation

The respondents were asked whether they felt that a multi-disciplinary approach to Open Innovation is appropriate. One of the respondents believed that this approach is perhaps the most beneficial process to adopt for the benefit of broader commercialisation of new products. All respondents agreed with this statement as it ensures that all core competencies are covered, which are not usually found in the same discipline. Recommendations were made by the respondents to ensure success using this approach, such as: having multi-disciplinary teams working together was not seen as a sufficient condition; one of the toughest challenges was seen to be managing people, it was commented that 'you can install a process and be systematic, but unless you have the people on your side it will fail'. Clear guidelines on who contributes and what outcomes are needed were recommended. It was commented that in practice interdisciplinary work takes a greater amount of project management, development of common platforms of understanding, as well as significant commitment from all partners—difficulties emerge at the interface between disciplines which may have different understandings of data, different time horizons, etc. It was suggested that the mix of the multi-disciplinary team should vary in terms of composition depending on the nature of the innovation, the stage of development and again the business sector. A real-life example of this approach was highlighted as being that of the Knowledge

Transfer Networks (Innovate UK, 2023), which have been set up by government, industry and academia to bring together diverse organisations and provide activities and initiatives that promote the exchange of knowledge and the stimulation of innovation in these communities. One of the respondents runs New Product Development Workshops and commented that it works better when a variety of sectors are there, as solutions can come from different disciplines.

4.1.3 Challenges Associated with Open Innovation Practices

Existing literature eludes that not all companies are successful in performing Open Innovation and that companies are faced with constant challenges around pro-actively managing Open Innovation (Chesbrough, 2019; Thomson, 2012). The respondents were asked to rate a list of challenges associated with achieving successful innovation whilst working in partnership from 1 to 6 with 6 being the biggest challenge and 1 being the smallest challenge. Not all of the six different ratings were used by each respondent, but the total ratings for each challenge gave some indication as to the respondent's opinion on the challenges faced, with selection of the partner being the biggest challenge, a key area identified in other studies related to collaboration (for example, Cundill et al., 2019), whilst building trust in the relationship is seen as the smallest challenge. It may be that building trusting relationships is something that the companies already had on their radar. Certainly, much literature implicates management communication as being effective in building trusting relations; however, the Covid-19 pandemic has led to more challenging problems for building trust (Balog-way & McComas, 2020).

4.1.4 Companies Performing Open Innovation

Except for one respondent, it was estimated that in less than 10% of the companies that they had worked for (in an innovation support role), the companies were explicitly or fully aware that they were using Open Innovation approaches. It was however expressed by one of the respondents that the system of Open Innovation is not widely employed in Scotland's Med-Tech community and that the industry is lacking a confirmed route to market, which allows for the production of prototypes, staged financing of the projects and an interaction between industry and academia. It was not apparent from the responses which part of the innovation process companies would be most likely to use Open Innovation. It was also thought that some companies are using Open Innovation practices but are not aware they are doing this. In terms of problems that the respondents have come across using these approaches, there was a shared view about the people and relationships being the biggest problem and more so than the process itself. For example, suggestions of unwillingness to co-operate, too high expectations, a blame culture if things do not work and a lack of openness came across. Regarding whether there were any practices in place to guide the companies through the Open Innovation process—it was suggested that to look at how successful companies like Eli Lilly have carried out Open Innovation. The rest of the respondents were not aware whether there were any practices in place. This is except for one respondent who suggested that more needs to go into the situation analysis at the start of an innovation project. It was suggested that a framework in the form of a checklist to cover all of the basics and get expectations, outcomes, plans, IP understanding and timescales all agreed would be advantageous. This therefore illustrates a varied opinion on Open Innovation practices and the need for practical assistance in this area, and gaining value from Open Innovation requires deeper understanding.

4.2 Discussion—First Phase: Scoping Study

This initial exploratory research confirms the original presumption that a framework is necessary for Open Innovation but that it also needs to be developed. Open Innovation introduces and assigns a name to a concept that has been in existence, but it has also been illustrated that it is not practised by all companies who have R&D functions. The preliminary research, however, showed that collaboration in the innovation process is important with a multi-disciplinary approach benefiting the company further. Open Innovation can be useful during the different stages of the innovation process with further research required to embellish on this. Open Innovation is on the agenda with many large organisations even appointing 'Open Innovation Directors' (akin to the creation of a department as mentioned in [Bianchi et al., 2009, pp. 464–465; Linder et al., 2003, p. 48]). The literature on companies that have been successful implies that if companies can embrace Open Innovation approaches and learn to implement these successfully within their culture and organisation, then they will be rewarded with a portfolio of innovations that can fuel the growth of their company for years to come.

However, little is known about how technologies evolve into successful products and services. Foresight is important in Technology Valorisation; by developing systematic practices for Open Innovation, this would be highly beneficial to Innovation Managers, who face decisions about technology sourcing, who are making effective choices on resource allocation or technology collaborations during the different phases of the innovation process. Technology Valorisation must be firmly embedded in the management of Open Innovation to bring value to technological knowledge and creativity, to help identify partnerships and modes of collaboration; there are implications for further research to investigate this further. Additionally, existing literature informs us of the impacting climate of accelerated technological change (Tidd & Bessant, 2020) and the need for Open Innovation by companies (Enkel et al., 2009a, 2009b, p. 311) but also of the challenges associated which can result in few companies capturing the full value of partnerships with external technology providers. Preliminary findings showed that the challenges recognised were in relation to people and culture factors associated with Open Innovation practices which should be given much more attention. It is known that value can be progressively built throughout the process of managing external innovation; however, providing new ways to create value outside corporate boundaries requires an innovation strategy that captures Technology Valorisation.

4.3 Findings—Second Phase: Exploratory In-depth Interviews

Using the qualitative analysis methods outlined in Sect. 3.3, the empirical data has been analysed. There now follows an analysis and discussion on the data collected in the in-depth interviews, which has been presented under the following themed areas: examples of Open Innovation Practices, Capturing more value from IP, Seeking External Expert Advice, User or Supplier input to innovation, Measuring Value, Impact of Dominant Designs in Innovation, Measuring Success of Innovation, Managing Intellectual Property and Open Innovation Challenges.

4.3.1 Examples of Open Innovation Practices

It became clear both by searching company websites and during the interview process that all of the companies interviewed engaged in Open Innovation practices to a varying level, just as Enkel et al. (2009a, 2009b, p. 312) comment that business reality is not based on pure Open Innovation, but that companies can invest simultaneously in closed as well as Open Innovation activities. There might even be a necessity since the concept of absorptive capacity (Cohen & Levinthal, 1990) dictates that the absorption of external knowledge is only possible through the existence of internal R&D capacity; this has been confirmed by many other studies (e.g. Fabrizio, 2009). This implies that Gassman and Enkel's (2004, p. 6) distinction between the three processes of Open Innovation: (i) the outside-in process, (ii) the inside-out process and (iii) the coupled process strongly depends on the existence of the internal innovation capabilities of a firm, which is demonstrated by the examples given in Table 1:

- In the *outside-in process* (i) the company sources external knowledge to increase their innovativeness through the integration of suppliers, customers and external knowledge sources. An example of this Open Innovation process from the empirical study is where Company A licenced-in algorithms from universities for the development of their cardiac monitors, they recognised that they did not have the knowledge in this area to do it themselves and more value could be achieved through sourcing the knowledge solution externally. Meanwhile, Companies G and H remarked that they are small companies and do not possess all of the expertises needed; they recognise that universities are a key source of knowledge and therefore source expertise for their products through university collaborations. Another example of the outside-in process is where Company F has a lack of expertise in material science and collaborated with another company to gain the expertise and knowledge to develop sophisticated technology that would meet the needs of their key product and importantly in a timely manner.

- In the *inside-out process* (ii), the company exploits their ideas externally in different markets, which involves selling their IP and multiplying their technology by channelling their ideas into the external environment. Whilst an example of this Open Innovation process from the empirical study is where Company B's business model is based entirely on licencing their technology, they realised that they do not have the capability to sell their products themselves due to the type of niche market that they are operating in, and gaining value through licencing the technology is currently working best for them. In addition, they are engaging in other Open Innovation practices, for example, for one of their new products, the technology is not core to them due to their product focus on woman's health care they are licencing the worldwide rights for any products using this technology to another company who they will then pay them an amount to supply the goods and then a royalty after that. Therefore, they are gaining value through engaging in this collaboration and gaining non-monitory benefits in terms of access to markets that they would not have achieved if they were doing this alone.
- Whereas in the *coupled process* (iii), the company is linking outside-in and inside-out processes by working in alliances with complementary companies, where the ethos of give and take is crucial for success. In addition, this process involves thinking along the whole value chain and new business models enable this core process. An example of the coupled process is Company D who is developing a novel real-time cardiac critical care monitor for launch on the market. Chesbrough (2006) said that valuable ideas can come from anywhere and the original idea for Company D's technology came from IP that the company sourced externally as a small start-up company. The company aims to seek external collaborators after the launch of their product, for example to amalgamate their product with another companies that would be complementary to their product and therefore add value or to look at other applications for their technology. This approach is crucial to their success. Another example demonstrating the coupled process is Company C who has signed a collaborative agreement with a company to develop a new blood glucose meter for their customers in the USA. Company C is the leading maker of blood glucose monitoring systems, and therefore by combining their technological expertise with another company's platforms, they are delivering a new high-tech product to the market to meet a particular market need and with an already existing customer base. The new meter wirelessly transmits glucose values to the other company's existing continuous monitoring systems thus capturing value for these complementary companies.

It is unclear which process Company E fit into as they were originally formed out of a spin-out from a university, so it could be considered that they are an Open Innovation practice, where the university was demonstrating out-bound innovation to form the spin-out. In addition, they are a design, development and manufacturing centre providing a service to companies to take their technology from concept into production at the same time they are also looking at proof-of-concept projects that they can collaborate on through to commercialisation, essentially using a coupled process. There is a growing trend for design consultancies to develop their own products and Open Innovation practices like those described here show how value can be gained to achieve innovation success (IDEA, 2008). To summarise, Open Innovation can be categorised according to three archetypes: in-bound, out-bound and coupled processes for practising Open Innovation. The companies interviewed provided illustrations of these archetypes being exhibited in practice. As Gassman and Enkel (2004, p. 15) say, the archetypes are core processes that companies that companies need to successful follow as part of their innovation strategy. However, each company has different characteristics and capabilities to engage. Perhaps sector differences may also have a bearing on the archetype that is more commonly used to gain value through the innovation process.

4.3.2 Capturing More Value from IP

It is reported that Open Innovation can help companies to capture additional value from their IP, and this is particularly true for technology companies, such as the med-tech, who are coming up with novel parts or systems that can be used elsewhere. The response from the interviews was that 'we just look at our own industry'; the companies have commented that it is difficult to expand IP to other product-markets combinations as they are still not covering everything themselves in their own area. Once the company puts the effort into designing their innovation to suit their own processes and business models, they move onto their next internal project. Company H mentioned the potential application of an innovation to a different industry (i.e. sonar) but did not mention that they were actively looking for other applications. Company G was very clear that they are too small to look at exploiting their IP in other industries and are too focused on their current business; Laursen and Salter (2006, p. 146) hint at firm size as well although they link it to incremental innovation. As Company C stated: the lack of ideas is not a problem, it is dealing with them all that has become the limiting factor. In essence, companies operate under time pressure and there are too many potential avenues to look at for the application of technologies; hence, they are not allocating time to explore external revenue streams.

These findings show that companies are exhibiting practices that could be characterised as Open Innovation (an inference from the previous subsection), but these appear to be occurring on a trial-and-error basis or as and when they become necessary when an opportunity arises. Tidd (2001, P. 173) explains that we have failed to provide a comprehensive framework to guide innovation research or management practice. The companies interviewed have not revealed that they have processes in place to actively manage Open Innovation or to look at the value that they could gain from looking at IP differently and thus innovating more openly. One area it has been suggested is that companies should consider other applications for their technology that would enable them to gain further value in markets that they are not operating in, for example Chesbrough (2006, P. 10) says *'open models can also enable greater value capture, by using a key asset, resource or position not only in the companies* *own business but also in other companies' businesses',* but this research reveals that this does not appear to be occurring in practice.

4.3.3 Seeking External Expert Advice

This leads us to looking at how companies decide on which product areas to pursue particularly if there is a plentiful supply of ideas as has been suggested. Company B explained how they deployed an ad hoc approach to selecting projects. However, they have now incorporated stage-gate decision-making into their product development, which ensures that not only technological viability but also a fit with their business model and with potential markets for their product. In addition, they use a form of Open Innovation where they seek external advice to feed into their Open Innovation process by consulting experts. Similarly, Company F seeks the ideas and comments from surgeons who would be operating their products, to guide product development; the firm has a structured design control process. Some consider this part of the Open Innovation practice (e.g. Gassmann, 2006, p. 225), but it might be questioned whether this is a trait of Open Innovation or rather common practice in certain industries (e.g. Letti et al., 2006). The company is achieving non-monitory value from this process and deploying a mechanism for Technology Valorisation. Company C challenged the stage-gate process for managing the product innovation processes, saying that sometimes products can be pushed through the system and pass through stages due to political issues within the organisation. The culture of the organisation is significant factor here and the interviewee had not seen any system that could not be affected by the human aspect of the procedure. Could a systematic framework for Technology Valorisation utilising Open Innovation be the answer? In any case, based on the limited sample of the interviews, stage-gate decision-making might support Technology Valorisation.

4.3.4 User or Supplier Input to Innovation

It is widely reported that user input (e.g. Bødker, 2000; von Hippel, 2005; Kontogiannis & Embrey, 1997) and supplier input (e.g. Lhuillery & Pfister, 2009, p. 56) can be advantageous to the innovation process; this is confirmed by three of the cases. Company H consults its customers but notes that some of the key customers have specific requirements. Company D is engaging with potential customers during the innovation process to trial their new product, which not only results in feedback but also exposure in academic journals and credibility before product launch. Company C's marketing department arranges customer feedback sessions; however, in some ways, this can be problematic, as feedback may be specific. Diederiks and Hoonhout (2007) demonstrate that a user-centred approach might support the development of new products; this has some parallels with the three cases mentioned here where the customer mainly provides feedback and support for marketing. Tidd (2001, p. 175) comments that customers are an important source of innovation and specifically mentions this in relation to examples from the medical instruments sectors. He also denotes suppliers as an important source of innovation (ibid. p. 175). This corresponds with the experience of Company C whose close collaboration with suppliers appears to be very effective. There are some parallels with Nokia who propelled themselves ahead of the competition when they sourced individual innovative components for their phones, and in March 2022, they advanced their technology by joining the 5G Open Innovation lab, bringing together tech companies, services providers, innovators and their use community (Nokia, 2022). Although user innovation is mentioned as an Open Innovation practice by Gassmann (2006, p. 225), in the three companies mentioned from this study, the focus seems to be more on feedback and user involvement than user-driven innovation; supplier input appears in only one case. Perhaps supplier input could be pursued as an avenue for more proactive engagement, to gain value.

4.3.5 Measuring Value

For companies to embed Technology Valorisation into their processes, they must also consider the value that they are creating at each stage and how best to capture this. Five of the interviews yielded an insight into the actual issues that companies are struggling with. These issues can be divided into challenges for forecasting and for assessment of the impact of technologies. The challenges for forecasting cover the uncertainty about the actual size of the potential market and the unpredictability caused by the lead-time for new product development. For example, Company D's technology is under development and their first product has not yet been launched. Initial attempts to value its technology have resulted in a 'gamble' and the initial financial plan was overly optimistic. As Company D informed, the development time might amount to 4–5 years of development before any returns on investment can be achieved and sometimes even longer. Company H note that having experience does facilitate a general assessment of market development but that this can rarely be quantified. In this sense, it was commented by company H that peer review might be more accurate than market research. In the same spirit, Company A reported that revenue streams are difficult to estimate and expectations are often unrealistic, which hampers reaching collaborative agreements. Both factors—the uncertainty about the actual size of the potential market and the unpredictability caused by the lead-time—create difficulties in estimating their Return-on-Investment.

Moreover, not only uncertainties about future demand make it difficult for the companies to capture value, they also experience difficulties in the appropriation of technology. For this reason, Company F does not directly measure value during the development stage but said that they probably should do. In addition, Company C finds it difficult to put a value on an idea whilst putting it through their product development process. Furthermore, Company A commented that problems associated with valuing technology make it difficult to reach collaborative agreements to take development forward. In this respect, several of the interviewees commented that most companies tend to overvalue their technology significantly until its factual commercialisation. An example was given by Company C who during product development where suddenly found that the response time of a glucose test could be reduced to 5 s. This became one of the most successful features of the product delivering a competitive edge; however, at launch the relevance had not been recognised. This example underlines the difficulty to understand the reaction of the market and the belonging value. Park and Park (2004, p. 387) comment that valuing technology might not be a science but an art.

Both the challenges for forecasting and the difficulties in assessing the value (including the non-monetary value) hamper the processes necessary for Technology Valorisation. During the 1980s and 1990s, there were attempts to pay attention to forecasting (e.g. Bayus, 1987; Twiss, 1984) often linked to diffusion processes (see Meade & Islam, 2006), but these did not cover any of the issues mentioned by the companies during the interviews (particularly, how well products are received within a market domain). Nevertheless, the recognition of the essential role of Technology Valorisation by the companies in the Med-Tech sector underlines the objectives of the research and the need to develop a framework.

4.3.6 Impact of Dominant Designs on Innovation

The assessment of the value of technologies can be made more difficult by disruptive innovation (e.g. Abernathy & Clark, 1985; Markides, 2006) caused by a shift in dominant designs (e.g. Murmann & Frenken, 2006; Suarez & Utterback, 1995; Tegarden et al., 1999). This can be impacted by the dynamics of markets, moves by competitors and result in changes in the time-to market. For example, Company C's system for measuring blood glucose was based upon photometric technology. However, the dominant technology on the market moved to using electrochemical technology. Company F commented that something similar happened with their endovascular project; new technologies emerged that overtook the ones they were using and it resulted in a late entry for them into the market. Company B was caught by surprise when a competitor brought out a new product that affected a product they had under development. In a rapid response, they changed their way of thinking and they allocated resources to match technology with this new dominant design. This implies that companies must monitor technological developments in their competitive environment actively to anticipate on disruptive innovations.

The companies interviewed also displayed possible strategies to deal with the disruption innovations and the shift of dominant designs. At the time when the shift in dominant design came, Company C had an existing collaboration with a company that had expertise in electrochemical technology; the company then simply acquired the collaborator. Similarly, Company A recalled that they have experienced several instances where they have had to embrace and redesign their product lines accordingly in response to emerging dominant designs. Company H said that monitoring the technological environment constituted a core strategy. They would await the maturing of a technology before embedding it in its designs. An example of piezo-composites was given where all their suppliers were moving over to this format, but unfortunately, they acted later. As a third strategy, Company E is a spin off from a company in the instant photography market. The emergence of electronic imaging led to the collapse of the parent company. In these strategies (acquisition, redesign of products, tactical monitoring, spin-off), it is not clear whether mechanisms of Technology Valorisation would have resulted in better performance. Theory on value innovation by Edwards et al. (2004) explains that a firm's competitive advantage no longer rests solely with static price competition but relies on a firm's ability to create and exploit knowledge faster than its competitors and to account for dynamics in its competitive environment.

4.3.7 Measuring the Success of Innovation

No matter what the uncertainties are in the valuation of technology and the effects of disruptive innovations, companies need to be able to measure the success of their innovation processes. The parameters used to identify success appear to differ. The outcomes of the interviews indicate that the companies have different views on how to measure innovation performance. To Company D, success is a product launch and recovery of R&D expenditures and profit. Company B acknowledged that they are not very good at measuring their innovation success; they do not measure patents but acknowledge that the number of patents might not be a good indicator. However, there is a system for rating new product development projects. Company A confidently reported that they measure their success based on the Return on Investment, sales revenues and productivity of product lines. Company E bases innovation performance on profits made as well as customer satisfaction—commenting that a flexible engagement process with each client is used. Company F engages its customers for assessments of the final products. Company H does not have a formal assessment process, saying that it is difficult to retrospectively measure success. Company C acknowledged that innovation is very difficult to measure, commenting that you can easily measure the innovation process retrospectively but that it is difficult to assess its current state; in their opinion, some metrics are useful, for example, product launches and patents, but these do not necessarily reflect the present state. This backs up Reeb and Zhao's (2020) review paper that patents do not measure innovation success. In this respect, predicting the future is even more difficult, which makes it harder to review the product development portfolio. Tidd (2001, p. 171) lists the strengths and weakness of different measures of innovation, but it is concluded here that there is no best measure of innovation (see, for example, Hagedoorn & Cloodt, 2003).

4.3.8 Managing Intellectual Property (IP)

Much of the literature surrounding Open Innovation discusses the management of IP or takes it as a starting point as demonstrated in the initial literature review; the portfolio of IP should inform decisions on collaboration and sourcing. Two of the companies deployed a deliberate strategy for collaboration. Company C had identified product development activities to undertake in-house and others that needed partnering; considerations include resource allocation and assets. However, management of the collaborative relationships could be improved. This was due to the need to establish rules of engagement, for example, for IP, and legacies in the relationships. The company viewed the P&G's Connect and Develop programme as a successful example of Open Innovation; in P&G's model, they define a problem where they need to source external ideas, and with this model, the guidelines for IP are more clear-cut (Ozkan, 2015). In Company E's business model, the management of IP is straightforward and the collaborations do not result in conflict. In this case, customers offer IP for a core technology and the company owns the secondary IP or downstream IP that has been developed under contractual arrangements. These two examples follow the thoughts of the Outsourcing and Partnering Matrix (Harris et al., 1996). Depending on the competitive impact of a technology and the internal technological capability, decisions can be made with respect to keeping the technological capability in-house or to collaborate in any form.

However, the emphasis on Intellectual property Rights (IPR) might also create barriers to collaboration. One of the interviewees (Company E) was aware of the issues relating to IP that collaborators would need to be careful of; in their opinion, companies are not carrying out due diligence on the quality of patents before licencing. Company F was more concerned about infringing other companies' IP. Additionally, Company A considered the IPR system to hinder Open Innovation, stating that legal requirements make it a more complex process; and even commenting that the patent system is severely broken. Company B remarks that IPR is essential as it operates on a licencing model with its partners who want to be assured that their IP is protected. However, the expense of the patent system was a factor, and this has resulted in companies needing to carefully consider what to patent and in which regions. In this respect, Company D agreed that the management of IP in Open Innovation practices could be a minefield and they would need to discuss the agreements before entering a venture. The positive and negative aspects surrounding the use of IPR are well recognised in academic literature, see Greenhalgh and Mark (2007).

4.3.9 Open Innovation Challenges

According to some of the companies, one of the threats associated with moving to an Open Innovation model is losing internal R&D capacity. Company C raised the issue of managing the internal research and development team when interesting projects are being sourced externally or carried out through external collaborations. However, it is still important for a company's in-house R&D to complement external sources (akin to the concept of absorptive capacity see Cohen & Levinthal, 1990) and competencies (embedded in people) are still needed to make decisions on technology sourcing and managing collaborative processes. The problem this company foresees is keeping the expertise in-house without having the product development and production in-house.

The interviewee has seen a lot of frustrated engineers as the challenging projects they would like to work on have gone elsewhere. This may become more of a problem as Open Innovation is implemented, if the challenges for internal employees are not managed effectively. Just as Hillebrand and Biemans (2000) report on the theory of organisational learning and suggest that the internal cooperation of a company is part of a continuous learning cycle which serves as a mechanism to interpret the results from external collaboration and to initiate new external collaborative efforts.

4.4 Discussions on Second Phase Findings and the Need to Revisit the Two Key Concepts

The emerging patterns in the qualitative data have led to revisit the two key concepts of Open Innovation and Technology Valorisation and more extensive insights will now be discussed.

One of the main findings is that companies are not systemically carrying out Open Innovation and that gaps exist and there is the need for a framework to guide practitioners through the process to gain maximum value, i.e. mechanisms for Technology Valorisation. This research is underpinned by two topics that are not yet well defined: Open Innovation and Technology Valorisation.

By improving the efficiency of their innovation processes, companies can access new markets, become more competitive, and gain enhanced value from their technology. Researchers have suggested that firms need to adopt more plastic and porous models of innovation by being open to external sources of ideas and routes to market and to engage with a larger number and wider range of collaborators (Chesbrough, 2003; Tidd, 1995). This approach is characterised by more fluid interactions between internal and external innovation activities, in which ideas, people and resources flow in, around and out of organisations. Issues such as workforce mobility and venture capital have eroded the ability of corporate R&D laboratories to contain their useful knowledge and a breed of independent research laboratories have created a new source of R&D contributing to an increasingly active and distributed market for ideas. Some of the basic principles put forward by Chesbrough (2003, p. 93) are that:

- Good ideas are widely distributed.
- First to discover is neither sufficient nor necessary for commercial success.
- A better business model beats a better technology.
- Intellectual Property is a perishable asset for which consumer and markets will not wait.

Despite growing efforts to explore Open Innovation practices including the impact on firms' innovation performance, many managerial and hence research questions remain unanswered. There are also doubts expressed as to the scope of this term, and the prevalence of the practices referred to with Open Innovation meaning different things to different people (INNO-Grips, 2009). The challenge for most is to first understand how to be successful at it. This includes even in research terms caused by a lack of inappropriate theory.

It has been identified that R&D carried out by other organisations can create value from which the firm can profit. However, firms also need to carry out R&D internally to create the absorptive capacity to capture some of the benefits from ideas generated externally (Cohen & Levinthal, 1990). Firms need to manage organised sources of idea generation more effectively and improve their ability to absorb useful information from outside. The degree to which R&D is internalised and the ways internal capabilities link with external sources of R&D are areas for consideration. The firm will succeed if it can improve the ways it uses ideas generated internally across the whole organisation, not just in R&D or design departments; and that building a better business model to exploit new ideas will provide a better return than focusing purely on first-mover advantage. Laursen and Salter (2006, p. 132) found that there were decreasing returns to openness, indicating that there is a point where additional searching becomes unproductive. Firms that were too open had lower performance than those able to balance openness with internal activities. Meanwhile, Dahlander et al. (2021) reflect on the original framework on openness by Dahlander and Gann (2010) and that important technological, organisational and societal changes in the past decade and identify the opportunities, costs and trade-offs of different modes of Open Innovation. A better understanding of the relationship that affects the nature of openness is needed. In addition, consideration of the dangers of opening up to external partners should be taken, such as; for danger of theft of ideas, managerial time demands and transaction costs, over-reliance on external parties, negotiating and managing external relationships slow down the innovation process by increasing coordination costs. Meanwhile, Chesbrough et al. (2018) bring new insights on the need for understanding value creation and value capture, which is paramount for advancing our understanding of sustained Open Innovation activities—which would be considered to build value over time.

Underlying issues such as those described that are relevant to how companies can create value which should be considered in Open Innovation. The term Technology Valorisation has been expanded here and developed from Andreissen's (2005) view of Knowledge Valorisation, where he introduces the concept of Knowledge Valorisation as explaining how firms create and capture value, and through the transfer of knowledge from one party to another ultimately for economic benefit. It is not clear from the literature in relation to how companies can improve upon the technology transfer, which takes place whilst undergoing Open Innovation mechanisms. This term is also expanded from Dekkers (2005) introduction to an integral view of Technology Valorisation.

5 Concluding Remarks

How companies are achieving maximum value (monetary and non-monetary) in the process of Technology Valorisation, whilst engaging in Open Innovation has been the subject of this study. A lack of systematic practice for managing Open Innovation was identified in the first phase scoping study, whilst the second phase in-depth interviews generated more detailed insight into areas underpinning value creation by the case companies, which requires further research. A theoretical framework (Fig. 2) was identified from the existing literature, connecting insights from theories on innovation to issues in the Med-Tech field and underpinning theories of Technology Valorisation, which supported the data collection. Thematic analysis using Nvivo software, to analyse the primary qualitative research, revealed core themes and deep insights into the Open Innovation mechanisms utilised by the companies interviewed, their challenges for forecasting and the difficulties in assessing the value (including the non-monetary value) which hamper the processes necessary for Technology Valorisation.

It has been identified that a framework is necessary for Med-Tech companies to carry out Open Innovation more systematically and to examine the process that companies in the Med-Tech industry can use to achieve full value through their innovation process, essentially a framework for Technology Valorisation. Innovation is not only vital for the success of companies but also determines a company's very existence. In an ever increasingly challenging and rapidly changing environment, adopting open collaboration or what has been popularised as Open Innovation is needed. It is a recognised concept, but there is still a lack of clear understanding of the mechanisms, in-bound and out-bound of the organisation, particularly for Technology Valorisation. This reflects in both managerial practice and the theoretical underpinning. It seems that to create value out of knowledge is needed, whether it concerns inventions or patents and in the context of Open Innovation more systematic practices to engage openly and capture this value are necessary for success.

5.1 Implications for Practice

Theories associated with Open Innovation are commonplace; however, they are merely reflecting what companies are doing on a conceptual level and they do not guide them through the processes. We find that companies are exhibiting principles of Open Innovation—taken as managing the outside-in, inside-out and coupled processes—by trial and error and accordingly when an opportunity arises (consummate with Teece [1986, p. 288]); this has parallels to the Schumpeterian model of Laursen and Salter (2006, p. 132). In this context, companies do not know how to capture value during the process but have developed opportunistic approaches, irrespective of these approaches being complete or appropriate. In addition, companies in the Med-Tech sector indicate that they operate under time pressure and there are too many avenues to consider for technology development. Hence, the most important and most surprising finding is that they are not allocating time and resources to explore external commercialisation and to create additional revenue streams.

Moreover, the valorisation of technology is strongly hampered by uncertainties in the positioning of products that incorporate new technologies. According to the findings of our study, these uncertainties appear as inaccuracies for predicting market size due to shifts in dominant designs, unforeseen moves by competitors and unexpected reactions by customers (features that were not considered relevant but unexpectedly play a large role in product diffusion). Gaining progressive insight during R&D processes, for example, by using stage-gate methodologies (e.g. akin Cooper, 1990), can mitigate but not compensate this uncertainty, although Phillips et al. (2006) state that this might not fit high-risk discontinuous innovation projects. However, the externalisation of risks is being used by companies in this research; by way of illustration, companies stimulate collaborators (suppliers, alliances) to develop alternative technologies, and they acquire companies with IP on emergent technologies or simply catch-up through re-allocation of resources. Part of the risks for technology development is compensated by collaborative relationships, whilst the assessment of non-monetary and monetary value is simply dependent on the capability of foresight.

Furthermore, this research has revealed that companies in the Med-Tech sector are engaging in Open Innovation practices to a varying level. Innovation is very difficult to measure, and the companies acknowledged that they are not very good at measuring their innovation success. Moreover, this research shows that Open Innovation could be useful to enable companies to overcome disruptive technologies in the field or to act fast and keep abreast of dominant designs. But this is only possible when the internal capabilities for innovation are of adequate level, when the management of the portfolio of technology and knowledge matches the market opportunities and when the people skills and culture of the organisation are open to this approach (Martins & Terblanch, 2003, p. 64). This might indicate that Open Innovation is not only portfolio management through collaborative relationships but also an organisational approach (Dodgson et al., 2006, p. 338).

5.2 Implications for Research

Consequently, as a first implication, this research revealed the importance of internal cooperation in a company and mentioned it as being part of a continuous learning cycle for the company with human resource aspects as being of particular importance to Open Innovation; this notion has parallels with the concept of absorptive capacity as also mentioned by Vanhaverbeke et al. (2007) but hardly links it to internal processes. Firms can create higher value by effectively managing these processes and human resources aspects. It is believed that the findings from the Med-Tech sector may be applicable to other high-tech converging technology areas; further research would be needed to establish this.

A second implication is that industry has not established practices for Open Innovation and academic research insufficiently addresses the appraisal of technological developments in this context. It has also been seen that there is an overemphasis on managing the value of IP rather than Technology Valorisation as a more encompassing concept. This is apparent when it is considered that not all companies seek to patent innovations as demonstrated by Arundel and Kable (1998), that patenting is industry dependent (ibid, pp. 138–139), that patents do not work in practice as they do in theory (Teece, 1986, p. 287), and that collaboration might induce patenting (Brouwer & Kleinknecht, 1999). This is amplified by the lack of inaccuracies for predicting the future of markets; the research on this has receded since the mid-1990s, but it still plays an important role in the valuation of technologies. The approach of Open Innovation cannot be implemented fully unless it comes along with more appropriate methods for evaluating and monitoring the market and technological developments; this would be an important cornerstone for Technology Valorisation and Open Innovation.

A final implication is that the definition of Open Innovation has expanded since Chesbrough popularised the term. For example, Gassmann (2006, pp. 224–225) adds globalisation and user innovation to the scope of Open Innovation although both these strands of research have been in existence long before this (e.g. Gerybadze & Reger, 1999; Rycroft & Kash, 2004). Open Innovation has only just begun to be associated with Social Enterprises, with the use of Open Social Innovation as a means of achieving social change being explored by Tuckerman et al. (2022) establishing how Social Enterprises manage Open Social Innovation could determine the impact they can have on tackling some of society's most challenging social problems. It becomes apparent that the scope of the term Open Innovation needs to be more clearly defined and how it differs from other innovation processes or well-established practices. Based on our research, we propose to restrict the term Open Innovation to the management of outside-in, inside-out and coupled processes as denoted by Gassman and Enkel (2004). This comes along with portfolio management, collaborative relationships and Technology Valorisation. In this respect, Technology Valorisation is defined as: *actions and decisions that companies make in the context of Open Innovation processes to lead them to the greatest value both monetary and non-monetary to achieve successful commercialisation.*

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Crowd Engineering—An Open Innovation Approach Adapted to Product Development

Michael Hertwig, Joachim Lentes, Adrian Barwasser, and Frauke Schuseil

Abstract Product development is a complex process that requires significant resources and expertise. Traditional product development methods can be slow, expensive, and may not always lead to successful outcomes. Crowd Engineering is a new approach to product development that leverages the power of crowdsourcing to accelerate innovation and reduce costs. This method involves breaking down complex tasks into smaller sub-tasks that can be completed by a large number of external innovators and developers, often through online platforms. By doing so, it allows for greater flexibility in development speed and iterations, as well as reducing the amount of work per step. The involvement of external innovators and developers in Crowd Engineering opens up new discussions that can lead to otherwise unachievable innovations. It combines methods of the stage gate model with agile development methods, making it suitable for adoption in various product development models depending on the product type and use case. However, there are potential challenges to using this approach, such as ensuring quality control and managing intellectual property rights. The following chapter will discuss the concept of Crowd Engineering and the implications of its implementation as an alternative product development process.

Keywords Crowd sourcing · Crowd engineering · Distributed product development · Open innovation · Product innovation

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1 Introduction

The diffusion of digitalization is happening in private and business context, resulting in changes in the way of doing business and commercial procedures (Matt et al., 2019). Based on Digital Transformation and Smart Manufacturing, enormous changes in the way to innovate, develop and produce products can be expected (Verhoef et al., 2021).

Working in distributed environments tends to become increasingly important. More and more people see the office at home as potential second workspace (Watts, 2021). In addition, digitalization allows processing office tasks, controlling and supervision of work progress from other places than usual workspaces at the employer's offices. This includes contributions to creative processes as well. Even more independent are Digital Nomads. These people determine their working environment and location of work themselves, instead of having them defined by their employers. Digital Nomads keep contact to their customers, clients and community almost exclusively via the internet (Nguyen et al., 2020).

At the same time, it is possible to detect an increasing interest among consumers and users to participate in product creation (Leipzig et al., 2017). The growth of open innovation formats, like Hackathons, Makeathons and Makerspaces with an innovation community, is a good indicator for this development (Aro et al., 2020). Additionally, the number of freely available product designs on sharing platforms is growing, accompanied by a trend of user-generated content (Cascini et al., 2020; van der Meer et al., 2021). Based on these trends, it can be assumed that technically minded people want to be more and more involved in the product development process of products they are interested in.

2 Challenges for Product Innovation in Small- and Medium-Sized Enterprises, Especially in Germany

Studies show for German small- and medium-sized enterprises' (SMEs) typical innovation barriers like funding difficulties, organizational and personnel problems, bureaucratic burdens and market risk (e.g., Zimmermann & Thomä, 2016). Thereby, funding difficulties may refer to the availability of internal or external financial capacities (Astor et al., 2013). Organizational and personnel problems may be a lack of appropriate experts and difficulties in managing innovation processes, among others. Concerning bureaucratic burdens, typical aspects are the existing normative framework and bureaucracy-related obstacles which influence the process of implementing this legal framework. Furthermore, the so-called digital transformation influences all areas of business. Companies need to rethink their proceedings and way of doing business. Especially, small- and medium-sized companies are challenged to cope with the resulting requirements (Yu & Schweisfurth, 2020).

Despite of the pandemic the last years, the trend to globalized value chains seems to be still ongoing (UNCTAD, 2021). Multi-national companies are expanding into new markets. They put high pressure on national governments to improve the business conditions like reducing trade barriers. The utilization of efficient communication technologies enables the collaboration among different countries even in real-time. The decrease of costs for transportation and the reduced barriers in logistic networks supported this trend as well (Forbes & Schaefer, 2017; Hallstedt, 2017).

The perceived increasing homogeneity of the markets allows the access to knowledge even in emerging countries. Connections via the internet support a mobility of knowledge and exchange between different stakeholders at various locations. Additionally, companies acquire required knowledge selectively which forces service providers to specialize and serve more customers (Djebbi et al., 2007; Szejka et al., 2017).

The development of Web 2.0 enabled the creation of new business models (Hsu et al., 2014; Rinner et al., 2008), supported by the technological progress. The matured information and communication technology laid a base for innovation in the business models (Hudson-Smith et al., 2009). Big internet companies like Facebook, Alphabet and Amazon turned the markets upside down by utilizing data as currency (Brunnermeier et al., 2019; Eggers et al., 2013; Westermeier, 2020).

All these are based on the speed of technological developments. The technological possibilities supported the companies to push these trends forward.

In the context of product development, digital tools have been established in recent decades. These tools cover a large area from requirement management all the way to Computer-Aided Design and are the basis for current methods of development (Singh et al., 2009). However, as the complexity of the products grows, the approach of component-oriented development reaches its limits. The reasons for the growing complexity are different customer requirements, each of which entails a variant or derivatives. Due to the increasing combination of mechanics, electrics, electronics, software and in the future business models and services, systems of different life cycle times are connected (Trippner & Theis, 2016). This results in decreasing life spans, because the introduction of new software does not fit with already existing hardware. These all speed up development times for new products and result in shorter product life cycles. With the increasing complexity and interdisciplinary, collaboration becomes more important. Only if developers of different domains understand needs, frameworks and requirements of the others, can friction during product development be reduced. Products need to be understood as systems that fulfill the customer requirements. Thus, the belief is, one can realize even complex products with a high degree of individualization, without the increasing complexity to lose the functionality (Kübler et al., 2018). To make this objective feasible, a consistency of all data objects is required to support a seamless interaction as a result. The consistency means in this consequence that all modeled objects with reference to the same "system-of-interest", even if modeled by different domains, do not contain contradictions in themselves (Masior et al., 2019). The data must be equally accessible by all participants in the product development process in order to ensure consistency and data continuity along the product life cycle.

Customers are interested in products matching as good as possible to their needs. In order to optimize products, companies face the challenge of setting up services and even individualize them (Wiesner et al., 2013). Sometimes, this requires the involvement of additional stakeholders. Therefore, the establishment of stable networks is needed. The creation of ecosystems is essential which is adjusted and adapted to the needs of the business opportunities and customer needs (Lüftenegger et al., 2013). The management of these ecosystems and framework conditions becomes more and more complex (Zheng et al., 2017).

3 Crowd Engineering

Crowd Engineering in our context is seen as a specialized application of Co-Creation methods. Like crowdsourcing, a group of individuals brings in their competencies, time and experiences and sometimes even their infrastructure to participate in the innovation and development process. Product design processes and product development are focused on "design" and development, which includes necessary activities for the creation of technical products (Koller, 1994). Crowd Engineering is opening the perspective in product development with methods, processes and approaches that enable an interdisciplinary group of individuals to be involved in the product development process. This involvement is not only peripherally, but rather gives the participating individuals an active role in the design and development process.

Already in 2015, Panchal discussed the idea of design development as a crowd-based process (Panchal, 2015). In his paper, he focused on the challenges, which community-based engineering processes would result in.

Key statements can be summarized in this regard as:

1. Expertise from different domains is required to successfully carry out complex engineering projects. Interdisciplinarity is a significant factor in the success of Crowd Engineering.
2. A breakdown of complex tasks is required. To create manageable tasks for the community members, a separation into smaller sub-tasks is required, reducing complexity to achieve reliable results. Subsequently, a combination of these partial results is needed to realize an overall result. This most effectively leverages the positive impact provided by distributed development.
3. The access to compatible and widely accepted development tools, resources and methods is important to create an integrative environment for all community members. This results in non-discriminatory participation of all stakeholders. In essence, the development tools and data formats must be compatible and interchangeable, to create an overall result from the partial results.
4. There must be clear approaches regarding the distribution of rights. This is the only way to create transparent ownership, exploitation and usage rights for all

involved stakeholders. It is also important to clarify the intellectual property and how the remuneration of these is structured, especially in the case of commercial exploitation.

To ensure the collaboration of larger distributed groups, most development processes must take place in the cloud-based IT infrastructure. Eigner, Eiden and Apostolov propose a platform that provides a structural framework for collaboration. Additionally, the possibility for communication between the participants allows virtual product development and provides a basis for Crowd Engineering (Eigner et al., 2017).

A definition of Crowd Engineering was developed by the team of the RoboPORT project (Hertwig et al., 2020):

> Crowd Engineering has the goal of improving technical developments through the participation of a large number of interdisciplinary actors. Furthermore, the participants can work on already existing projects to further develop results in this field. Collaboration takes place independent of location and based on division of labor using information and communication systems with a development environment adapted for this purpose and suitable tools. The network of actors provides services reactively based on external impulses or proactively through the contribution of identified gaps in requirements and opportunities on the performance object.

Regarding the innovation funnel (see Fig. 1), Crowd Engineering is an application of open innovation methods and techniques to a later phase of product realization (van de Vrande et al., 2009). The opening of the innovation space will be enlarged to the development phase.

4 Requirements for Implementation of Crowd Engineering

For companies, Crowd Engineering is a novel approach. This means that many companies and community members lack experience regarding the suitability of their project for development in the community. For community members, this hurdle may not be very critical. Through a simple and barrier-free access to other community members, they can rely on the experience and knowledge of those around them, sometimes also referred to as "Wisdom of the Crowd" which was first postulated by Surowiecki (Surowiecki, 2005).

Core aspect of Crowd Engineering is the integration of a community into product development. Therefore, some organizational and technical key prerequisites have to be considered. This is required to facilitate or enable collaboration within a community.

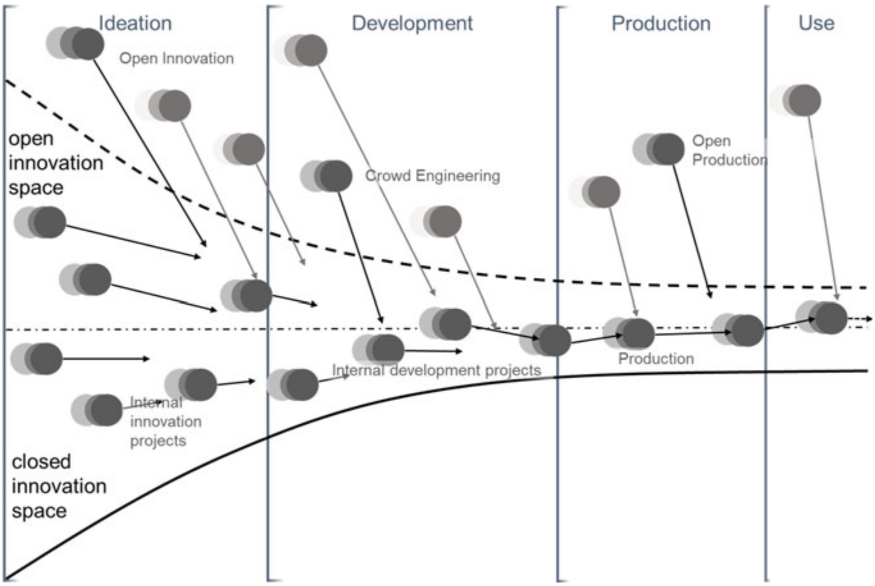

Fig. 1 Innovation funnel for the phases from ideation to use (top—open approach, down—closed approach) (Hertwig et al., 2020)

4.1 Organizational Prerequisites

4.1.1 Addressing a Suitable Target Group

The most important requirement concerning the interaction with a community is a suitable target group. Addressing the wrong target group may result in bad collaboration. The collaboration could be too slow or even unsuccessful regarding the output quality.

To motivate a sufficient number of supporters for a Crowd Engineering task, a large enough portion of the community must be able to contribute to the task. This requires a sufficient overview of the subject area and fitting qualifications. Of course, not all crowd workers are experts in the subject area of any given project, but on average the community must have access to a sufficiently applicable expertise. Otherwise, the result achieved can never meet the requirements (Afuah & Tucci, 2012).

- Considerations of the knowledge level of the community are a success factor when planning to integrate a community to development tasks.

4.1.2 Willingness to Collaborate

For a successful community project, it is essential that all parties involved have sufficient motivation to contribute. All participants need to show a fundamental willingness to collaborate with all involved stakeholders, which also includes the sharing of knowledge and experience. Incentive measures or incentive structures may prove helpful in motivating the community to cooperate in advance (Simperl, 2015). Extrinsic motivation can be achieved, for example, through monetary incentives, such as prize money or compensation. However, intrinsic motivation should be strengthened where possible. Prioritizing the intrinsic motivation should be a major aim of all community project managers. This is expected to push the community participation, as it plays a far greater role, when compared to pure extrinsic motivation (Zheng et al., 2011). In order to develop intrinsic motivation, the meaningfulness of the development task is important for many community members. If a task is meaningful from the employee's or participants point of view, the person identifies with it and takes responsibility. At the same time, it is important to know what contribution the individual task makes in the overall context to increase the sense of purpose. This increases the value of the individual, which has a positive influence on the overall result (Hackman & Oldham, 1975).

The given degree of freedom in the performance of the task has a great influence on the autonomy understanding of each contributor. The greater the autonomy in processing the development tasks, the more the interests and ideas of the community members can be realized in the result. This increases the willingness to provide labor (Nerdinger et al., 2011). In addition, greater freedom allows the full exploitation of the conceivable solution space, which holds additional potential not previously considered. This must be balanced with the previously mentioned need to integrate all partial solutions into an overall result. Thus, clear establishment and communication of requirements are essential.

- When community members understand the significance of tasks in the overall context, there is a higher likelihood of contribution by members.
- A high degree of freedom supports the intensity of collaboration, enlarges the solution space and possibly optimizes the generated results.

4.1.3 Community Management

In most cases, it does not make sense to "let go" of a community without any guidance on tasks and projects. Motivation quickly flattens out, and results could drift in the wrong direction. This is not the only reason why the introduction of community management seems to make sense. Motivating the community via small challenges and new interesting tasks can therefore promote crowd participation. Transparent communication further increases trust and thus acceptance among community members. If a community manager is designated, in addition to maintaining the platform, he or she can be used as a moderator during discussions and furthermore can bring in other experts for discussions (Rohmann & Schumann, 2018).

Discussing the potential ecosystem, an analysis of the stakeholders was performed during the project RoboPORT. The application of personas allowed an extensive human-factors perspective. Based on these results, it was possible to identify different utilization scenarios. These scenarios were played out in real Crowd Engineering projects with the participation of several hundred community members. The following were some of the key learnings regarding community development and management:

- Physical event formats are particularly necessary in the start-up phase of the community. They create a sense of community and allow users to establish the necessary relationships through exchange. After all, this initial community represents the nucleus for the growing community. This first group of users develops the initial identification characteristics and values of the community.
- In order to create a longer-term active and self-fertilizing community, sufficient "noise" must be generated. This noise refers to activities on the platform that are also reflected in entries in the newsfeed and communication. In the start-up phase, this must be done by the community management. However, in order to achieve this in the long term without major efforts by community management, a critical mass of community members is required. This ensures that there is sufficient activity on the platform, even if the frequency of activity varies.
- Every community member has a life cycle. This life cycle varies in duration depending on the background, current life situation, interests and role of the community member. To avoid stagnation or regression after the expansion phase, the community must be continuously rejuvenated. This can be achieved by creating a regular range of opportunities for participation which also has a positive impact on the community health. As in any social space, ethical hygiene plays a significant role in the community. Disruptive elements must be reduced, and positive communication has strengthened. To this end, community managers must be appointed to ensure compliance with the rules in the digital space and, if necessary, to sanction any deliberate transgressions.
- The greater the discrepancies in design, operating concept and tools used, the more difficult it is to create the impression of a consistent workspace. Different work environments can be designed differently, but it must be possible to switch between the work areas in a way that is easy to understand. Changes in user interaction may influence the community building negatively. Therefore, it requires a single sign-on, in which all work areas are made accessible without barriers with a single login. The menu arrangement and design should also be similar in order to achieve a consistent operating concept.

These core results have been qualified by a survey performed with members of open-source communities. Additional aspects have been added. Therefore, co-determination of all involved participants is important based on the perspective of the questioned developers and has an impact on the path to results. For a successful community project, an equal access to data and information is as important as clarified competencies and responsibilities.

- Building and maintaining the community are a core component of success.

4.1.4 Suitability of Tasks

The community must have the opportunity to solve the problem in the first place. The tasks need to be suitable to the community, and this includes decomposability into smaller sub-tasks and shareability of these tasks (Benkler, 2006). In addition, the participants must have the appropriate qualifications to solve the tasks and the tasks themselves must be described in detail (Blohm et al., 2014).

Concerning the tasks to be performed by the community members and the related activities, a differentiation can be done based on the criteria, if the activity is performed alone or with others as a group activity. Single activities include typical engineering tasks, like described in the ontology of generic engineering design activities by Sim and Duffy (2003). The respective set of activities is divided in design definition activities, design evaluation activities and design management activities. Thereby, design definition is done by means of activities like abstracting, associating, composing and decomposing, defining itself, generating and so on. Design evaluation is done by modeling, analyzing, evaluating itself, decision-making and other activities like testing and experimenting. Besides, these design content-related activities and design management activities like constraining, exploring, information gathering, planning and prioritizing are needed. When regarding the set of engineering activities defined by Sim and Duffy, it is obvious that at least a part of them may not only be done alone but together with others as a group task or activity. A classification for suchlike activities, or group tasks, was introduced by McGrath (1984) with four quadrants of tasks, i.e., to generate, to choose, to negotiate and to execute. Thereby, *'to generate'* refers to generate ideas by creativity tasks or plans by planning tasks, to choose with regard to solving problems with correct answers by means of intellective tasks and with regard to deciding issues with no right answer by decision-making, to negotiate to resolve conflicts of viewpoint (cognitive conflict tasks) or conflicts of interest (mixed motive tasks), and to execute performance tasks or to resolve conflicts of power. Consequently, technically oriented activities and collaboration-oriented tasks have to be considered and potentially supported in Crowd Engineering.

Products with a modular product architecture can be developed independently (Afuah & Tucci, 2012). This decoupling allows sub-tasks to be distributed among different actors. Since the individual sub-results interact through clear interfaces, development speed and iterations can be freely defined for each module, which increases flexibility (Benkler, 2006).

The granularity per sub-task may reduce the amount of work per step. This enables crowd workers to share successful results more quickly. Many crowd workers work on so-called "pet projects" (Your Dictionary, 2021) during work breaks or free time, which limits the total available working time. If the time required for a positive result is low, the required incentive is significantly lower (Benkler, 2006) and more people are willing to participate (Tran et al., 2012).

The greater the dependence of a task on various factors, the greater the complexity of its processing. Tasks with high complexity have limited communicability. This can make it difficult for community members to understand. Thus, processing becomes coordination-intensive and error-prone (Afuah & Tucci, 2012). Extreme examples are "immobile problems" that can only be grasped by on-site analysis.

- The definition of a suitable granularity and modularity of the development task is essential to ensure a successful output.
- A high complexity in development tasks is limiting the application of community-based processes for these development tasks.

4.1.5 Compatibility

Crowd Engineering is a possible extension of company-internal processes to innovate. The alignment of the culture of an open community and the company's culture is important to ensure the success of Crowd Engineering. The corporate strategy, mainly the "culture" and the "branding", must be in line with the idea of openness (Gassmann et al., 2013). For a high compatibility, a flat organizational structure is also very advantageous (Townsend et al., 1998). Many management levels, a strong hierarchy thinking and a large distance in power are hurdles which need to be reduced to implement co-creation approaches (Teece, 2010). Therefore, often corporate processes need to be reorganized and methods of agile development are implemented.

4.1.6 Legal Certainty

When collaborating with external actors, legal certainty is of great importance. Above all, ownership and usage rights should be secured in advance, and the same applies to non-disclosure agreements (Herstatt & Nedon, 2014). Therefore, there is the need for safeguarding by means like contracts or, in the case of an online platform, the provision of detailed and easily understood terms and conditions.

- A defined legal framework supports clarity with all stakeholders and supports a fair and equal collaboration.

For Crowd Engineering projects and related tasks, a broad spectrum of legal approaches is possible, ranging from typical contracts as used for engineering service providers in "closed-shop-like projects" to open-source licenses. The appropriateness of the legal approaches depends on the respective case so that a Crowd Engineering platform should offer a set of pre-defined legal approaches, which may be customized for a specific project or task.

4.1.7 Quality Assurance

A community may consist of stakeholders with various backgrounds. Based on that, the quality of contribution may vary. However, for successful Crowd Engineering projects, a sufficiently high quality of the projects' results is important. Therefore, it makes sense to introduce a quality assurance. This can be either done by the project manager, company representatives, or by other community members. In the last case, it would be necessary to evaluate the contributions of community members to identify reliable experts with the ability to perform these checks. By earning certificates and ratings, the choice of these members could be supported. In any case, a transparent communication about the competencies and skills required for a project or task is paramount. This gives community members the opportunity to compare the required qualifications with their own in advance, which may lead to higher satisfaction for both the participants and the project owner.

- Contributions within Crowd Engineering projects must be subjected to systematic quality assurance.

4.2 Technical Prerequisites

4.2.1 Shared Platform

A common platform for collaboration, ideally made available online, facilitates cooperation and exchange among individual community members. This supports them with the opportunity to work on tasks and projects simultaneously. From the community point of view, a common platform is not crucial but increases the performance significantly. But considering the needed digital continuity of product development processes to avoid manual transfer of data and information, it seems to be reasonable to use an online platform to support the collaboration of geographically distributed individuals, which offers typical functions as offered by PDM/PLM-systems (Product Data Management or Product Lifecycle Management Systems, respectively). This not only relates to collaboration ("group") tasks as mentioned above, but to engineering software systems, which may be offered in cloud-like approaches to the community members, thereby enabling them to consistently use authoring systems like Computer-Aided Design (CAD) and the according master data and structures.

4.2.2 Providing a Variety of Functions

For community-based processes, it is valuable to have an independent and creative community. To attract these types of people, providing the right working environment is crucial. At the most basic level, all users must have access to related needed functions (Broekhuizen et al., 2021). To enable collaboration by building on existing deliverables, each contributor with a related role must also have access to the same needed functionalities. This makes it possible to use intermediate results to develop them further or to use them for new approaches. For the greatest flexibility, it is important that community members should be able to generate content independently, optimally by creating and editing projects themselves (Rohmann & Schumann, 2018).

- Offering suitable and equal functionalities to participants of a Crowd Engineering project allows successful content generation.

4.2.3 Lowering Entry Barriers

A large set of users can be supported by low entry barriers for joining the community and the related platform. Therefore, the platform design needs to be simple and easy to use, especially for new members. To lower the barriers of entry, familiar user interfaces provide a suitable base by increasing the ease of use and flattening the learning curve. A simple layout and comprehensible operation make sense from the perspective of users (Rohmann & Schumann, 2018).

4.3 Additional Aspects Relevant for Success of Crowd Engineering

Next to the organizational and technical prerequisites, there are further aspects which may influence the performance of Crowd Engineering. These aspects influence the performance positively or negatively.

4.3.1 Implicit Knowledge—Framework and Interests

Implicit knowledge, which is not documented and available to others, may give those who have it a competitive advantage. Ideally all contributing parties in a Crowd Engineering process would share access to this knowledge equally, which would be of great benefit to the project (Balka et al., 2014). There are however many reasons for participants not to share their implicit knowledge. The responsible party may find it difficult to present the relevant information and contexts in a comprehensive way (Felin & Zenger, 2014). Some might also withhold information on purpose to support individual interests. This could also be influenced by framework conditions set by a third party (Afuah & Tucci, 2012). This limitation of openness reduces the satisfaction of contributing parties and inhibits the proceedings of product development by the crowd. It is therefore important to nurture an environment, which encourages openness in that regard (Broekhuizen et al., 2021).

4.3.2 Confidentiality

Confidentiality has a similar aspect like implicit knowledge. The limitation of sharing information and thoughts due to non-disclosure agreements reduces the success of Crowd Engineering. The limited knowledge and information reduce the overview and insights of the participants on the tasks. This may result in solutions outside of the targeted solution space (Dawson & Bynghall, 2012). On the other hand, it also limits the amount of involved community members. This diminishes the potential outcome and results. But of course, for specific engineering projects and activities, confidentiality may be crucial.

Confidentiality is especially relevant in projects which are defined as "closed". This means that the project owner limits the participation in the process as well as the flow of related information as needed. Either the project owner invites potential contributors or community members have to send an application. In that case, access and contributions are only allowed after a check and approval. A result of that could be that relevant experts are overseen or cannot participate because they do not match the criteria of choice. Given the dynamics and general attitude of the observed community, the application of confidential projects is likely going to be used only for the minority of Crowd Engineering projects, as these tend to conflict with the values of open access. It can however not be ruled out that a more commercially oriented subsection of the community with a focus on these kinds of projects will emerge.

4.3.3 Limitation by Laws and Regulation

Also in Crowd Engineering, normative regulations must be considered concerning activities, methods, processes and generated results. In certain industries, there are specific rules and regulation defined by the government or legal institutions. Sometimes, these regulations have an impact on the business field and application field. Very well known for such regulations are the aviation industry as well as health science. In this case, the main reason is that nonconformity may lead to illness or death. This means that restrictions resulting from directives, laws, or sovereign orders have a serious impact on the development of products. It is not always possible to achieve conformity between requirement from the directive/law and the type of community-based development, which limits the use of Crowd Engineering (Harer & Baumgartner, 2018).

5 Impact of Crowd Engineering on the Product Development Process

In project development, different approaches for process definition are established. Product development models sub-divide the involved processes into an idealized form of individual work steps with a hierarchy of phases and subordinate activities (Jänsch & Birkhofer, 2006; Moehringer & Gausemeier, 2003). Various process models exist for product development that can be applied depending on the product type and use case (Gürtler & Lindemann, 2016; Schlink, 2018). Coming from the most widely established ones, it was possible to identify a suitable approach for

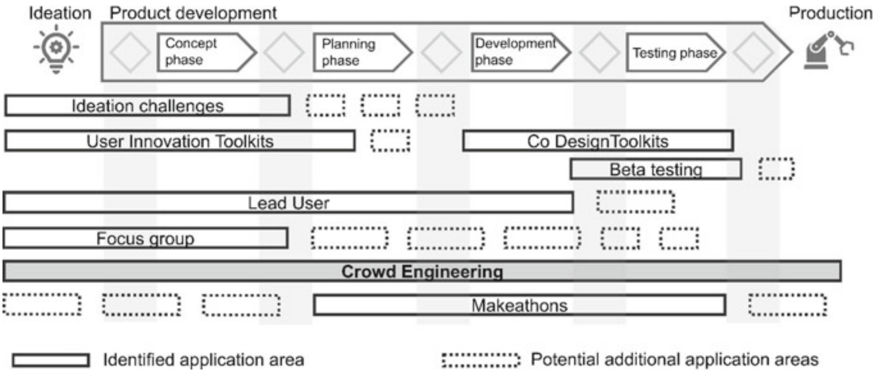

Fig. 2 Phases of a community-based product development process, assignment of innovation methods with focus product development (Cooper, 2002)

the adoption in Crowd Engineering. This approach combines methods of the stage-gate model with agile development methods. While the stage-gate model forms the framework with self-contained phases, agile development methods are used within the phases. It creates a stable framework. Within the phases, the agile development supports the flexibility and dynamic nature of a community-based process. In the case, the outcome of a phase does not match the needs or the defined requirements that it can be restarted or extended to ensure a sufficiently satisfying result.

As shown in Fig. 2 the analysis was also performed on innovation methods by incorporating a community. However, the already existing and applied approaches are only successfully applicable to individual steps or sections of the entire product development process. Crowd Engineering is bringing together different approaches or open ways to integrate results out of these methods.

In the following, the identified standard phases of the product development process in Crowd Engineering projects are discussed in detail.

5.1 Crowd Engineering Phase 1: Concept Phase

The objective of the concept phase is to develop the joint product concept. The basis could be market research. This lays the base for a target market or a target group for which customer requirements can be identified. The most plausible concept is selected based on user requirements, concept development, comparisons and evaluation of the concepts. Traditionally, concept development is initiated and led by the company. However, prosumers, being very active consumers with the will to participate in the development process, could also be utilized to push a development via the community. When considering the involvement of such external participants, it is necessary to choose the right individuals. In the following, these are referred to as the “main users”. This designation does not limit the community to the end users of the products but is meant to reference the users (of an online platform) in an online community. Main users have strong problem-solving skills, are highly engaged in the community, and know the products well. Furthermore, they have good ideas—similar to the lead user concept (Hippel, 1986). Of course, requirements for and ideas of the rest of the "normal" users are also considered, as they might behave differently from the main users both in their use of the product and in their purchasing decisions. In addition, already submitted concepts are reviewed and evaluated, and the decision for a final concept follows.

5.2 Crowd Engineering Phase 2: Planning Phase

The goal of the planning phase is to work out a development plan for the product. A discussion about product concepts takes place, and the community and especially the main users are involved in decision-making processes. Also, developed solutions are considered by key users. If users find it difficult to put requirements into words, or if they sometimes differ greatly, it makes sense to provide them with a development environment that helps them to express themselves better.

5.3 Crowd Engineering Phase 3: Development Phase

The development phase can be considered as the main phase. This is where the intended product gets its shape and functions up until the development of a prototype. Based on the requirements which have been set in phases 1 and 2, the community works on the tasks to concretize the product. As mentioned before, it is required to sub-divide the task of product development in small simple tasks. This approach was already discussed in the 1990s as concurrent engineering (see Fig. 3). These smaller sub-tasks need to be solved independently with limited knowledge and experience. After solving each task or work package, these results are joined together for the overall result. Clearly defined interfaces are required to make a seamless fusion of all partial results possible.

The development phase can be subdivided in several development steps, depending on the complexity of the system to be developed. A key challenge is ensuring that all parties involved in the development process have access to all relevant information concerning the development, while at the same time encouraging the developers to document their proceedings and thoughts to share this information with the community, both during the project or afterward. This is required to later build on the generated knowledge. The digital nature of Crowd Engineering promotes this type of documentation; however, ensuring a uniform structure and format of all relevant results can be challenging given the diverse backgrounds of the participants.

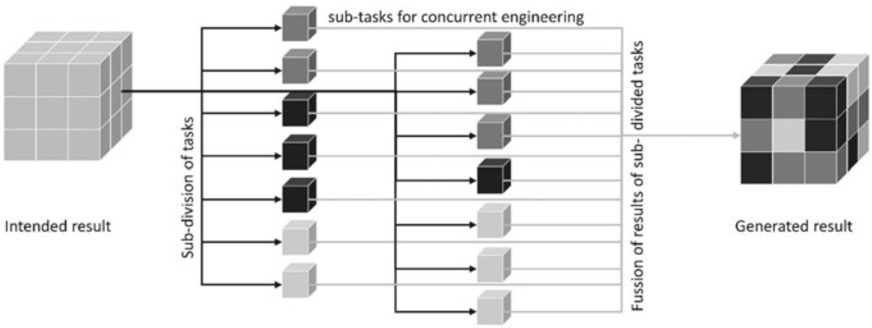

Fig. 3 Methodic approach for concurrent engineering (Welo et al., 2019)

5.3.1 Decision Management

Classically, technical concepts, developments and innovations are pushed and further advanced by a company. The company's objective is to reposition itself better on the market and earn money with the new product or innovation. Opening up this area to integrate a community allows the participation of external parties. Besides the many benefits, it also poses dangers, e.g., the loss of control over the content provided by community members (Di Gangi & Wasko, 2009). Another issue is potential conflict between the project owner and the community. For these reasons alone, careful choices should be made about which ideas, concepts and developments are adopted and which are not.

In a study (Di Gangi & Wasko, 2009) on the approval of ideas on the IdeaStorm platform, researchers concluded that ideas with the greatest potential for relative advantage were not necessarily adopted, as previously suspected. Further, contrary to expectations, adopted ideas were not statistically different from unadopted but popular ideas (in terms of the ability to capitalize on assets already owned). The final hypothesis, that the most popular ideas would be adopted, was also not confirmed. These results suggest that the decision to adopt an idea is also based on other factors that are comparably important, such as complexity, observability and trialability.

In the Crowd Engineering approach, the crowd plays a large and important role in such decisions, namely which ideas and concepts to pursue. In this context, the tasks or function of the community differs depending on which phase of decision-making it is in (Chiu et al., 2014).

Chiu's team used the decision-making process model developed by Herbert Simon to analyze the role of the crowd in decision-making processes (Chiu et al., 2014). This approach can be well applied to Crowd Engineering. Simon's model includes three main phases before implementation (Simon, 1959):

- Intelligence Phase

The intelligence phase is the initial step. It is often referred to as problem finding or problem recognition. It is used to analyze the environment for conditions or problems requiring a decision. This includes aspects of the project that are not going according to plan. However, it could also refer to opportunities for further steps in the proceedings. It is crucial to create a complete understanding of the problem. This includes to analyze the current situation in relation to the aspired state. Next, it is necessary to understand the differences between those two states, as well as to identify potential risks and dependencies. This could also give an insight into the importance of the problem.

- Design Phase

The following design phase has the objective to develop sufficient solution outlines for the identified problem. The number of potential solutions may only be limited by time and mental power of the involved parties. Each potential alternative needs to be evaluated. The evaluation can be performed by quantitative examination or qualitative approaches. The objective of this is an identification of positive and negative aspects of each solution.

This phase involves a lot of creativity and innovation to design sufficient solutions. It incorporates idea creation as well as discussing these generated ideas to identify advantages and disadvantages of each idea or derivate.

- Choice Phase

Based on the results of the design phase, the choice phase encompasses the comparison of all alternative solutions. The objective at the end of this phase is the decision.

For identification of the best solution, there are different approaches applicable. There are either qualitative or quantitative tools to support the comparison process. These techniques support the prioritization of different scenarios which are connected to the alternatives. Often uncertainties increase the complexity of comparison because not all aspects can be clarified. However, the design of this phase has a huge impact on the outcome of the decision.

The decision model of Simons was extended by two further phases (Marume et al., 2016). The first would be the implementation phase. The decision will be set into practice and all connected stakeholders are informed. The monitoring phase is the last phase where the impact of the chosen solution is regularly checked to improve conditions or adapt the situation accordingly.

Taking this decision process as a base, the members of the community can contribute to the three main phases of the model of Simon. The contribution could be different in each phase.

The crowd could be useful in the search and identification of problems. On the one hand, the members find concrete challenges to be solved. In this case, after the identification, the community members discuss the problem and its causes. This supports the definition and detailing of the problem or challenge. On the other hand, the multi-disciplinary perspective of the participants can be used to identify most of dependencies and conditions connected to the problem. The community accumulates the individual’s knowledge and experience. This enhances the understanding of the problem. Additionally, because of the diverse nature of the crowd, the members could make predictions or identify limitations from different perspectives. Based on this, potential bias could be reduced or minimized.

The application of methods of open innovation to engineering tasks is a sufficient approach to utilize the community for the design phase. The co-creation of ideas based on the defined problem or challenge and corresponding conditions is full of creativity. Creating contributions is not left to a single person. Instead, groups of participants are creating contributions together. Through the discussions and adaptions of preliminary results of the creation process, different aspects of experience, expert knowledge and validated solutions can be contributed by the community. The number of relevant alternatives, as well as the speed at which they are generated can be higher than in conventional developments. The solution space may be wider because of submission from domain-external members. All these may contain benefits for the product development process.

The participation in the choice phase is characterized by voting, evaluating and identifying of preferences. The method for identifying preferences has great influence on the overall outcome. A simple voting method is focused on individual preferences, which show a deviation of the community members. The voting based on different criteria is more complex, but also more structured (Fig. 4). This may lead to better technical performance or better market positioning. However, the involvement of prosumers is strengthening the feedback because prosumers combine the perspectives of developers and customers.

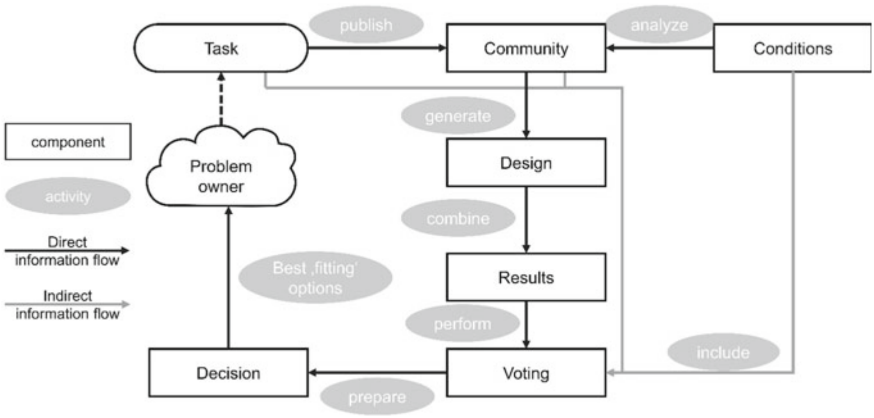

Fig. 4 Decision process for community-based processes, adapted from (Chiu et al., 2014)

5.4 *Crowd Engineering Phase 4: Testing Phase*

The goal of the testing phase is to conduct prototype testing and evaluate the results in order to gain valuable data on the functionality and performance of a product, often also under real-life circumstances. The α-test refers to an early prototype test, and a β-test often involves the customer(s). Key users can be involved in the early stages to increase efficiency and to test solutions developed by the community through key users. Once all tests are passed, new products developed with the help of the community can be launched.

6 Use Case—Roboy

6.1 *Description of the Use Case*

One of the robots most closely resembling the human body is that of the "ROBOY" research project. "A robot as good as the human body". What started in 2012 with the idea of building a robot boy as a messenger for embodied robotics was adopted by Rafael Hostettler and has now become a unique visionary initiative. Taking the idea of embodied robotics further and looking at the human body through the eye of a roboticist, one quickly realizes that it is a marvel of engineering. It is fast, agile, dexterous, quiet and self-repairing—simply an ideal robot. On the way to this ideal, the vision was born to build a robot that is as good as the human body. To achieve this goal, Roboy became a biologically inspired platform for robot development that unites students, researchers, companies and artists from a wide range of disciplines. There, students bring their theoretical knowledge to interdisciplinary development teams and learn to apply it, companies see their products come to life in a future market and artists reflect the moral implications of the changes brought about by this technology.

Roboy Junior was built by Prof. Dr. Rolf Pfeifer's team at the University of Zurich as the final culmination (Wick, 2013) of his research on embodied robots: a 3D-printed humanoid robot that mimics the locomotor system of the human body. Driven by Swiss entrepreneur Pascal Kaufmann and led by Adrian Burri, now a professor at ZHAW, the engineering was a collaboration of three engineering firms: Quo AG designed the body, Zurich Engineering was responsible for the flexible spine and Sedax AG was working on the iconic head. Roboy Junior, powered by Maxon motors and equipped with feel by Baumer sensors, rightly attracted international attention and fame when it was first presented at "Robots on Tour" in March 2013 (Landwehr, 2013). At this point in time, the current "driver" of the Roboy initiative, Rafael Hostettler stepped into the initiative, and took Roboy over after "Robots on Tour". At the end of 2013, he moved to the Technical University of Munich to the Robotics & Embedded Systems Lab of Prof. Dr. Alois Knoll, where the metamorphosis from a technology demonstrator to a visionary initiative started (Hostettler, 2020).

6.2 Application of Crowd Engineering in the Use Case Roboy

Crowd Engineering seems to be a great fit to the needs of General Interfaces, the company now responsible for Roboy (Fig. 5). For this, there are several reasons. The project Roboy serves as an illustration of a community-based development in open-source hardware. Since the development is freely accessible, anyone can contribute to the development or even create or use a related company. So, the legal framework including disclosure issues is quite simple, as open-source licenses may be used. Furthermore, General Interfaces is a small, very innovative company, which already leverages digital means to a high degree.

Roboy as an open-source project is an appropriate use case for the platform. The development of Roboy 3.0 was done by using the Crowd Engineering platform as backbone for the project and documented all proceedings on the platform. In the use case, Roboy developers, students and engineers, who are already involved in the development, were brought closer together. In addition, the possibility was offered that external interested parties can inform themselves about the project and participate. This opened the path to distributed innovation and development process performed via an online platform. The use of the online Crowd Engineering platform supported the application of process flows used by co-creation communities to develop open-source hardware components and systems. The Crowd Engineering platform advanced these process flows by adding required features to support collaborative development, evaluation of developed solution and discussions about problems

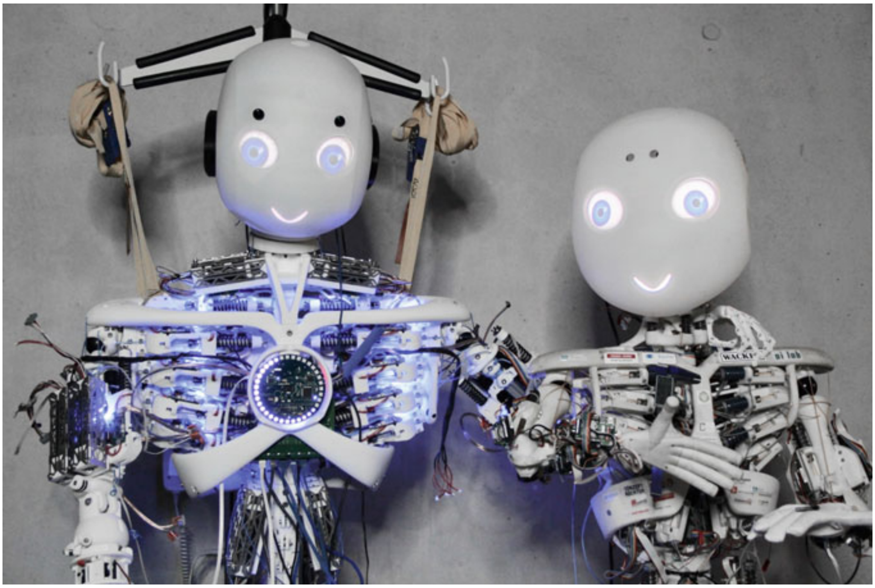

Fig. 5 Roboy Junior and Roboy 2.0 (General Interfaces, 2021)

and challenges. The active interaction of the developers of the Crowd Engineering platform and the Roboy project team was essential for this. The platform improved the division of labor, planning and communication via the platform. For the moderator, it was possible to control and manage the entire development workflow by using digital tools and bringing together assignment and overview of work packages. This mapping was essential meeting the requirements of industrial users and developers. Roboy supplied commercial and open-source functional assemblies such as hardware kits and robotic subcomponents, which contributed significantly to the success of the Crowd Engineering platform. Completed projects expand the knowledge and experience database, so that the documented experiences and solution approaches are available as an "idea pool" for the developers of later projects.

6.3 Evaluation of Applying Crowd Engineering to the Use Case

According to Yin, the validation of the outlined theory can be done by means of the case study methodology (Yin, 1992). The approach aims to test the previously developed theory in a practice-based environment (Avison et al., 1999). The Roboy use case also served to examine the usability of Crowd Engineering in the RobPORT project using a concrete example.

Since Roboy is an open-source project, the legal framework is clearly defined. The community contributes through its contribution to the development of further functions and details, which are also made available to the community as an open-source solution. By using the Crowd Engineering approach, it was possible to virtualize the development. Work that previously took place at institutes of the Technical University of Munich or on the premises of General Interfaces could thus also be carried out in a distributed manner. This made it possible to address participants beyond the boundaries of the university and to inspire them to participate. Even though the focus was not on gaining additional personnel resources, it was possible to gain many different competences for the project, which expanded the diversity in the project environment. This co-production of proposals also led to more solution proposals and more diverse discussions at Roboy. The theoretical basis for achieving better products or functional groups was confirmed by Ostrom in terms of complementary contributions (Ostrom, 1996). Another added value was the multiplication of usable hardware solutions in the open-source community (Mies et al., 2019). Even if these were not implemented in the Roboy project due to framework conditions or the community-based selection process, further use was possible in other projects (Schmidt, 2019).

However, during use, it became apparent that the community built up through physical events showed increased identification with the project, as evidenced by increased exchange activity and a greater number of contributions to proposed solutions. Since a large number of contributors made their labor and creativity available to the project on a voluntary basis, it was not possible to check the corresponding efficiency of the effort. This is because a considerable part of the community identified with the project's claim to develop innovative humanoid robotics solutions.

A positive factor in the organization of the complex and dynamic project was the platform as a digital backbone on which everything could be brought together. Predefined project and process templates reduced organizational issues. The platform also resolved time invariances, as requests or amounts could be processed by all members according to their availability. In this way, organizational management effort was generally reduced, even if quantification was not yet achieved. In terms of market risks, early feedback from potential customers, gathered through the open innovation aspects of Crowd Engineering, helped assess the product's potential for success, with the open approach helping to raise awareness of Roboy as a future product.

7 Summary and Outlook

As presented in this chapter, Crowd Engineering offers a possible solution to challenges in creating product innovations. An overview of the design and interactions of community-based product development is presented. In contrast to the open innovation approach, Crowd Engineering also takes into account framework conditions such as technical requirements, manufacturing feasibility and, if applicable, legal regulations.

Since Crowd Engineering is primarily driven by the creativity of the community, the boundaries to in-house product development must be clearly drawn. Crowd Engineering can be used to find innovative approaches to issues in the product development process. This is because the involvement of external innovators and developers leaves established paths and opens up new discussions that often lead to innovation. The global pressure to innovate has a particular impact on European small and medium-sized enterprises, which must bring attractive solutions to the market despite regulations, increasing competition in terms of personnel and resources of big companies. With Crowd Engineering, small and medium-sized enterprises in particular can address aspects relating to finance, personnel, organization, bureaucracy and market risk in an adapted manner. This is because Crowd Engineering addresses the need to innovate faster, be more flexible in distributed development and bring in external and diverse talent and perspectives that are currently lacking in the development department without the risk of hiring new staff. When needed, a number of developers many times the existing team can be mobilized to develop and validate a variety of solutions in a matter of days. By being able to collect feedback on the solutions developed, risks to implementation, applicability and attractiveness can be reduced.

Limiting aspects are the required openness of the companies. Only if sufficient information on the intended product or solution is made available to the community, can viable concepts emerge. From research, the definition of the demarcation between internal, IP-relevant knowledge and published shares has proven to be particularly challenging. An intensive exchange with the company representatives is needed in order to cut out partial aspects for community-driven development or to define them in a suitable form. A standardization of this delimitation procedure fails due to the diversity of competition-relevant characteristics of companies. In many cases, the core contents that make the company unique are insufficiently known to the companies and must first be worked out. Subsequent research can take up this aspect and examine it systematically. A clustering of the companies and an associated procedure model would be helpful to identify the Crowd Engineering relevant content. In this context, the investigation of suitable interactions between the explicit project organization (within the companies) as well as the implicit project organization (supplemented by the community) can yield clear indications to detail the exchange of information and rules for integration and communication for companies in order to optimize the management effort on the part of the company for the integration of community-based processes.

The design of IP-legal issues is also unclear. Up to now, only the maximum options have been clearly defined: The company receives all IP rights, or all community members have an equal share in the IP. This gives rise to various fields of action. One task for research could be how to measure the contribution of each community member to IP-relevant content. This question includes various sub-aspects, such as share of value contribution, relevance of contributed information, share of rejected concepts and invested time. There was a lack of criteria to carry out this assessment and to present it transparently and comprehensibly for all parties involved. For the legislator, the task is to also legally secure new types of participation in order to establish general, transferable rules for cooperation in community-based processes. This is because, in addition to participation in the proceeds, the liability of the community members plays a role that should not be neglected, especially in highly regulated industries. There is a lack of regulations for this, which makes it difficult and unattractive to use and also makes it difficult to recruit a suitable community.

The future of Crowd Engineering will depend on mainly two factors: Will companies accept Crowd Engineering as a viable addition to current development processes? And can enough people be motivated for a longer period to participate in Crowd Engineering communities? For companies, legal concerns, a conservative mindset regarding the disclosure of information, as well as uncertainty whether the invested time and effort will pay off, present the greatest challenges. Meanwhile, the results of the RoboPORT project as presented above show that there are already an ample number of potential participants for Crowd Engineering projects, as long as a suitable environment for development, sufficient incentives as well as interesting challenges can be provided.

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Exploring Conditions for Successful End-User Involvement in New Product Development

Marianna Koukou and Rob Dekkers

Abstract New product development is important to the competitiveness, growth, and survivability of companies. End-user involvement in NPD is seen as a determinant for successful new products, and hence, companies are increasingly shifting towards a direction where they co-create products with end users. However, currently there is little consensus regarding the contribution of this involvement to new product outcomes. This study investigates the effects of three different approaches to end-user involvement in NPD and explores how end users are involved in and influence the NPD process and end product. The NPD processes of six companies were investigated on account of the exploratory nature of this study. The findings provide a holistic overview of three approaches to end-user involvement and emphasise factors that impact the end-user involvement outcomes. Additionally, the findings provide direction to managers for making informed decisions regarding how and when to involve end users for creating more effective and efficient NPD processes.

Keywords New product development · Co-creation · Open innovation · User involvement · Customer involvement

1 Introduction

New product development (NPD) is widely viewed as a key strategic process for commercial success and increased sales' volume of new products. At the same time, NPD is a very risky and uncertain process, and as a result, managers are often under pressure to effectively manage it and improve its performance. Nevertheless, many new products that reach the market fail to be adopted by end users who have long been believed to be able to provide needs and solution-related information that a company may lack. Particularly in the last two decades, the role of end users in NPD has been transformed from passive buyers to active players where end users are invited to co-create products with companies. Within the NPD field, studies

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related to NPD and co-creation process put emphasis on the active involvement of end users into the NPD process through activities and social interactions that have been initiated by the company (e.g. Cooper, 2019; Piller et al., 2010). In this sense, it is widely recognised that end-user involvement in the NPD process may bring many benefits to the companies such as more appropriate products or increased market share. However, despite the popularity and great enthusiasm among practitioners and researchers for end-user involvement, most NPD studies have taken a 'passive' stance to this practice and there is little consensus regarding its contribution to new product outcomes (Cui & Wu, 2017; Roberts & Darler, 2017). More specifically, an understanding of the active involvement of end users throughout the NPD process and how to manage the process for successful NPD outcomes is rare (Galvagno & Dalli, 2014; Roberts & Darler, 2017). In addition, existing studies have mainly focused on customer relationship management and neglect to examine how and to what purpose end users are involved in NPD processes (Filieri, 2012; Hoyer et al., 2010). There is also little academic research on how end users get involved in NPD in terms of their roles and contributions, and the capabilities for managing and leveraging them as a resource of NPD. This implies that there is a need for more detailed studies which would enable a better understanding of involvement patterns, effects, and challenges faced by the companies. Additionally, there is lack of in-depth insight on a better understanding of the conditions under which end users should be involved in the NPD process.

Thus, how end users get involved in NPD and what their contributions are is necessary to investigate in order to increase the effectiveness and also to direct resources for new product development and innovation. This study investigates the effects of three different approaches to end-user involvement in NPD (design for end users, design with end users, and design by end users) and explores how end users are involved in and influence the NPD process and the end product. While NPD practices may vary across different contexts, the study focuses on NPD practices in three European countries including the UK, France, and Greece-Russia. By exploring comparing and amalgamating three different levels of end-user involvement in NPD within different European countries, the study attempts to gain more creative insights and a multiparadigm understanding of the investigated phenomenon (Lewis & Grimes, 1999).

Therefore, this exploratory study is focusing on three main research questions:

- How and why are end users involved in the NPD process?
- What are the effects of end-user involvement in each successive phase of the NPD process?
- What is the contribution of end-user involvement to the (design and functionality of the) end product?

2 Theoretical Background

2.1 Challenges in NPD

NPD has been discussed to be central to business prosperity (Frishammar & Ylinenpää, 2007), with contributions to increased competitive advantage (Lin & Huang, 2013; Tzokas et al., 2004), sustained corporate growth and market leadership (Barczak & Kahn, 2012), and profitability (O'Hern & Rindfleisch, 2010). Nevertheless, successful NPD is still a complex and challenging task. Some of the challenges associated with NPD processes are summarised in Table 1.

A widely accepted way to reduce the above risks and challenges associated with NPD is to obtain accurate information and understanding of end users' needs (Cooper, 2011; Rejeb et al., 2006; Trott et al., 2015). Appropriate need analysis is a major concern in new product development projects (Boly et al., 2016). However, end users have long been believed to be able to provide needs (i.e. end users' input about their needs and preferences) and solution (i.e. end users' input about potential ways to solve problems)-related information that a company may lack (Chang & Taylor, 2016; Griffin & Hauser, 1993; von Hippel, 1986). Hence, it is suggested by many (e.g. Cooper, 2019; Barczak & Kahn, 2012; Griffin & Hauser, 1993) that by actively involving end users in the NPD process, the above-stated challenges can be minimised.

Building on the definition of O'Hern and Rindfleisch (2010) in this study, end-user involvement in NPD is seen as a form of co-creation and is defined as: a set of

Table 1 Main challenges for successful NPD processes

Challenges for successful NPD process	Discussed by
Inadequate market research techniques. Companies may neglect to invest on before-launch marketing activities or may rely on traditional market research approaches (e.g. surveys) that are guided by specific and direct questions. These fail to accurately capture end users' needs	Cooper (2019), Carlgren (2013), Goffin et al. (2010), Prahalad and Ramaswamy (2000)
Acquiring, transferring, and using 'sticky' information that end users hold is a challenging and costly task	Füller and Matzler (2007), Jeppesen (2005), von Hippel (2001)
General trend towards more heterogeneous end-user needs coupled with fast-changing market trends, and the globalisation of markets	Cooper (2011), von Hippel (2001), Ogawa and Piller (2006)
Rapid changes in end users' preferences supported by changing technologies may add extra cost and time on a company's NPD process and may result to the development of less relevant products	Chang and Taylor (2016) and Lakhani et al. (2014)

collaborative activities that are initiated and facilitated by the company and in which (current or potential) end users may contribute at various NPD phases and may select or provide suggestions on the content of a new product offering, to create (new) superior products, improve new product success, and to gain competitive advantage.

2.2 Three Different Approaches to End-User Involvement in NPD

End-user involvement in NPD can be distinguished by the roles end users can play. Bringing together perspectives from strategic management literature, quality management literature, new product development literature, and design studies, researchers have identified five main roles for end users in value creation. These include the end user as resource (or information source), co-creator (or co-producer, co-developer, or partner), buyer, user (or consultant), and product (or subject) (Cui & Wu, 2017; Damodaran, 1996; Lengnick-Hall, 1996; Nambisan, 2002; Olsson, 2004; Sanders & Stappers, 2008). The first two end-user roles (resource and co-creator) are at the input side of co-creation activity, whereas the other three are at the output side of the process. The end user as a buyer and as the product is less relevant to the active involvement of end users in the NPD process and the NPD context in general (Nambisan, 2002). The different roles end users can take during the NPD process differ in a number of ways and entail some contrasting attributes. For instance, whereas some end users may provide information about possible solutions, other end users may be better suited to evaluation of concepts or to get involved in the refinement of a prototype. However, all of the different roles are important for improving not only the NPD output (i.e. end product) but also for improving the overall NPD process (e.g. reducing costs).

Kaulio (1998) and Piller et al. (2010) have proposed a three-levelled categorisation on the degree of end-user involvement. While different terminology has been used to refer to the approaches of end-user involvement (Kaulio [1998] has taken a designer's perspective, whereas Piller et al. [2010] have taken a broader NPD view), the descriptions and arguments are identical. More specifically, the three approaches to end-user involvement as proposed by Kaulio (1998) and Piller et al. (2010) include.

2.2.1 Design for

Refers to an NPD approach where products are designed without end users' direct involvement in the process (Kaulio, 1998; Piller et al., 2010). Companies mainly use existing end-user information from diverse input channels (e.g. feedback from sales), or research reports from third parties (Dahan & Hauser, 2002). Companies may also analyse statements posted by end users on online communities (Kozinets, 2002) or information gathered by engineering-based methods like quality function deployment (Akao, 1990). End users are consulted, but do not actively participate in the decision-making process and do not significantly influence or change the design and the final product (Bergvall-Kåreborn & Ståhlbrost, 2008). It is rather the NPD team that has the active and controlling role (Kanstrup & Christiansen, 2006) as they initiate, stage, run the NPD process and create 'the solution space' (von Hippel, 2001). There is some iteration process between the NPD team and the end users where the NPD team creates something, and the end users comment upon it. Hence, the end users have a relatively responsive role, whereas they may provide information when requested while it is the NPD team that act as experts and represents end users' interests.

2.2.2 Design with

The company gathers and utilises data on end-user needs and preferences as in the 'design for' level. However, what is different is that end users are given the opportunity to react to different proposed solutions (Kaulio, 1998; Piller et al., 2010). In this sense, in the early NPD phases' surveys, interviews or focus groups may be utilised for capturing end users' need and preferences (Piller et al., 2010). In the later NPD phases, the company may present different concept testing solutions to end users and ask for their opinion and suggestions (Kaulio, 1998). In this level of involvement, whereas the NPD team still has the more active and controlling role (especially, in relation to initiating, staging, and running the process), the end users have a strong voice; especially when it comes to the control over form and content and to some degree the solution space (Bergvall-Kåreborn & Ståhlbrost, 2008). Hence, the end users are empowered with control, and in their most active role, they may strongly influence the design and the final product. In this sense, the NPD team supports the end users and ensures that they have the opportunity to make suggestions that are important to them.

2.2.3 Design by

In this level, the end users are actively involved in the design or development of new products (Kaulio, 1998; Piller et al., 2010). This is aligned with the notion of co-creation where end users are actively involved and take part in the development of new products. Subsequently, through the end users' input, the company gathers information about needs, applications, and solutions (Piller et al., 2010). In this level of involvement, the end users may design and develop parts or ideas for a product working with and supported by the designers and by different kinds of tool kits. In this way, the end users inspire the NPD team, which takes over and shape and finalise versions of the end users' products (Kanstrup & Christiansen, 2006). The lead user approach is included in this level of end-user involvement but is seen as an extreme where end users may take the role of a sole developer in the NPD process.

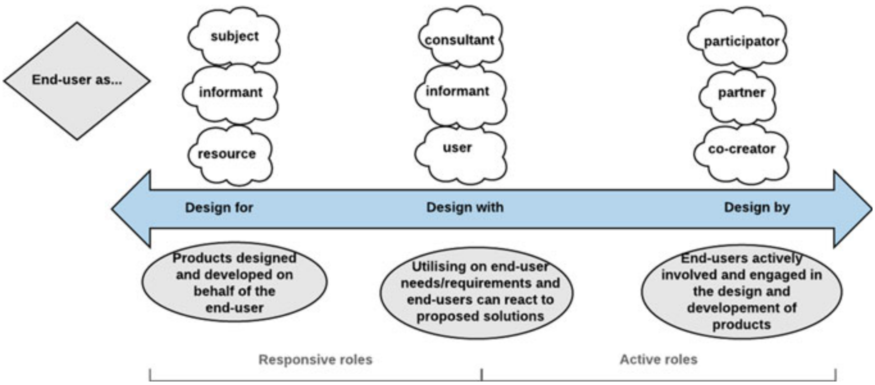

Fig. 1 End-user involvement continuum

Considering all the above, Fig. 1 illustrates the end-user involvement continuum together with the different roles end users can take. At one extreme of the continuum, the NPD team makes assumptions about needs and requirements and may even ignore end-user input. At the other extreme of the continuum, end-users design and develop products with the NPD team.

However, despite the three approaches emanating from different perspectives, they have been found to not only have differences but also to share similarities regarding the outcomes of involving end users in NPD. For instance, in terms of the benefits that end-user involvement may bring, all three approaches have been discussed to be able to successfully identify end-user needs and requirements (Ahmed & Amagoh, 2010; Dahlsten, 2004; Tsimiklis et al., 2015) and to reduce risks related to the uncertainty of product designs (Cauchick Miguel, 2005; Dahlsten, 2004; Nagamachi, 2002; Sandmeier et al., 2010) Table 2 is based on the findings of the systematic literature review conducted prior to this empirical study (Koukou et al., 2015) and provides a summary of the characteristics of each approach.

Nevertheless, the systematic literature review (Koukou et al., 2015) has identified a number of shortcomings in the current literature discussing end-user involvement in NPD. First, risks and challenges associated with end-user involvement in NPD are not very often discussed which indicates that within the current literature, the conditions, outcomes, and effects of end-user involvement in NPD may be poorly understood. Second, extant literature rarely has distinguished between distinct approaches or methods of end-user involvement in NPD. That way, most of the previous empirical studies have neglected to consider how different approaches may focus on different ways for capturing and transferring end user's needs and requirements, within different levels of comprehensiveness (richness of information). Third, most studies have focused on discussing end-user involvement on specific NPD phases (e.g. the fuzzy front end) and most of them have not considered the potential contribution or potential challenges of involving end users throughout the NPD process. These three shortcomings indicated that there is no solid evidence in

Table 2 Summary of the characteristics of the three approaches

	Design for	Design with	Design by
What are the benefits of involving end users in the NPD process?	Follows a systematic way of thinking that results to better planning of product requirements, better market analysis, enhanced communications within the company, reduction of development costs, and time-to-market	Mainly aims at reducing development costs and time-to-market as well as increasing the number of new ideas generated	Supports identification of new markets, increased number of different ideas, and better insights into product requirements
What are the challenges of involving end users in the NPD process?	It is stressed to be time consuming, and it is not recommended for complex products	Successful implementation of end-user involvement is mostly dependent on the selection and use of the right tools and right type of end users at the right time	Brings concerns on appropriate selection of tools and which of these tools is best suited for specific design questions
When end users get involved?	Applicable mostly during the initial phases of NPD; very rarely it has been discussed for later stages of NPD	Implemented in every phase of NPD	Mainly used during the early development phases of NPD although more recent studies indicate that it could be used during other phases as well
How end users get involved?	It makes use of 'indirect' tools (e.g. surveys) and it is explicitly used for improvements of already existing products	Relies mostly on web technology-based tools for involving end users in the NPD process	Broad range of different tools

Source Amalgamated from Koukou et al. (2015)

the current literature to substantiate how best involving end users in the development of a product is related to successful NPD. Hence, by simultaneously investigating and comparing three different approaches of end-user involvement in NPD, this study seeks to offer a broader and more complete understanding of the contribution of end-user involvement to NPD outcomes.

2.3 Methodology

As there is only limited research that has investigated the effects of end-user involvement throughout the NPD process, this study intends to gain a better understanding on how and why end users get involved in NPD and how they impact the end product. Therefore, a case study deemed to be the most suitable option for generating in-depth insights and achieving a profound understanding of the NPD process (Eisenhardt, 1989; Yin, 2003). The appreciation of different settings and complex dynamics of end-user involvement in NPD requires focusing on cases of particular firms in order to be confident that all the levels of end-user involvement have been investigated. Additionally, end-user involvement and engagement in the NPD process involves many different individuals, different organisational departments and depends on different (organisational or individual) cultures and attitudes. Hence, a multiple case study methodology matches this study's comparative research. Six case studies were selected to be carried out within six different companies. The selection of appropriate cases was based on the individual characteristics of the firms, as well as the overall composition. Companies were selected that operate in a business-to-consumer market, in a consumer's product (not service) domain. To allow for more insightful comparisons between the cases and between the different approaches to end-user involvement, the size of the companies was equally distributed among small, medium, and large sizes.

The information on end-user involvement in NPD was approached from multiple sources of evidence and did not rely on a single method (Miles & Huberman, 1994; Yin, 2003). Data collection methods included semi-structured interviews with individuals from different departments (e.g. production, marketing, designing), focus group, secondary data (e.g. product development documents, brief, and presentations), and (participant) observations (e.g. site visits). The unit of analysis was set on a project level, and in each of the case companies, a specific NPD project was discussed addressing activities and impact of end-user involvement in each one of the NPD phases. Table 3 provides an overview of the case characteristics and main data collection instruments.

In line with the nature of this research's aim and questions, the collected data was analysed following the general thematic analysis approach indicated by Braun and Clarke (2006): first, the interview transcriptions were read, and notes were taken about initial ideas and repetitive or unique patterns within the data. This process facilitated the identification of some key themes and uncovered initial similarities and differences among the interviews of each case. After all the interviews across the six cases were transcribed and read, relevant secondary data for each case was read and assessed. After that, initial codes were created. Once all data were coded and collated, the analysis were re-focused on the broader level of themes. This included sorting and clustering all the different codes into potential themes. The relationship between codes, between themes, and between different levels of themes was assessed and resulted in a collection of themes and subthemes. Finally, the developed themes and subthemes were reviewed and refined.

Table 3 Case characteristics and main data collection instruments

Case	Field	Size	Location	Participants' profiles	Interviews	Project
Alpha	Product development agency	Medium	UK	General manager, project manager, designers	3 and 1 focus group 60–90 min	Medical device
Beta	Publishing	Large	Russia and Greece	General director, marketing director, group product manager	3 70–110 min	History of fashion (monthly magazine)
Gamma	Textile	Small (< 50 employees)	UK	CEO, general manager, shop floor employees	4 50–90 min	Clothing line
Delta	Medical food	Micro (< 10 employees)	UK	Research team lead, principal investigator, research assistant	3 60–110 min	Treatment-diet
Epsilon	Water heaters	Large	France	R&D manager, marketing and product innovation manager, project manager	3 60–80 min	Square water heater
Zeta	Food	Medium (< 250 employees)	France	General manager, project consultant	2 110–140 min	Chorizo project

Table 4 Companies' characteristics

	Industry	Size	Operation country	Culture of sharing and receiving information	Experience with end users
Alpha	Engineering/ NPD consultant	Medium	UK	Open	> 5 years
Beta	Publishing	Large	Russia and Greece	Towards open	> 10 years
Gamma	Textile	Small	UK	Open	5 years (since it was founded)
Delta	Food (medical)	Small (micro)	UK	Open	First project
Epsilon	Heating systems	Large	France	Towards closed	7 years
Zeta	Food	Medium	France	Closed	First project

3 Findings and Discussion

3.1 Context Differences

The companies that served as cases have some differences in context and characteristics which may have an impact on end-user involvement in NPD (Table 4). While irrespective of the industry, all studied companies follow similar NPD processes that end-user involvement in some NPD phases may be restricted due to policies and regulations that need to be followed when working on a specific project. Furthermore, this study has found that smaller companies promote a more collaborative 'company culture' (in contrast to larger companies) which makes them more open in working closely with end users and keener in listening to and implementing end users' suggestions. This conduct may also be related to the country of operation of each company, as the French companies were found to be more resistant in accepting end users' suggestions and requests. Finally, the findings suggest that a company's level of experience of involving end users does not have a significant effect on the NPD process and the outcomes of the involvement.

3.2 Classification of Cases

Although with the chorizo project Zeta attempted to actively involve end users in the NPD process, it is closer to the 'design for' (DF) approach. End users were asked about their opinion on the product, but they had a rather passive role throughout the NPD process. Instead, it was the NPD team who made all the decisions and in cases acted as experts, ignoring end users' input (e.g. although end users raised issues related to the shape of the product, during the product re-design end users were only involved in organoleptic tests) (Fig. 2).

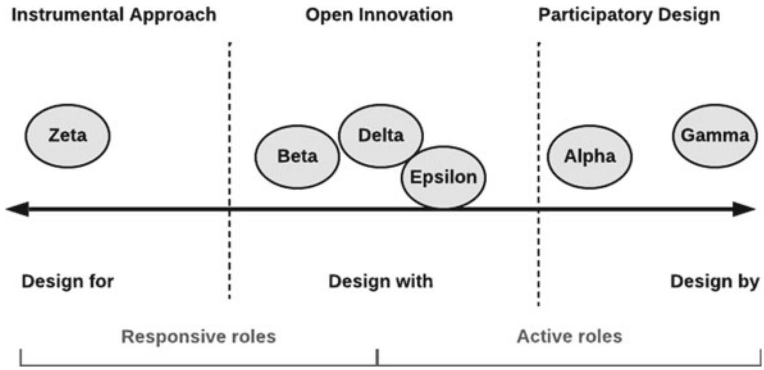

Fig. 2 Classification of the six case companies against the end-user involvement continuum

On the other extreme of the continuum, 'design by' (DB), Alpha and Gamma have been closely collaborating with and involving their end users in the NPD process. Alpha made sure to actively involve end users from the beginning to the end of the NPD process. Although at the boundaries of 'design with' and 'design by', the close collaboration of Alpha with end users especially during the prototype phases positions it closer to a 'design by' approach. Due to its customer-centred business model and ethical principles, Gamma perfectly fits the 'design by' philosophy. This is evident in the involvement of lead users who were actively engaged in the design and development of products as equal members of Gamma's NPD team.

The rest of the cases fall into the 'design with' (DW) approach, as end users were involved mainly for validating solution as these had been suggested by the NPD teams. Epsilon, however, made some attempts in more actively involving end users in some NPD phases by collecting and implementing end users' ideas. It could, therefore, be noted that comparing to Beta and Delta, Epsilon is closer to the 'design by' approach. Also, it is possible that if Delta was not restricted by regulations, end users would be more actively involved in the NPD process.

3.3 Benefits and Challenges of End-User Involvement in NPD

Six sets of benefits were identified as contributing to more successful NPD processes (Table 5). All three approaches were found to be beneficial for identifying end users' needs, reducing the uncertainty of product designs, and increasing number of ideas. These benefits have been widely discussed in prior literature (e.g. Ahmed & Amagoh, 2010; Dahlsten, 2004; Wilkinson & De Angeli, 2014). However, and among other benefits, each of the approaches was found to have some more distinct benefits. For instance, in DB, the mutual benefits of NPD teams working closely with end users were emphasised in the form of knowledge exchange. Specifically, it was found that end users were able to acquire new skills, and accordingly, NPD teams were benefited from gaining new knowledge from end users which they could use in other projects. This is something that to best of the researcher's knowledge has not been investigated in literature in the NPD and innovation domain. Hence, whereas involving end users in NPD may bring typical benefits such as better identifying end users' needs, some other benefits are more likely to be achieved by following one of the three approaches to end-user involvement.

Table 5 Benefits of end-user involvement across the six cases

Benefits		Alpha	Beta	Gamma	Delta	Epsilon	Zeta
End user	Needs identification	x	x	x	x	x	x
	Increase end-user engagement/adoption	x	x		x		
	Help end users to acquire skills			x			
Planning	Better insight into product requirements		x			x	
	Prioritise product requirements	x				x	
	Better overview of the project					x	
	Reconsider own strategy/product offerings						x
Financial	Increased profitability		x				
	Identification of new markets	x				x	X
	Identification of new segments		x				
Risk	Reduced uncertainty of product designs (and avoid mistakes)		x	x	x	x	X
	Increase success rate		x		x	x	
Ideas generated	Increase the number of ideas	x	x		x	x	X
	Increase the novelty of ideas	x		x			X
Company	Knowledge gained	x		x			
	Increase motivation/confidence in project				x	x	X
	Contributing to solving disagreements within NPD team					x	

Difficulties in articulating end users' needs and suggestions are one of the most cited challenges in the literature independently of the approach followed by companies (e.g. Cui & Wu, 2016; Enkel et al., 2005; Rejeb et al., 2011). However, only three out of the six companies in this study were found to face difficulties in articulating end users' needs. More specifically, the study has found that success of involving end users in the NPD process may be affected by different challenges that companies have to face depending on the approach they follow (Table 6). End-user involvement following a DB approach faces challenges which are related mainly to appropriately managing end-user involvement. End-user involvement through DW was found to be challenged mainly by appropriately organising end-user involvement and managing communication in heterogeneous groups. Finally, appropriately organising end-user involvement and managing information and knowledge are the main challenges for companies following the DF.

Table 6 Challenges of end-user involvement across the six cases

Challenges		Alpha	Beta	Gamma	Delta	Epsilon	Zeta
Organising end-user involvement	Identification of right type of end user		x		x	x	
	Finding enough end users	x			x	x	x
	The best period to involve end users						x
Managing end-user involvement	Changing end user's opinion	x		x			
	Focusing on details			x			
	Constant changes on designs			x			
	Overpowered end user			x			
	Cultural differences		x				
	Managing communication	x	x				
	Jumping to solutions	x					
	Emotionally involved			x			
Managing information and knowledge	Articulating end-users needs	X	x	x			
	A high number of ideas				x		x
	Accept end users' opinion and feedback						x
Complexity	Complexity of products	X	x	x	x	x	

3.4 Impact on NPD Time and NPD Cost

Prior literature on DW and DF studies has reported that end-user involvement leads to faster and less costly NPD processes (e.g. Herstatt & von Hippel, 1992; Lettl, 2007). However, the findings of this study show that involving end users in the NPD process is a lengthy and time-consuming process. Similarly, most companies recognised that end-user involvement is associated with increased costs. These are mainly related to organising and facilitating end user involvement as well as to pursuing changes and alterations according to end users' feedback and requests. Nevertheless, all six companies highlighted that irrespective of the cost and time-commitment end-user involvement in NPD is a very crucial and perhaps necessary condition for developing more appropriate new products and for increasing the new products' success rate in the market.

3.5 When and How End Users Get Involved in NPD

The different approaches to end-user involvement were found to be suitable for certain NPD phases. When following a DB approach, end users play an active role throughout the NPD process, and they are involved in decision-making about the characteristics and functions of the product. On the contrary, in DW and DF, end users are contacted after the company has developed a new concept for a product in order to evaluate it. Nevertheless, across the three approaches, end-user involvement is more intense and is seen as most important during the concept development phase and the prototype development and testing phases. This contradicts with discussions in the current literature that the value of end-user involvement diminishes during the development (middle) NPD phases and that end users should be involved much earlier than in prototype development phase (Chang & Taylor, 2016; Daecke et al., 2015; Enkel et al., 2005; Gruner & Homburg, 2000; Roberts & Darler, 2017). Overall, whereas the three approaches were found to be better applicable in different NPD phases, the findings also support that end-user involvement is most beneficial during the concept development and prototype development and testing phases. Table 7 is an overview of the NPD phases that end users get involved and the tools they use.

The study concludes that the three approaches favour different types of tools. Specifically, DB employees mainly direct[1] type of tools (e.g. brainstorming, mock-ups), DW both direct and indirect[2] (e.g. surveys, diaries), and the DF traditionally uses indirect tools. Interestingly, in any of the three approaches, web-based tools are hardly used for involving end users. This finding does not reflect the notion in the literature which investigates and discusses many practical applications of how

[1] Direct tools: end users take part in a number of tasks along with designers, such as the development of prototypes or workshop sessions.

[2] Indirect tools: end users provide information about their needs and requirements and the designers take that information and translate it into product characteristics.

Table 7 Overview of the NPD phases end users get involved and tools used

	NPD Phase	Alpha	Beta	Gamma	Delta	Epsilon	Zeta
Ideation (early phase)	Idea generation	Indirect & direct	Indirect & Web-based	Direct	Indirect	-	-
	Idea screening	-	Indirect & Web-based				
	Concept development	Direct	-	Direct	Indirect	Web-based	Direct**
	Concept screening		Direct			Direct	
Development (mid-phase)	Prototype development	Direct	Indirect	Direct	Indirect & direct	-	-
	Prototype testing	Direct	Direct	Direct	Indirect & direct	Direct	Indirect & direct**
	Market test		Indirect			Indirect	Direct**
Launch (late phase)	Pre-launch/product development	Indirect	-	Direct		Indirect*	Indirect
	Communication test		Direct				

(hatched) : The company does not have this phase
- : End users were not involved in this phase
* : Happens traditionally but not for the square heater project
** : Happened for the chorizo project only

online technology is used for better integrating end users in the NPD process (e.g. Antorini & Muñiz, 2013; Füller & Matzler, 2007; Wu & Fang, 2010). The companies in this study only made occasional use of basic online tools. In this respect, the main reasons for not using web-based tools were (i) lack of information accuracy and (ii) privacy issues.

3.6 *End-User Involvement Impact and Effects on NPD Process and the End Product*

The study found that end-user involvement through the DB approach has a strong impact throughout the NPD process, and they can influence decisions and become co-creators of new products. When following the DW approach, end users have a moderate impact during the overall NPD process. This mainly happens because managers and NPD teams are always in control of defining the end-product characteristics. Even when end users are asked for their opinion and suggestions, their empowerment happens with control. With the DF approach, end users have little to no impact during the NPD process. An explanation for that is that the companies may not appropriately or adequately organise and facilitate the involvement activities in order to gather valuable information and suggestions from end users. Also, although end users' opinions and suggestions may be recorded, companies simply choose not to follow them.

When viewing and comparing all the six cases together, it becomes clear that the frequency of end-user involvement in the NPD process is not necessarily associated with the outcomes and the influence they have on the end product. Contrastingly, what is of highest importance is how (tools) end users get involved and for what purpose. For instance, in Beta end users are involved mainly for validating predefined options and solutions; hence, they only have a weak influence on the end product.

Table 8 Overview of reasons for not implementing changes as requested by end users

Type of reasons for changes not implemented	Alpha	Beta	Gamma	Delta	Epsilon	Zeta
Economic constraints	x	x		x	x	
End-user ideas regarded as not important	x	x				
Impact on functionality			x	x	x	x
Above the company's capabilities			x			
Impact on usability	x			x		
In use by competitors					x	
Legal agreements					x	
Regulations	x				x	
Phase of NPD	x					
Were all end users' change requests implemented?	NO	YES	YES	NO	NO	NO
End users' influence on the end product	Strong	Weak	Strong	Medium	Medium	Weak

In the cases of Alpha and Gamma, end users had a strong influence on the end product. Compared to the other four cases, it is evident that end users had been provided many opportunities throughout the NPD process to express their views and to actively contribute to the end product. Furthermore, the NPD teams did not always provide predefined solutions to the end users and hence created a more open and engaging environment for collaboration. Nevertheless, giving opportunities to end users to actively participate in the NPD process does not necessarily mean that all their feedback and suggestions will be followed by the NPD teams. Table 8 provides insight on the reasons as to why companies may not be able or chose not to implement changes requested by end users.

3.7 Appropriateness of Each Approach to End-User Involvement in NPD

Putting it all together, it can be seen that the three approaches may have a quite different impact on the NPD process. However, the findings also suggest that the appropriateness of each approach depends on four situation-specific factors. These include i) a company's defined purpose for end-user involvement, ii) a company's culture and receptiveness to external knowledge, iii) industry associated regulations and policies, and iv) a company's allocation of resources. Moreover, experience in an industry and prior experience with end users does not seem to affect successful end-user involvement in NPD activities. Hence, when a company decides to involve end users in the NPD, clear NPD strategy and clear objectives need to be set and decisions need to be made in advance regarding what and how the company is willing to invest in this involvement.

Furthermore, another interesting finding of this study is that the prospect of end users successfully influencing the end product depends on the way end-user involvement is being facilitated and controlled, and the openness (or not) of NPD teams in working with end users. This finding supports Roberts and Darler's (2017) view that co-creation activities are contingent upon the level of end-user involvement (responsive or active) that a company is adopting, and also upon the purpose of being involved. The main factors for supporting end users' influence on the end product are associated with the level of involvement (approach) and the tools used to support this involvement and collect relevant information. This association can be better illustrated in Fig. 3.

Putting together the findings presented and discussed on the above sections, the study suggests that for companies to have successful end-user involvement in NPD which provides opportunities for creating (new) superior products, improving new product success, and gaining competitive advantage, the following questions should be considered: is there a defined purpose and clear objectives for end-user involvement? Has the company invested on a sufficient and clear plan regarding allocation of resources (time, budget, space)? Is the NPD team open enough in accepting,

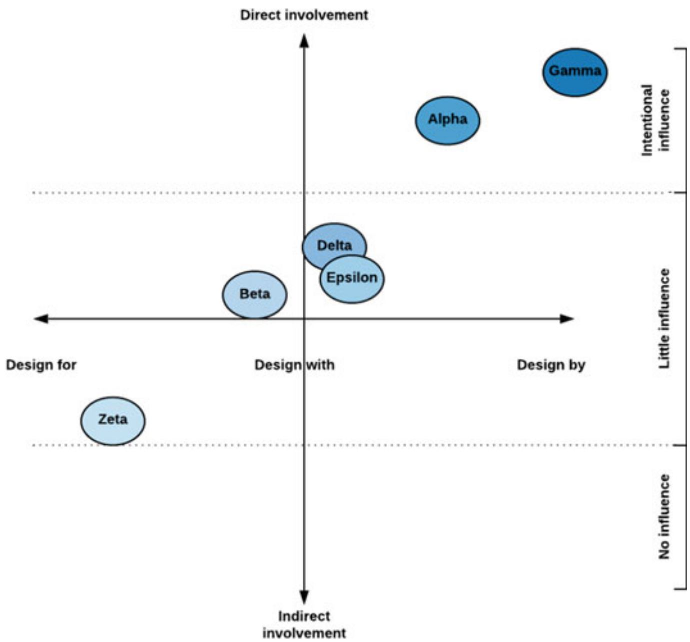

Fig. 3 End-user involvement matrix

considering, and integrating external knowledge coming from end users? Are there mitigation measures in place to overcome restrictions coming from regulations and policies? If the answer to the above questions is ‘yes’, then Table 9 may assist companies to make more informed decisions for selecting and following the most appropriate approach to end-user involvement.

4 Concluding Remarks

Returning to the purpose of this study, the aim was to explore and develop a deeper understanding on how end-user involvement is embedded in NPD and what could be the effects to the end product. The findings contribute and extend the growing body of research on end-user involvement in NPD by providing a comprehensive, holistic overview of three different approaches to end-user involvement and by emphasising a set of factors that impact the end-user involvement outcomes.

First, the findings demonstrate that the three approaches to end-user involvement entail different benefits and challenges and emphasise different tools and articulation of end-user requirements across different NPD phases. Second, the appropriateness of each approach, as well as the impact it may have on the NPD process and the end product, depends on four situation-specific factors. Third, the prospect of end users successfully influencing the end product depends on the way end-user involvement is being facilitated and controlled, and the openness (or not) of NPD teams in working with end users. Fourth, the study has developed a contingency framework (Table 8) which allows for simultaneous comparisons between different approaches to end-user involvement in NPD and identifies different benefits and challenges which may influence the successful implementation of each approach. Finally, in contrast to previous research, the findings of the study suggest that whereas the three approaches are better applicable in different NPD phases, end-user involvement is most beneficial during the concept development and prototype development and testing phases.

4.1 Contribution to Knowledge and Implications for Practice

While previous research (e.g. Filieri, 2012) tends to mainly focus and investigate end-user involvement in a specific NPD phase, this paper provides (to the best of our knowledge) the first qualitative study to investigate and compare the effects of three different levels of end-user involvement in each NPD phase in a business-to-consumer context. The consideration and investigation of three different approaches together allow for a more coherent conceptualisation of the role of end users in developing new products. As a result, the contingency framework (Table 8) allows for simultaneous comparisons between three approaches to end-user involvement in NPD and identifies a number of different benefits and challenges which may influence the successful implementation of each approach. This is different from previous

Table 9 Overview of conditions and characteristics for the three approaches

	Design for	Design with	Design by
Culture	Generally, not very open to receiving external knowledge End users may have limited influence to end product	Open to receptivity of external knowledge but somewhat suspicious Blind trust to company's NPD and R&D teams End users may have some influence to end product	Open to receptivity of external knowledge Intentionally allow and support end user influence on the end product
Commitment	NPD team has very sporadic contact with end users	NPD team in frequent contact with end users May require follow-up activities (although not always the case)	NPD team in continuous contact with end users Intensive collaboration End users are considered to be part of the NPD team
Resources	Use of indirect type of tools for involving end users Not very time consuming	Use of combination of direct and indirect type of tools for involving end users Relatively time consuming	Use of mostly direct tools for involving end users Time consuming
NPD phase	Applied in middle and/or late NPD phases	More applicable for early NPD phases (after concept development) and middle NPD phases. Emphasis on concept development and on prototype testing phases	May be applied throughout NPD process
Distinct benefits*	Identifying end users' needs Increase on number of ideas generated Opportunity for reconsidering company's strategy	Identifying end users' needs Better planning of NPD process Increase product success rate Increase confidence of employees on project	Identifying end users' needs Knowledge exchange between end users and NPD team
Main challenges*	Managing and organising information from end users Organising end-user involvement	Organising end-user involvement	Managing end-user involvement

(continued)

Table 9 (continued)

	Design for	Design with	Design by
Most appropriate for	Simply testing and choosing among predefined product characteristics and predefined solutions Captures need-related information	Ensuring that the project is on the right path by frequently evaluating and validating existing solutions with end users and by offering opportunities to end users for small changes on product designs Captures needs-related and solution-related information	Companies who invest on and trust that their end users may come up with new or different ideas and solutions Captures needs-related and solution-related information

[*] These should be considered in addition to the general benefits and challenges discussed in earlier sections

literature which has focused mostly on the benefits of end-user involvement and has neglected the challenges (Gemser & Perks, 2015). The findings of this study also give valuable insight on when and how end-user involvement is best embedded in NPD for each of the approaches. Differently to previous research (e.g. Chang & Taylor, 2016; Daecke et al., 2015; Roberts & Darler, 2017), it is suggested that whereas the three approaches are better applicable in different NPD phases, end-user involvement is most beneficial during the concept development and prototype development and testing phases.

This study has identified four situation-specific factors that may affect the appropriateness of each approach for end-user involvement in NPD (a company's defined purpose for end-user involvement; a company's culture and receptiveness to external knowledge; industry associated regulations and policies; and a company's resources). Although previous literature (e.g. Roberts & Darler, 2017; Laage-Hellman et al., 2014) has implicitly touched on these factors, they have never been brought together in a study with a focus on end-user involvement in NPD. Moreover, this study found that experience in an industry and prior experience with end users does not affect successful end-user involvement in NPD activities. These factors advance our understanding of the conditions under which customer participation can be a viable strategy for companies.

The study has also concluded that when companies decide to involve end users in the NPD process, they are not very concerned about the difficulties in cost and time that this involvement may entail. More specifically, the decision on when and how to involve end users is based mainly on potential benefits that end-user involvement can offer, rather than in conjunction with practical and resource-based criteria. Although this is not necessarily a good practice, this finding expands our knowledge on how a company evaluates decisions regarding inviting end users to participate in NPD.

The results of the study have also uncovered a relationship between the level of end-user involvement, the ways of involvement, and the influence on the end product (illustrated in Fig. 3). More specifically, it is suggested that the prospect of end users successfully influencing the end product depends on the way end-user involvement is being facilitated and controlled, and the openness (or not) of NPD teams in working with end users. This finding contributes significant value to the current literature as it has not been established in any previous studies.

The findings may also provide direction to managers on selecting and adopting the most appropriate approach of end-user involvement for creating more effective and more efficient NPD processes. The three approaches to end-user involvement have proved to be quite different on a number of aspects, and the findings may assist managers to be better prepared as to what to expect, to embrace benefits better and accurately overcome challenges, and to build capabilities for better implementing these approaches. For example, because in DB most challenges are associated with managing end-user involvement, it is recommended that managers should clearly define tasks, responsibilities and decision-making processes between the NPD team and end users and should plan ahead in case of disagreements occur. Finally, the findings of the study provide information to show which one of the end-user involvement approaches is best suited and when, depending on a company's goals, resources, and (organisation) culture.

4.2 Limitations and Suggestions for Further Research

The findings and the contributions of this research are somewhat constrained by certain limitations, which are worth noting as they may form opportunities for future research. First, it should be noted that in this research, an explorative qualitative research approach was applied, and the findings were mainly inducted from empirical evidence. Therefore, future research could make use of quantitative research methods for testing the validity of some of the findings across a larger sample.

Second, while this study found that end-user involvement is more beneficial in the concept development and prototype development phases, previous research has stated that end users should be better involved in the initial NPD phases. As such, additional research is needed to investigate and consolidate in which NPD phases' end-user involvement is more beneficial in terms of contributions to product characteristics. Similarly, and with the technological advancements which characterise this era, more research is needed in identifying web or technology-based methods and tools for end-user involvement in different NPD phases.

Third, while earlier research shows that end user increases the likelihood of developing more appropriate and more successful products, this should be also weighed against the costs in time and money that end-user involvement may bring. While this study has highlighted benefits of end-user involvement, it has also identified that there is no conclusive evidence to support that at the same time this practice has a beneficial effect on reducing NPD cost or NPD time. Previous research has also been inconclusive in this matter with studies supporting different views. Hence, it is suggested that further research is needed for getting a better insight into the relationship between end-user involvement and effects on time and cost.

Finally, a fourth opportunity for future research arises from the finding that company culture plays a significant role in successfully involving end users in the NPD process. Although previous research has also supported this observation, it is mainly confronted as a symptom of poor organisational learning in an attempt of companies to avoid ambiguity and inertia (Olson & Bakke, 2001). This only strengthens the argument that there is a lack of studies on explicitly exploring the effects of company culture on end-user involvement in NPD. Therefore, it is suggested that future research could investigate the receptivity of knowledge and information between end users and different NPD departments.

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Excavating the Role of NPEs in the Innovation Process: Turning into a Mission Possible?

Rob Dekkers

Abstract Past decades have seen a rise in activities for the commercialisation of intellectual property (IP), particularly by non-practicing or non-producing entities. Publications have weakly discussed their impact on the effectiveness of innovation processes and the development of technology in industrial sectors, the quest of this study. As a first step a systematic literature review retrieved 91 relevant papers, but finds they address 'the good, the bad and the ugly' in an almost canonical way. During twelve interviews with experts, it became clear that the canonical classification is too simplistic for modelling. In addition, the array of interventions was larger than originally presumed. These and other findings were used for a focus group of twelve academics. The outcomes confirmed that theory is lacking in the domain of innovation management, particularly with respect to the generation and exploitation of IP. The road to decisive research seems far away: a mission impossible, perhaps.

1 Introduction

The past decades have seen growing markets for technology (already noted by Arora et al., 2004) and a rise in activities for the commercialisation of intellectual property (IP), particularly the emergence of numerous new business models offered by technology market intermediaries (Tietze & Herstatt, 2010); in this context, the rise of so-called Non-Practicing or Non-Producing Entities (NPEs) has attracted attention. These NPEs are typically companies or entities that do not invent new technology directly but acquire IP from third parties and strive to sell licences and obtain licence royalties or any other income stream from exploiting that ownership situation. Whereas some, such as Tietze (2012), relate the NPE concept to a wide range of organisational forms, among them consultancies, bridge layers, gatekeepers, technology transfer offices, or rather the economic concept of market intermediaries in general, the onus of this paper is on patent trolls, patent aggregators, etc. who hold patents but do not invent or practice the patent.

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In the context of this attribute of these entities, Yoshino et al. (2009) identified more than 125 NPEs in the U.S.A. operating more than 800 subsidiaries holding more than 9,000 patents. They estimate that 20,000 patent families are controlled by NPEs. Additionally, NPEs account for 30–40% of all patent suits filed in the IT and electronics industries worldwide (Denicolo et al., 2008, p. 574). Moreover, Ghafele and Gibert (2012, p. 23) found that 2,600 firms were confronted with litigation by NPEs (in this case, so-called 'trolls') in 2010. Compared to 1998 this represents a dramatic increase from 250 firms. Hence, these figures from across the globe and headline cases suggest that the role of NPEs for the exploitation of IP has grown substantially over time.

1.1 Research Objectives

Leaving what exactly constitutes a NPE alone for the moment being, their expanding role in the exploitation of IP might indicate that they could have an impact on innovation processes. In addition, the high-profiled cases make it regularly to the headlines of the news and just from those cases one might wonder how NPEs affect the innovation processes and technological developments. At the same time, academic interest in those entities has risen, but is still in stages of infancy. Those that are investigating this phenomenon do so from a variety of perspectives but have weakly addressed the impact of the entities on the effectiveness of innovation processes and the development of technology in industrial sectors; a quest that this study seeks addressing.

This search for the role and impact of NPEs on innovation processes and technological developments brings about as research questions:

- What exactly are these NPEs and what is their impact on the innovation process?
- What dynamics are they causing for the innovation process of firms and for technological developments in industrial sectors?
- Are the NPEs altering the effectiveness of the innovation process?

By addressing these questions, the study also looks how the role of the NPEs and their impact might be modelled for the innovation process of firms and technological developments in industry. Hence, the study contributes to appreciative theory developing before formal modelling may take place (Nelson, 1994, p. 48). Potentially, the outcomes of this study might guide further research.

1.2 Scope and Outline of Paper

To this purpose, the paper takes a wider perspective than existing related publications by conducting a systematic literature review and adding empirical data. For example, Hemphill (2014) restricts himself to a literature review on the business model of NPEs for the situation in the United States of America (U.S.A.). In addition, Perkmann and Walsh (2007) in their work focus on the specific class of technology transfer offices. It should be noted that university-industry relationships have been well studied; for example, Perkmann et al. (2013) focus on academic engagement and commercialisation in their systematic review. Hence, this paper looks at the contributions and impact of NPEs to the innovation process, but by putting less emphasis on universities as those entities in the first instance.

To this end, the paper starts with a systematic literature review, centred on what is known about NPEs given that it is a relatively new topic for researchers from various disciplines. The literature review does not look at technology transfer offices given the precedence in literature. The outcomes of the literature review have directed the empirical research, since it confirmed that actually little is know about the impact of NPEs on innovation processes. The Section Research Methodology describes the research rationale and approach for the interviews and focus group, from which the results are published in the next section. The results are followed by the Section Discussion of Findings and a final section with conclusions, managerial implication and directions for further research.

2 Systematic Review of Literature

As a first step in this study, the systematic literature review has followed the guidelines of Cronin et al. (2008) and Tranfield et al. (2003) for the selection of databases, the use of keywords for retrieving relevant sources and the structured analysis of these sources.

2.1 Process for Retrieval

For the retrieval of papers EBSCO*host*, Google Scholar (justified by Harzing and Wal [2008]) and ProQuest have been used; this complies with the guidelines of Green et al., (2006, p. 104) to use at least two databases for a systematic literature review. Only studies until 2013 were included in the literature review (the empirical study took place in 2014). Furthermore, the three research questions have guided the retrieval process from the search engine. To find relevant sources for addressing the research questions, combinations of specific keywords have been used. It should be noted that NPEs also appear under a variety of labels, when referring to more specific forms and specific activities, a case in point being patent trolls. Other labels that have been used for NPEs are: ‘patent troll’, ‘IP broker’ and ‘IP intermediary’. When using the search term ‘non-producing entities’, it has also covered ‘non-practicing entities’ and ‘patent assertion entities’. For retrieval the term NPE was used in combination with ‘innovation’ and ‘technology’. During the retrieval, all papers were inspected on relevance of title and abstract for inclusion in the analysis; if an abstract was absent, this was replaced by a quick inspection of the contents. Publications that were only discussing legal aspects have been discarded. Also, papers that were addressing the relationship between patenting and setting standards have been excluded; a case in point is the study by Baron et al. (2011). Finally, working papers and contributions to conferences were substituted by publications in journals if the latter still fell within the period for the search. After completing the retrieval from search engines, snowballing has been used, following the guidelines of Greenhalgh and Peacock (2005) for complementary search strategies. The combinations of keywords and retrieval by database and origin have been captured in Table 1.

The actual sources, as regrouped in Table 2 based on the combination of keywords, are spread among very different outlets. Some of them are publications in academic journals, but also contributions to conferences, working papers and presentations can be found among them. Hence, the retrieved sources indicate a wide range of perspectives, even including those from practitioners. Table 3 indicates that this specific research topic is in its infancy stage, though the earliest paper appeared in 1977 (Ryan and Ford); the table shows the increased number of publications and justifies those claims that NPEs attracts increasingly attention from researchers. In addition, this table demonstrates that many papers are propositional from the perspective of the impact of NPEs on innovation processes and technology cycles. Hence, both the wide spread, the increasing number of publications and the propositional nature of many writings are symptomatic for this domain being in development.

Table 1 Retrieved sources by database

Combination of keywords	EBSCO *host*	Google Scholar	ProQuest	Total
"Non-Producing Entities"*AND innovation	2	21	–	23
"Non-Producing Entities"* AND technology	4	10	–	13
"Patent brokers" AND innovation	2	7	–	9
"Patent brokers" AND technology	3	9	–	12
"Patent intermediaries"** AND innovation	4	12	–	13
"Patent intermediaries"** AND technology	6	11	–	13
"Patent trolls" AND innovation	6	40	6	44
"Patent trolls" AND technology	7	31	–	34
Subtotal	**17**	**72**	**6**	**77**
Snowballing				14
Total				**91**

* The additional search terms that have been used are: "Non-Practicing Entities" and "Patent Assertion Entities"

** For patent intermediaries the additional search terms "IP intermediaries", "patent aggregator" and "innovation intermediaries" have been used. In the case of ("innovation intermediaries" AND innovation) the Boolean expression has been replaced with ("innovation intermediaries" AND patents)

Table 2 Overview of retrieved sources by keywords

Keywords	Innovation	Technology
"Non-producing entities"	Addy and Douglas (2012), Alexy and Reitzig (2013), Bessen et al. (2012)*, Chien (2010, 2013), Fischer and Henkel (2012)*, Fusco (2012), Greenspoon and Cottle (2011), Hall (2009), Hall and Ziedonis (2007), Jeruss et al. (2012), Johnson et al. (2007), Lemus and Temnyalov (2013), Mayergoyz (2009), Mazzeo et al. (2013), Merges (2009), Morgan (2008), Pohlmann and Opitz (2013), Reitzig et al. (2010), Scott Morton and Shapiro (2013), Shapiro (2012), Shrestha (2010), Tucker (2013)	Addy and Douglas (2012), Alexy and Reitzig (2013), Bessen et al. (2012)*, Fischer and Henkel (2012)*, Hall (2009), Hall and Ziedonis (2007), Johnson et al. (2007), Lemus and Temnyalov (2013), Mayergoyz (2009), Morgan (2008), Pohlmann and Opitz (2013), Reitzig et al. (2010), Scott Morton and Shapiro (2013)
"Patent brokers"	Benassi and di Minin (2009)*, Gredel et al. (2012), Hagiu and Yoffie (2013), Millen and Laurie (2008), Monk (2009), Pollard (2006), Tietze (2008), Waltl (2013), Yanagisawa and Guellec (2009)	Benassi and di Minin (2009)*, Gredel et al. (2012), Hagiu and Yoffie (2013), Henry (2011), Kirk and Pollard (2002), Millen and Laurie (2008), Monk (2009), Pollard (2006), Tietze (2008), Waltl (2013), Wang (2010), Yanagisawa and Guellec (2009)
"Patent intermediaries"	Abril and Plant (2007), Agogué et al. (2013), Benassi and di Minin (2009)*, Benassi et al. (2012), Gredel et al. (2012), Hagiu and Yoffie (2013), Hefeng and Yang (2011), Huang and Chang (2010), Kirk and Pollard (2002), Millen and Laurie (2008), Monk (2009), Pénin (2012), Pollard (2006), Tietze (2010)	Abril and Plant (2007), Benassi and di Minin (2009)*, Benassi et al. (2012), Ford and Ryan (1981), Hagiu and Yoffie (2013), Hefeng and Yang (2011), Hine et al. (2010), Kirk and Pollard (2002), Millen and Laurie (2008), Monk (2009), Pollard (2006), Tietze (2010), Wang (2010)

(continued)

Table 2 (continued)

Keywords	Innovation	Technology
"Patent trolls"	Alexy and Reitzig (2013), Ball and Kesan (2009), Bessen et al. (2012)*, Blonder (2005), Boyle (2012), Dalmarco et al. (2011), Fischer and Henkel (2012)*, Fusco (2012), von Graevenitz et al. (2011), Graham and Sichelman (2008), Gredel et al. (2012), Hagiu and Yoffie (2013), Hall and Ziedonis (2007), Helm (2006), Henkel et al. (2012), Henkel and Reitzig (2010), Johnson et al. (2007), Kahin (2007), Kartus and Kukrus (2013), Khoury (2010), Lampe and Moser (2011), Laperche et al. (2011), Layne-Farrar and Schmidt (2010), Lee et al. (2013), Léger (2007), Lemley (2008), Litan et al. (2008), Macklem (2005), Magliocca (2007), Mayergoyz (2009), Merges (2009), Pénin (2012), Pénin et al. (2011), Polhman and Opitz (2010, 2013), Reitzig et al. (2006, 2010), Schultz and Urban (2012), Schwiebacher (2012), Shrestha (2010), Trappey et al. (2012), Tucker (2013), Turner (2011), Veer and Jell (2012), Wang (2010)	Abril and Plant (2007), Allison et al. (2009), Benassi and di Minin (2009)*, Bessen et al. (2012)*, Blonder (2005), Dalmarco et al. (2011), Fischer and Henkel (2012)*, Fusco (2012), von Graevenitz et al. (2011), Graham and Sichelman (2008), Graham et al. (2009), Gredel et al. (2012), Hall and Ziedonis (2007), Helm (2006), Helmers and Rogers (2011), Henkel and Reitzig (2010), Johnson et al. (2007), Kahin (2007), Kim and Song (2013), Layne-Farrar and Schmidt (2010), Lemley (2008), Macklem (2005), Magliocca (2007), Mayergoyz (2009), Mello (2006), Merges (2009), Park et al. (2012), Pénin (2012), Polhman and Opitz (2010, 2013), Reitzig et al. (2006), Shrestha (2010), Somaya (2012), Trappey et al. (2012), Tucker (2013), Veer and Jell (2012)
Snowballing	Bessen and Meurer (2012), Bone (1998), Chien (2010), Cotropia (2010), Dequiedt and Versaevel (2013), Ford and Ryan (1981), Henkel and Reitzig (2010), Love (2013), Macdonald (2004), McDonough III (2006), Niro and Greenspoon (2007), Risch (2012), Su (2011), Turner (1998)	

*Original retrieved source substituted by publication in academic journal

Table 3 Number of publications and classification in percentages

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Total
Total	1	2	5	8	6	11	9	10	18	15	85
Practitioners' view	–	100%	–	38%	17%	–	–	20%	6%	13%	13%
Propositional	100%	–	100%	38%	67%	55%	67%	20%	39%	20%	44%
Statistical analysis	–	–	–	13%	17%	36%	11%	10%	22%	13%	16%
Quant. mod./ regression	–	–	–	–	–	–	22%	40%	22%	27%	16%
Qualitative analysis	–	–	–	13%	–	9%	–	10%	6%	–	4%
Case studies	–	–	–	–	–	–	–	–	6%	27%	7%

Furthermore, the use of the keywords 'technology' and 'innovation' yielded similar papers; that possible indicates that the terms 'technology' and 'innovation' are loosely used. On closer inspection of papers it seems that most use 'innovation' and 'technology' as a substitute for 'invention'. In the context of this paper, innovation stands for those new products (or services) that are introduced in the market (conform canonical definitions). However, this finding and this note have little bearing on the analysis of the sources in the context of the study.

2.2 *Interpretation of Retrieved Sources*

After the check on relevance and inclusion in the review, the papers were scrutinised. To this purpose, a spreadsheet was used for recording the research methods, for evaluating the (theoretical) contributions from the perspective of innovation process and technological developments in (specific) industrial sectors, and for noting how the sources addressed the research questions (posed in the beginning of this paper). For the research methods a classification 'propositional' was used if the paper was a literature review or proposed a new line of inquiry or was mathematical modelling without using (empirical) data. Also, many of the publications in the discipline of law were categorised as propositional; though advances are made in law through constructivist papers and discourse, the label propositional was justified since the impact on the innovation process was hardly underpinned with empirical evidence. The classification and analysis in the spreadsheet paved the way for directing the empirical component of the study.

With respect to what NPEs are, only a limited set of papers presents typologies. These categorisations have been summarised in Table 4. Without dwelling too much on definitions, a distinction in this paper has been made between those that hold patents but do not practice them (NPEs) and those that act as intermediary for commercialisation of IP but do not hold any patent or IPR; the classification in the table is a variant of Tietze (2008, 2010) with the purpose of making this distinction more explicit. Note that for legal terms an other classification is often used, the one proposed in the unpublished work by Lemley and Myrhvold (for example, cited by Allison et al., 2009, p. 10); however, this classification was found less appropriate for the purpose of assessing the impact of NPEs on innovation processes. It might be that specific papers use different terminology but these have been classified in the terms of Table 4 as much as possible to demonstrate that studies do not cover necessarily all types of NPEs and intermediaries. Within the context of this paper, the onus is on the category of NPEs.

Since this study focuses on the impact of NPEs on innovation processes and technology development, the interest goes to empirical research. Given the high rate of propositional papers, see Table 3, it seems that this specific research domain is full of opinions, commensurate with the notion by Fischer and Henkel (2012, p. 1521). This gravitation towards opinions is partly due to the number of papers that address the legal aspects of NPEs. In these papers, authors dwell on court cases and implications, often resulting in propositions for improving the legislature of the patenting system. From the perspective of the impact of NPEs on innovation processes and technological developments, the actual papers containing empirical research are limited; those empirical papers have been captured in Table 5. Might this few papers shed some light on the impact of NPEs? This analysis is the next step of the systematic literature review.

2.3 Reflecting on Direction of Research

The majority of the retrieved papers focus on legal aspects and their consequences, especially with respect to litigation costs and judicial awards, and holds what one could call a 'traditional' view. It should be noted that some, as can be derived from statements by Chien (2010, p. 1572) and Risch (2012, pp. 466, 498), claim that patent extortionists only constitute a very small percentage of the legal cases in the U.S.A., despite the fact that they get a lot of attention. Love (2013, p. 1312) states that 'though asserting just over 20% of all studied patents, NPEs account for more than two-thirds of suits and over 80% of infringement claims litigated in the final three years of the patent term'. This indicates that NPEs intent to maximise monetisation. In the canonical perspective propagating practices of litigation, NPEs, particularly the 'patent trolls', facilitate innovation because they offer smaller firms and inventors the possibility for protective litigation (e.g. Shrestha, 2010, pp. 149–50) and contribute to their liquidity (Risch, 2012, p. 459). However, Bessen et al., (2012, p. 35) note that small firms and independent inventors benefit little from what larger companies lose. In addition, a large part of the works also state that litigation diverts cash-flows from R&D investment into litigation costs, judgements and settlements; for example, Bessen and Meurer (2012, p. 19) estimate this to be $ 29 bln. in 2011 (5842 defenses concerning U.S. 2150 firms). In this context, it should

Table 4 Typologies in publications

Source	Purpose of study	NPEs					Intermediaries						
		Patent aggregators	Patent intermediaries	Patent pools	Patent troll	Technology transfer offices	IP Auctions	IP Brokers	IP Consultants	Innovation intermediaries	IP Intermediaries	Licensing agent	On-line brokerage
Benassi and di Minin (2009)	Patent brokers	•			•	•		•	•				
Chien (2010)		•			•	•							
Chien (2010)		•		•	•	•							
Fischer and Henkel (2012)	Acquisition by NPEs	•	•		•	•							
Hagiu and Yoffie (2013)	'Patent intermediaries'	•		•			•						•
Love (2013)	Patent assertion	•	•	•	•	•							
Millen and Laurie (2008)	Practitioners' point of view	•	•	•	•	•	•	•	•				•
Tietze (2008, 2010)	External commercialisation	•	•	•		•	•	•	•			•	•
Wang (2010)	Rise of intermediaries	•			•			•					
Yanagisawa and Guellec (2009)	Patent markets	•	•	•		•	•		•	•		•	•

Table 5 Overview of empirical studies (by keywords during retrieval)

Keywords	Empirical studies
"Non-Producing Entities"	Alexy and Reitzig (2013), Bessen et al. (2012), Chien (2013), Fischer and Henkel (2012), Hall and Ziedonis (2007), Jeruss et al. (2012), Lemus and Temnyalov (2013), Mayergoyz (2009), Mazzeo et al. (2013), Pohlmann and Opitz (2013), Reitzig et al. (2010), Shrestha (2010), Tucker (2013)
"Patent brokers"	Benassi and di Minin (2009), Gredel et al. (2012), Waltl (2013)
"IP intermediaries"	Agogué et al. (2013), Benassi and di Minin (2009), Benassi et al. (2012), Gredel et al. (2012), Hine et al. (2010)
"Patent trolls"	Alexy and Reitzig (2013), Allison et al. (2009), Ball and Kesan (2009), Benassi and di Minin (2009), Bessen et al. (2012), Dalmarco et al. (2011), Fischer and Henkel (2012), Graham et al. (2009), von Graevenitz et al. (2011), Gredel et al. (2012), Hall and Ziedonis (2007), Helmers and Rogers (2011), Kim and Song (2013), Lampe and Moser (2011), Laperche et al. (2011), Magliocca (2007), Mayergoyz (2009), Pohlmann and Opitz (2013), Reitzig et al. (2010), Schwiebacher (2012), Shrestha (2010), Trappey et al. (2012), Tucker (2013), Turner (2011), Veer and Jell (2012)
Snowballing	Bessen and Meurer (2012), Chien (2010), Love (2013), Risch (2012)

be noted that the legal patenting regime in the U.S.A. differs from the arrangements in most of Europe, effectively leading to less cases and less questionable court cases by patent trolls (Mayerogoyz, 2009, p. 257 ff.); that is reflected in which countries are addressed in the retrieved papers, see Fig. 1 (note that 30% of the papers have not defined which national legislative system they addressed). Most interestingly, Magliocca (2007) points out to a parallel situation in the nineteenth century when farmers were targeted by 'patent sharks', much alike today's activities by patent trolls. However, generally speaking, NPEs, particularly patent trolls, are seen as hindering innovation because their activities divert resources from R&D to costs of litigation and could ultimately even result in higher prices for consumers, affecting competitive positions.

At the same time the overview by Hall (2009, pp. 5, 7) notes that increased innovation activities due to the patenting systems is most likely to happen in pharmaceutical, biotechnology and specialty chemicals sectors, and possibly in medical and scientific instruments and small-scale machinery sectors. In fact, a little later she states that firms consider generally lead-time for new product and service development and superior sales and service more important for appropriation of returns on product and service innovation. Others (e.g. Kahin, 2007, p. 389) have suggested that the pharmaceutical, biotechnology and specialty chemicals sectors benefit from patent protection, whereas the electronics and ICT sectors could be subject to litigation, particularly by patent trolls. Several studies (for example, Allison et al., 2009, p. 18; Henkel & Reitzig, 2010, p. 130; Risch, 2012, p. 477; Scott & Shapiro, 2013, p. 3) point out to software, data-processing and other ICT related domains being the most litigated by NPEs; that is often attributed to incremental innovation taking place and that products (and services) are complex making them more vulnerable to litigation. A case study by Tucker (2013) shows that incremental innovation comes to a halt and

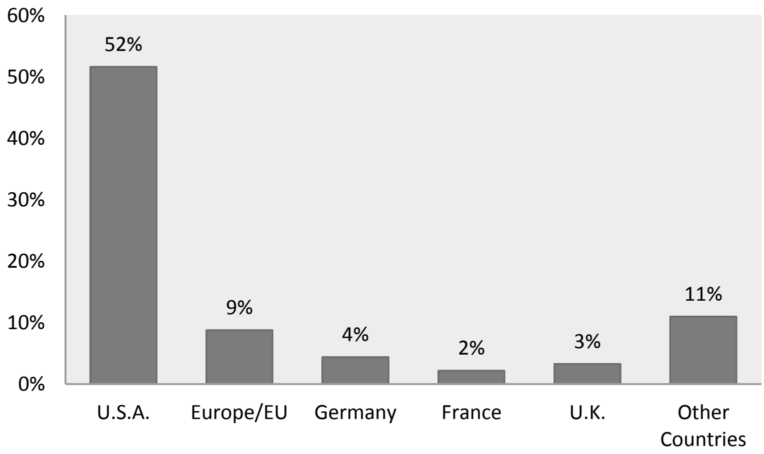

Fig. 1 Countries addressed in retrieved papers

consequently sales decline during the period of litigation. The distinction between incremental and radical innovation for the effects of litigation is also mentioned by others (for instance, Magliocca, 2007, p. 1820), though interestingly the term 'radical innovation' is not used by these types of works (perhaps underlining the weak connection to 'theory' for innovation management). This leaves others to reason that radical innovation is more common among independent inventors than firm-based inventors (e.g. Morgan, 2008, p. 177). Nevertheless, this leads only to conclude that the impact of NPEs has been mostly studied at an aggregate level and not in detail with respect to the consequences for innovation processes and technological developments in sectors.

In addition to these aggregate effects, little is written about the actual role of NPEs in terms of the impact on innovation processes and technological developments in (specific) industrial sectors. Even though touched on in the sources with a legal perspective, the impact of the activities of NPEs on innovation processes and technological developments in industrial sectors continues to be elusive (e.g. Risch, 2012, p. 461). In this perspective, Hall (2009, p. 5) states that 'economic theory yields in an inconclusive answer to the question of whether patents encourage innovation in general'. Differently, Greenspoon and Cottle (2011, p. 205 ff.) discuss three economic theories (reward theory, prospect theory and commercialisation theory), but only hint that NPEs might fit better with commercialisation theory. In this sense, Pollard (2006, p. 166) states that '… innovation may be multi-layered as well as being a multi-factored process', but does not go into further detail. Henceforth, little is known about the actual role of NPEs in addition to the lack of knowledge about their impact on innovation processes and technology cycles.

Inherent to their nature, a more active role in terms of engaging is only found in intermediaries (not the primary focus of this study, though frequently mentioned in publications). Mostly they are seen as networking opportunities (e.g. Howells, 2006,[1] p. 724) or as creative hubs (for example, Agogué et al., 2013) connecting 'users' and 'providers' of technology. Benassi and di Minin (2009, p. 83) also confirm that the role of connecting diverse parties for technology and knowledge transfer is an important one for intermediaries. But even for these studies hardly any theories are formed except for classification and typologies of these actors (see Table 4); although it is clear that these intermediaries seek an active role for commercialisation they do not hold any patents and thus are not directly considered further in the deliberations of the paper.

Therefore, the findings from the systematic literature review suggest that whereas NPEs are receiving more academic attention, their actual impact on innovation process and technological developments in (specific) industrial sectors remains under-researched. This finding has far-reaching implications for industry. While companies find themselves drawn to active patent management, its impact and necessity are ill-understood. Hence, the conjecture necessitates research that looks at aspects for innovation process and technological developments in (specific) industrial sectors to understand how companies and industrial sectors should deal with NPEs and patenting strategies; consequently, this should be done in terms of patenting as intervention and countermeasures in the innovation process and technological development.

3 Research Methodology

Because the activity domain of NPEs is relatively specialised, potentially diverse and the impact on innovation processes and technology cycles poorly described, the consultation of experts was the natural choice for this research for finding out to which interventions and countermeasures patenting leads and what the role of NPEs is in this matter. For the consultation of experts two methods have been combined. One was the traditional method of interviews to obtain insights from experts about activities and impact of NPEs on the innovation process and technology cycles. Experts were chosen with complementary knowledge about NPEs, following guidelines by Homburg et al. (2012) and Kumar et al. (1993). The panel included key informants from patent law firms, university technology transfer offices, academic experts and experts from firms providing IP services others than those of classical legal services provided by patent law firms (e.g. patent analytics). The second research method was a focus group. According to Kitzinger (1994, p. 116; 1995, p. 302), the use of focus groups has advantages in terms of engagement with participants and elevating topics that might not have come to the table during interviews. Hence, the topics of the focus group were directed at forming theory for innovation processes and

[1] This paper was not included in Table 2 due to its scope only being intermediaries that are not holding patents.

the position of NPEs in it. Both methods for data collection yielded complementary insight for addressing the three research questions.

3.1 Design of Research Instrument for Interviews

For the interviews, it was essential to elicit as accurately as possible and open-minded the impact of NPEs on innovation processes and technological developments. To achieve this, five models and one classification of archetypes were chosen for the interviews and for provoking discussions with the experts:

- The innovation funnel, derived from Dunphy et al. (1996) and Stevens and Burley (1997).
- The open innovation process, derived from Tidd (1995) and Chesbrough (2003).
- The interrelationship between major innovative activities, derived from Kline and Rosenberg (1986).
- The model for technology cycles, derived from Anderson and Tushman (1986).
- The model for collaborative networks, derived from Dekkers (2009).

These models illustrate the innovation processes and development of technologies from different perspectives. To support the interviews and to evoke responses from the interviewees a visualisation was used. That was done because the use of visualisation has been connected to exploratory research (e.g. Knigge & Cope, 2006) and might even stimulate interviewees' thoughts (Crilly et al., 2006, p. 345). Hence, the semi-structured interviews with visualisations offered the potential to engage in rich dialogue with the interviewees.

3.2 Selection of Experts

The twelve experts for the interviewees were drawn from those active in two specific European countries (the choice for Europe is partially justified by Fig. 1, which demonstrates that European countries are looked at less than the U.S.A.); the countries are similar in size of the economy and legal context. The experts wished to remain anonymous, mainly due to the sensitivity of the information disclosed as well as the community of practitioners being relative small. This corresponded with the motivation in terms of anonymous consultation of experts. The spectrum varies from academics to practitioners, from IP generators to those that commercialise, from wider perspectives of innovation processes and technological developments to actors with specific functions (see Table 6). The variety also induced a wide variety of responses, but above all elevated relevant aspects.

Table 6 Overview of interviewees

	Role	Country	(Main) activities
A	Professor	I	Open innovation, fuzzy front end of innovation
B	Chamber of Commerce	I	Advisory services to companies, knowledge centre for IP
C	Patent consultant	I	Intermediary, consultancy for patenting and commercialisation
D	Professor/patent lawyer	I	Copyright, patent law, infringement cases
E	IP Consultant	I	Consultancy for patenting, developer of software support
F	Technology Transfer Office	I	Patenting and commercialisation of inventions of regional universities
G	Patent lawyer	I	Advisory services, patent law, infringement cases
H	Associate Professor	II	Intellectual property rights
I	Professor	II	Innovation, intellectual property rights
J	Patent lawyer	II	Copyright, patent law, infringement cases
K	Chambre of Commerce	II	Advisory services to companies, knowledge centre for IP
L	Patent lawyer	II	Copyright, patent law

3.3 Data Collection and Analysis from Interviews

Given the nature of the domain and interaction necessary with the experts, handwritten notes were made during the interviews. After the interview, the notes were recorded in documents, one for each interview. Surprisingly, some of the questions made the interviewees ponder on their response. Whereas some of them liked chatting away about specific cases and trends or responding to more specific matters (mostly for clarification), questions related to impact on innovation and technological developments proved difficult. Such responses were recorded, too. In this sense, the interviews yielded ‘stories’ for illustration, insight in actual practices of NPEs, directions of travel for industry next to direct responses to the ‘interview guide’ with its visualisations.

The analysis followed more Foucault’s approach then a typical process of coding and aggregation as typically found in the approach of grounded theory. As Allan (2003, p. 1) states, in principle, the grounded theory investigates actualities in the real world and analyses the data with no preconceived hypothesis (Glaser & Strauss, 1967). In this case, the available models served as a starting point, which gave the research preconceived knowledge, rendering grounded theory more or less obsolete. Since the study was consulting experts, it made more sense to use Foucault’s (1969) principle of discourse analysis. This allowed extracting relevant statements of the experts rather than focusing on all statements during the interview.

3.4 Design of Focus Group

The outcomes of this research formed the input for a focus group meeting as complementary research method. To capitalise on the principal advantage of focus groups—participant interaction to gain in-depth and rich data, according to Webb and Kevern (2001, p. 804)—the meeting was structured. It used the main findings from the interviews and defined topics to set a discussion in motion about the feasibility of developing appreciative theory before formal modelling. In addition to a brief presentation of the outcomes from the interviews, see Section Results, basic models of innovation management and technology cycles were addressed (as during the twelve interviews). Hence, the onus of the focus group was on modelling of innovation processes and technology cycles, on the position of NPEs and on the interventions by actors that should be incorporated into appreciative theory. Minutes were taken for these themes and these notes were again analysed using Foucault's (1969) principle of discourse analysis. By building on the interviews and the models as starting point for the discussion, the set-up of the focus group complied with guidelines for best practice in conducting focus groups.

After structuring the focus group meeting, the only thing left was to select a group of experts for the focus group. Normally, it is advised to use a number of focus groups and to ensure homogeneity of the participants across these groups (Kitzinger, 1995, p. 300). In this case, only one focus group was organised with a research group in Europe. This group was specialising in innovation and technology management within a technological university, and the expertise of the group also included appropriation of IPR and open innovation. From the research group, twelve members participated, presenting senior researchers, early career researchers and doctoral students (the latter had gone beyond their literature review). Since one of the criteria for the number of groups is the expectation that subsequent focus group meetings will lead to furthering insight, the data collected from this first meeting with this particular European research group warranted no further meetings.

4 Results

The results of the interviewees and the focus group meeting have been analysed against the research questions posed at the beginning of the paper. Note that for the labelling of actors mentioned by the interviewees the classification in Table 4 has served as a guide, no matter how they designated specific entities.

4.1 What Are NPEs?

Returning to the role of the NPEs in the innovation process, the first research question, generically that was seen by the interviewees as tapping in the reservoir of unused patents (or IP). As an almost converse perspective, interviewee B saw NPEs as ‘risk investors’ and that this role means they are sieving out inventions that are failing (in terms of feasibility of new product and service development and opportunities for commercialisation). Moreover, some interviewees (such as E and G) also pointed to the role as generating IP, though that seemed to be based partly on exceptional cases and strategies; such an exception is an European patent aggregator that originated patents related to a standard for the sole purpose of obtaining licensing revenues as a monopolist of technological knowledge (intriguingly, the founder of this firm has been allegedly involved in setting the standard). According to interviewee A this should be placed in the context that private research organisations, contract research and universities have more opportunities for IP protection and therefore can be more active. Furthermore, NPEs could play a role in protecting IP, either by individual firms or cluster of firms that joined forces. Some of those strategies by (producing) firms for engaging with NPEs might find its origin in the lack of resources and the specific expertise needed for specific activities. However, almost all interviewees pointed to the ‘patent trolls’ as pariahs that extort other firms without participating in commercialisation (one interviewee had been directly involved in headline cases and gave a vivid account of tactics used). Hence, the views of the interviewees represent the spectrum for NPEs in Table 7.

4.2 Dynamics Caused by NPEs

The second research question focuses on the dynamics NPEs are causing. Ultimately, the most common view held by the interviewees is that NPEs shift the 3,000:1 effect of Stevens and Burley (1997) to an increase of the number of inventions reaching the marketplace; the impact on the generation of ideas was seen as being marginal. However, none of the interviewees was able to neither specify the effect nor indicate evidence that might underpin this belief. Therefore, this conjecture must be taken as an assumption about the effects of NPEs rather than as firm attestation. This implies that the role of NPEs for IP protection and commercialisation has become more prominent in the view of experts, but its impact undefined.

When looking into more detail at the positive impact of NPEs on the innovation process, generically speaking, the effects of individual activities and actions of NPEs could be easily identified, though not always agreed on. The overview of the positive impact is found in Table 7. Partly, this overview builds on the canonical conceptions of the effect of NPEs on innovation processes and technological developments in economic sectors. Where the positive impact from the experts’ interviews deviates is

Table 7 Impact of NPEs

	Specific impact	Interviewee(s)
Positive	Provide inventors and smaller companies with possibility for protection of IP and litigation	B, C, D, H, K
	Tap into the reservoir of unused patents for opportunities for commercialisation	B, C, K
	Offer IP commercialisation out with business models of firms	A, C, D, K
	Seed-funding	B
	Activities of NPEs might induce higher quality of patents	A
	'Patent trolls' could enforce design-around, only beneficial if more functional	A, C, E, G, H
	Activities of NPEs have lead to growing awareness in industry about IP, patenting and protection	A, D, E, H, I, L
	NPEs are creating new business models for IP	F, G, J
Negative	Particularly 'patent trolls' increase litigation costs at the expense of investments in R&D	A, D, H, I
	Generation of ideas and new product and new service developed inhibited by patent thickets and pools	G, H
	Disturbing market for technology licensing and technology transfer	D, F, H, I
	Quality of patents is source of litigation and ambiguity	H
	NPEs are closed once they have acquired IP	G, L
	'Patent trolls' create a negative image for patenting and litigation	D, G, J, L

especially that design-arounds should be more functional than the patent they try to avoid and the notion that the activities of NPEs might increase the quality of patents.

The negative impact of NPEs on innovation processes is also presented in Table 7. Again, commonly held perspectives are found here. However, remarks were made about how NPEs are disturbing the markets for technology licensing and technology transfer. Moreover, some NPEs create patent thickets for blocking developers of new products and services from tapping into specific technologies or that for specific functions in products and services they hold (all) relevant patents. Again, the case was mentioned in which a particular firm had built a dominant position in that manner (it was told that this amounted to a monopoly position that was consequently blocked the European Community). Hence, patenting, IP commercialisation and innovation are hindered by the activities of the NPEs.

Notably, interviewee E explained that the activities for patenting and the involvement of NPEs is not restricted to specific phases of the innovation process or the stage-gate approach for new product and new service development. According to him, activities for assessing patent portfolios happen on a continual basis. Moreover, in the discussion came up that dormant patents may have more effects than those actually in use. The consequence is that continuously using a feedback and feedforward mechanism 'producers' have to assess infringement of IP and the generation of IP for diverse reasons, including appropriation of patents in the future and defensive patents strategies.

4.3 Impact on Effectiveness of Innovation Processes and Technology Cycles

Nevertheless, from the interviews it can be derived that NPEs act on three related levels of aggregation (see Timpf [1999, p. 131] and Dekkers [2009, pp. 44–47] for a generic explanation of aggregation). At the first level, NPEs have an impact on processes of individual firms; that could be either defensive strategies, such as design-around and striving for higher quality patents, or commercialisation of patents [used or not used by the firm itself]. The second level of the effect NPEs have is on technology cycles within specific industries, for example, collaborative arrangements to limit or guard competitive positions and inducing the intensity of innovation. Third, NPES can affect innovation processes across sectors, for instance by appropriating IP beyond the firm's industry, licensing approaches and complex products that integrate diverse disciplines. Despite statements about these effects of NPEs for all three levels, interviewees found it more difficult to give examples of successful activities and attribute it to one of these levels. However, interviewees C and H mentioned that commercialisation of IP was easier in 'mechanical' products, electronic products and IP related to physics and chemistry than IP pertaining to ICT, software and service design. It should be noted that none of the interviewees made a similar remark. Combined with statements in some paper found during the retrieval process for the literature review that indicates that commercialisation of IP must be considered in industry (or sector) specific context.

For the analysis of the interviews this leaves to look at the models as potential representation for the impact and effectiveness of NPEs' activities. Table 8 contains the overview of the responses by the interviewees to the models. The widespread responses possibly indicate that it is difficult to position NPEs in the existing models for innovation and technology cycles. It is evident that actor-oriented modelling would be necessary but it is not directly clear how. Some of the points mentioned direct towards game-theoretical approaches, however, that seems to apply more to specific situations of IP, decision-making and negotiations. This means that the interviews did not directly set out the contours of generic modelling for integrating appropriation of IP in the levels of innovation mentioned in the previous paragraph; such generic modelling could be used by other researchers and would allow developing more coherent views across studies; otherwise, the 'academic' views on NPEs are set in a flux of discourse of subjective positions on their merits and detrimental effects.

Table 8 Responses to models for innovation processes and technology cycles

Model	Responses	Interviewees
Innovation funnel	• Does not represent role of NPEs	A, H, I
	• Opportunities for NPEs at 'gates' as selection mechanism	A, B, H, I
	• NPEs are positioned in innovation funnel	C, E, L
Open innovation	• Opportunities for NPEs at 'gates' as selection mechanism	A, B, I, K
	• Position of NPEs in idea generation through various mechanisms	E, G, J
	• New service development less likely to rely on external ideas/inventions	B, K
Interrelationships major innovative activities	• Not suitable; onus on singular firm	A, C, G, H, I
Technology cycles	• Not applicable or suitable for IP	A, C, I
	• Too much focused on single product	B, I, K
Model for collaborative networks	• Actors are visible in interaction	A, H
	• Focus of model on production and supply chain	E, F, G, L

Moreover, the results from the focus group point in the same direction; see Table 9. Again, the lack of appropriate formal models was noted; this contention that empirically developed theories for innovation management are not adequately encompassing appears in the work of Damanpour (1996, p. 693) and Tidd (1995, p. 180), too. In addition, inventors, practicing firms, intermediaries and NPEs have very different roles; by way of illustration, the study by Howells (2006) gives some insight in the diversity of activities and business models of intermediaries. Consequently, such diversity lends itself to a wide variety of exchange relationships, making modelling extremely difficult. Alternatively, modelling might lead to an oversimplification as present in some of the papers found during the literature review. Without modelling and sufficiently encompassing causal models, it will be difficult to establish how markets for technology can be shaped or governed (or alternatively academics have to undertake advocacy research, perhaps).

4.4 Archetypes of NPEs

The final part of the interviews consisted of the verification of the archetypes for NPEs. In the four out of the five archetypes from Table 4 ('patent pools' as collaborative agreement between firms for often defensive and competitive reasons were not included), the private and contract research organisations were missing, according to interviewee A; although at the same time it was said that they might be viewed partly as inventors and universities. Interviewee B found that 'risk investors' were missing;

Table 9 Outcomes of focus group

Topics	Responses
Generic models for innovation management and technology cycles	• Models for innovation management do not account sufficiently for effects of innovation funnel • Lack of adequate models beyond Schumpeter's destructive business cycles, organisational routines, etc. • Evolutionary (biological) models might provide some base for modelling but connect weaker to internal processes for technology and innovation management (i.e. internal to firms) • Large numbers of studies focus on determinants, without necessary developing causal models; this hinders generic models and fecundity
Position and role of NPEs	• Actors within technology cycles and innovation management: inventors, producing firms, commercial research institutes, universities, intermediaries, NPEs (see Table 4 for classification) • Different actors having different roles and business models (for example, implying that agent-based modelling might be limited) • Also, interaction between actors vary significantly depending on business models, approaches to monetisation and strategies for commercialisation
Interventions by NPEs and firms (from the perspective of appropriation of IPR)	• Different NPEs (and intermediaries) aim for different interventions, but range from commercialisation to monetisation of practised patents (patent trolls and patent aggregators primarily through litigation) • In addition, firms have diverse strategies: selling of patents, acquisition of patents, (defensive) patent pools, licensing among them

these venture capitalists might want to acquire IP for start-ups and then later sell off the companies. Since these venture capitalists build on the feasibility of ideas, they are hardly active in the fuzzy front end of innovation. Also, interviewee B pointed out that technology transfer offices are far more diverse than suggested by the classification. Interviewee C made a strong plea that IP brokers have a different business model than patent intermediaries; the latter take risk, whereas the former more or less negotiates between two parties but has no involvement with the risks associated with patents; this was also hinted at by interviewee H. Both interviewees C and F did not see the distinction between universities and technology transfer offices, since they are interconnected, no matter the form it takes (e.g. collaboration between universities for commercialisation or separate legal entities for knowledge transfer). Furthermore, interviewees G and I suggested that there are also 'knowledge-producing entities' that solely focus on generating patents for the purpose of creating patent thickets that inevitably lead to licensing of IP. Therefore, the interviews provided evidence that either the classifications in Table 4 might need to be revisited or that the diversity in forms of NPEs is so large that a classification is of little use (also, the latter is an alternative inference that might be drawn from Howell's [2006] study on intermediaries).

5 Discussion of Findings

In the network of actors and from the perspective of our research, the first question is when and how does IP commercialisation take place? The traditional view is that IP is patented and subsequently offered to interested parties for developing product and services. Principally, such is reflected in the underlying literature that takes a linear view. By contrast, most of the interviewees saw IP commercialisation as a more intricate process where there is a continuous interaction between actors to generate IP, to identify opportunities for commercialising IP, to monetise IP and to take competitive measures to protect IP. That means that even during the new product and service development process there might be continual, iterative loops for assessing IP identification, exploitation and protection. Moreover, tools are being developed to facilitate this process for all actors in this process, which lowers access to IP. With the procedure and processes for registering IP remaining relatively stable, this might lead to more incentives, from a diverse nature, to identify and to commercialise IP. This finding that the process surrounding IP have become more intricate and that all actors are more active, appeared in most interviews.

Despite colourful stories, scaremongering and making the case for their own perspective, the impact at an aggregate level was very difficult for the interviewees to pinpoint or even foresee. Some of the effects for individual firms are quite clear in terms of cash-flow for R&D (or inventions) perhaps diverted to the cost of protection and litigation; however that does not justify the conjecture that innovation is hampered since companies could create a design-around or take advantage of modular design to limit or divert the effects of infringement. However, it was less clear how the activities of NPEs and the more prominent role for IP are affecting technological developments in industry. This said, because of the dynamics that NPEs are causing, firms are compelled to pay attention to it; in game-theoretical terms this would be called tit-for-tat and in management terms the Abilene paradox (Harvey, 1974). In addition, interviewee G stated that patents (and IP) are more and more treated as a commodity; if so, it becomes subject to trading, speculation and making deals, which does not necessarily equate with turning inventions into new products and new services. In other words, despite the intentions of some or all of the actors, a situation for patenting, litigation and constantly looking over the shoulder has been reached, that nobody necessarily wanted.

From a theoretical perspective, the focus group adds that modelling has become extremely difficult because of the variety in actors and their broad arsenal of interventions resulting in a high variety of exchange relationships (as base for social-economic relationships). This comes suspiciously close to Rosenblueth's and Wiener's (1945, p. 320) statement that '… the best material model for a cat is another, or preferably the same cat'. This would be good news for positivists who take the stance that the identification of factors in a real situation will lead (implicitly) to theory-building (e.g. Weick, 1995, p. 388). However, research does not contribute to theory unless it is woven into a logic of 'why', according to Sutton and Staw (1995, p. 378). Moreover, this study shows that inevitably that due to the context of the activities, the diversity of roles and contributions to commercialisation of inventions (better, patents) and the potential range of exchange relationship that any study will only be partial. Since appreciative theory is more or less ruled out due to this variety, modelling is difficult or insufficiently encompassing; hence, the original mission of this research (see Subsection Research Objectives) could not be established.

Returning to the practical side, despite this trend towards trading of IP (and patents), it is becoming apparent that IP services provision is becoming more professional. Whether this professionalism effects positively the innovation process and the technology developments in industries remains uncertain. However, and in addition, the growth of awareness among actors has caused a shift in thinking and dealing with IP.

6 Concluding Remarks

Putting it all together, this paper makes three contributions to scholarly knowledge. First, it highlights that although the view that activities caused by litigation siphon funding from R&D is predominant, some are of the opinion that NPEs may also have a positive impact by forcing firms to look for innovative design-arounds and by leading to increased quality of patents. However, actual evidence for both perspectives is thin and could not directly be evidenced in this study. The second contribution is that the activities of NPEs have led to more are awareness for patenting. In this respect, NPEs take different forms with different purposes; for example, intermediaries focus on commercialisation of patents whereas patent trolls seek monetisation. Thus, when speaking about NPEs studies should clearly indicate which type of NPEs they are focusing on rather than considering it one and the same. In the interviews the different roles and objectives of entities were regularly mentioned. Third, activities by NPEs have made innovation more dynamic with more actors potentially involved in innovation and product and service development. This includes consultancy firms that provide information on granted patents and suggest patents to firms so that their IP for development of products and services is not obstructed. These contributions to scholarly knowledge pave the way for further research.

Even though the findings so far point in the direction of a diversity of actors, behaviours, approaches, etc., this study serve as starting point for further deliberations. The interviews brought to the fore a number of notions that might have been more difficulty captured by quantitative studies or case studies; a point in case are the 'knowledge-producing entities' that are creating patent thickets to create licensing incomes (see Table 7). Notwithstanding its limitations, the study has yielded findings stretching beyond the initial intent as reflected in the research questions.

6.1 Temporal Consideration

Since this study was conducted in 2014 and 2015, the question arises whether any new insight has emerged pertaining to NPEs and innovation performance of firms. With regard to the first research question, there are few studies that have looked at patent trolls and their influence on innovation. For example, Yin et al., (2022, p. 101695/11) using Chinese patent data find that patent trolls stimulate R&D expenditures and patent applications by firms, as long as they do not engage with patent trolls. However, they do not mention the mechanisms of design-arounds, mentioned in this chapter. Nevertheless, their research concurs with findings here. There is also evidence to the contrary. For instance, Cohen et al.'s (2015) review of evidence reports a negative effect on innovation in the US. And, Appel et al. (2019, p. 724) indicate the positive effect of anti-troll laws in the US on employment at start-ups. This means that the contradicting insights remain with regard to the effect of NPEs. As a second point, the diversity of NPEs this has been confirmed by further studies. A case in point is the study by Kwon and Drev (2020) into defensive patent aggregators, again based on data from the US. Sometimes, the different roles are not recognised by publications. By way of illustration, Thumm (2018), focusing on Europe, seems to focus more on patent trolls and alike, with some attention for universities and individual inventors, but does not address the broad variety in Table 4. This also means that the complex of interactions between the diverse actors with regard to patents, enforcement and litigation is getting less attention. A final point for the temporal considerations is that NPEs in the institutional settings, particularly patent trolls, have continued to attract more academic attention than their European counterparts. An example of an exception is the work by Sterzi et al. (2021) looking in the dormant NPEs in the UK. Moreover, other regions and countries are investigated, too, as illustrated by Yin et al. (2022) study into Chinese patent data. Thus, the contributions claimed by this chapter have stood the test of time.

6.2 Managerial Implications

For practice, it has become clear that the attention for monetisation of patents and the headline cases by NPEs have increased awareness in firms to actively manage a portfolio of patents (whether as single firm or as collaborative effort in patent pools). Particularly in industries, such as software and data-processing, this seemed to have turned into a tit-for-tat game (due to the stages of development leading to incremental innovation and products [or services] being 'complex'; both reasons make these types of industries vulnerable to litigation). Furthermore, add an increasing number of intermediaries and NPEs and there is now a situation in which actors have no choice than to behave the way they do and for others to set out defensive strategies.

For those defensive strategies, firms have an arsenal of interventions at their disposal. These interventions have an impact on product design and engineering processes, e.g. the use modular design to reduce effects of litigation and design-around to avoid litigation. Furthermore, to increase manoeuvring space for innovation processes, firms can opt for defensive patenting, collaborative aggregation, etc. Whereas there is a range of approaches, the literature is less conclusive towards what is best or most effective. In this sense, practitioners are left to their own devices, might have to rely on their experience and intuition and search for best practice; in terms of informed choices based on theoretical underpinnings, it will take a little time before research in this domain will reach a stage of maturity so that practitioners can be adequately informed.

6.3 Further Research

This applies also to this study; since this is the first step, the findings should be interpreted with care. Without doubt, next studies will lead to some shared conceptualisations and thoughts among the experts, but there will be also patches in the research where their opinions and evaluation of previous rounds will lead to continued difference of opinion. Nevertheless, the findings already lead to deliberations about the overall direction we are travelling. Are the NPEs just emerging and do we have to learn to deal with it? Temporary or not (some are likely to stay, some may disappear)? Are larger firms building their own expertise (more or less Late Schumpeter)? Or could we construct a reality in which NPEs have a overall positive impact on IP beyond awareness?

The study started with a post-positivist approach. However, the results and the findings indicate a more blurred picture than one would expect; no matter, the less-clearer conceptualisations also make it more difficult to create an overarching model for the overall activities of NPEs in relation to innovation process of firms and technological developments in industry. This means that research has to move towards a constructivist approach, rather; Delphi studies (see Gupta & Clarke, 1996; Landeta, 2006; Mullen, 2003) might serve an appropriate approach to do so, given the need to consult experts in a systematic manner.

6.4 A Final Thought

Nevertheless, given that the findings also indicate that the original quest has become more convoluted that raises doubts to what extent it will be possible to address the original research objectives at the beginning of this paper. While it is easy to highlight that NPEs have changed the landscape for IP commercialisation, and are still doing so, the diversity of approaches and developments indicate that the context and processes have not yet reached a stage of stability. At the same time, one might say that the diversity and the increasing awareness by all actors imply more maturity with regard to the appropriation and commercialisation of IP. Whereas some of the infringement cases make the headlines, most of the activities for IP commercialisation happen at the background, sometimes invisible to the naked eye. Does the complexity and the relatively obscureness of its activities make our search for excavating the role of NPEs and the modelling for their impact on the innovation process of firms and on the technological developments in industry a mission impossible? Time will tell.

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Regional and National Innovation Systems

Opportunities Recognition and Collaborative Networks in Converging Industries: Insights from Sustainability Transitions in Germanies Coal Mining Regions

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Abstract The necessity to mitigate climate change requires a major transformation of regional economies demanding for novel innovation systems. However, the evolution of a new regional innovation system depends on the capability of entrepreneurial actors to integrate distant knowledge and to recognize opportunities in novel inter-industry segments. This book chapter explores entrepreneurial opportunity recognition in a setting of inter-industry fields that emerge from the integration of hitherto unrelated fields. We draw upon the case of the German high-tech network "INNOSpace®2Agriculture" characterized by the collaboration of heterogeneous actors that need to remove existing barriers due to cognitive distances between different industry sectors (Space and Agriculture). We elaborate a new role of start-ups as a mediator between hitherto separated industry sectors. This book chapter contributes to the research body of opportunity recognition by shedding light on the particularities of cross-sectoral collaboration of partners from distant knowledge fields.

1 Introduction

The necessity to mitigate climate change requires major transformations of existing business models, value networks, infrastructures, and resource systems. For example, the decision to abandon coal mining in the Rhenish region triggers the question of how to foster "green growth" to engage in regional transformation toward new industrial districts and innovation system, which follow the vision of a sustainable, integrated bioeconomy. Consequently, local firms need to strategically react to the emerging dynamics of a new substitutive bioeconomic industrial setting. To remain competitive in this transformation process, opportunity recognition capabilities of

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regional firms seem to be crucial. This is because cross-sectoral collaboration (e.g., Farming and IT) is a key driver for regional sustainability transformation process. The integration of distant knowledge fields by industrial actors fosters the emergence of novel sustainable technologies and start-ups, which have a key enabling role for sustainability transitions in Europe (Geels & Schot, 2007; Laibach et al., 2019). These socio-technical dynamics mitigate the job loss due to phasing out current coal mining activities. The integration of technologies and development of new business lines outside the company's origin industry triggers the development of new inter-industry segments. Recognizing novel "hybrid" business opportunities arising at the interface of previously separate sectors is challenging for managers due to a lack of prior knowledge and industry experience. By integrating opportunity recognition and convergence literature, this book chapter contributes to our understanding of the role of start-ups for opportunity recognition. This book chapter explores cognitive distance as a barrier for entrepreneurial opportunity recognition and cross-sectoral collaboration that seem critical for the successful development of regional firms. We elaborate a new role of start-ups as a mediator between hitherto separated industry sectors and enabler for the emergence of inter-industry segments.

To this end, we draw upon the case of the German high-tech network "INNOSpace®2Agriculture", as an example reflecting heterogeneous firms dealing with cognitive distance in a collaborative network which arises at the industry boundaries of agriculture, high-tech and space—all relevant for the emerging bioeconomy in the Rhineland area. The chapter examines opportunity recognition in the context of convergence to understand competence-building-processes, network collaboration and interaction between incumbents and start-ups stemming from different backgrounds. The bridging function of start-ups between distant knowledge fields and distinct industry sectors (e.g., agriculture sector and space industry) seems to be an enabler for a successful opportunity recognition in the Rhenish lignite mining area. Given the need for sustainability transitions, we aim to understand how the adaptability of firms (Teece, 1988, 2007) and their opportunity recognition capabilities (Ardichvili et al., 2003; Shane, 2000; Tang et al., 2012) contribute to the combination of rather distant knowledge fields and technologies. We consider the analysis of firm-specific competence profiles and typology of firms as essential to draw conclusions on the regional innovation potential and transfer activities in collaborative networks that are impeded by existing barriers for knowledge integration.

2 Emerging Inter-Industry Segments as a Result of Convergence Processes

The emergence of new regional innovation systems seems crucial for the phase-out of coal in Germany's coal mining districts, as well as for the overarching socio-economic development of European regions toward a competitive and "SDG"-compliant future driven by transformative technological change (Dosi, 1988; Biggiero, 1998, Geels &

Schot, 2007; Jacobssona and Bergek, 2011). We understand industrial districts as local networks of SMEs, which are usually characterized by a highly innovative and self-organizing capability (Gary, 1993). In a territorial constraint region, SMEs should be strongly interconnected to enable a quick reorganization of entire cycles of industrial organization and response to environmental changes in a flexible way (Biggiero, 1998). Universities are expected to play a renewed supporting role to modernize increasingly knowledge-based economies, to transfer novel technologies into industrial applications (Etzkowitz and Leydesdorff, 1997; Geels & Schot, 2007) and to drive innovation success of regional firms (Bellucci & Pennacchio, 2016; Hewitt-Dundas et al., 2019; Laursen & Salter, 2004; Mansfield, 1995). We can observe that companies in traditional industries often fail to adapt fast and efficiently to changes in innovation-ecosystems due to path dependency and inflexibility (Leifer et al., 2001).

In any transformation process, industrial structures need to be replaced by new industry segments, which ideally emerge as a result of industry convergence. More particularly, industry convergence refers to the merging of previously separate industrial sectors, which previously operated separately from one another (Bröring, 2010; Bröring & Leker, 2007). Trends of industry convergence can be identified in many different areas and characterize a wide range of industries. From an entrepreneurial perspective, industry convergence represents a special setting, because communication between previously separate sectors via technology platforms that allow knowledge combination becomes essential for competitiveness. At the interface of converging sectors, companies face major challenges in terms of their ability to identify entrepreneurial opportunities. Collaborative cross-industry networks or open innovation approaches seem crucial to exploit these opportunities (Bröring, 2013; Bröring & Leker, 2007; Bröring et al., 2006). Companies directly or indirectly affected by the government's decision to phase-out coal mining must elaborate how to participate in novel inter-industry segments.

For the Rhineland, the field of Life Sciences (chemical, pharmaceutical, food and biotech industry) is a relevant example of previously separate industries, which overlap and form a completely new industry segment. Sectors such as Bioinformatics or Nutraceuticals (neologism of "nutrition" and "pharmaceuticals") reveal a fusion of knowledge areas, technologies, and value chains from traditional industries (Bröring, 2010; Curran et al., 2010). Therefore, companies are exposed to new fields of knowledge, new competitors, and industrial structures. In this context, different types of convergence exist depending on the extent of the process of convergence. The case of a complete merger of industries and formation of a single resulting sector is descripted as substitutive convergence ($1 + 1 = 1$). In contrast, complementary convergence ($1 + 1 = 3$) is present, if partial segments of separate industries merge or new inter-industry segments are formed while the original industries remain (the case of nutraceuticals) (Bröring, 2010; Greenstein & Khanna, 1997). A new industry segment emerges with hybrid products that combine functions from the different sectors of origin.

An example of substitutive convergence is the area of information and communication technology (ICT) in the early 2000s. Driven by technological leaps in the areas of information technology (IT) and communication technology (KT), new products were developed at the interface of formerly separate industries. For example, Apple succeeded in combining the formerly separate IT, KT, and entertainment industries in their final hybrid product. The development of the smartphone can be used as an illustration of the merging of knowledge, technology, and industry boundaries from several sectors. The almost complete displacement of conventional cell phones, MP3 players or Personal Digital Assistants shows the substitutive nature/power of industry convergence. The technical capabilities and the resulting combination of previously separate product characteristics as well as the broad applicability of the smartphone, for example telephony, data traffic, and photography, clearly show that a convergence process has taken place at the science, technology, product, and industry level, which ultimately leads to the emergence of new Technology Innovation Systems (TIS) (see Fig. 1). This can recently be empirically observed in life sciences (chemistry, biotechnology, food, and pharmaceuticals). New hybrid fields of technology such as bioinformatics and nutrigenomics are just a few examples of how new technology innovation systems are emerging between previously separate sectors.

As Fig. 1 illustrates, convergence dynamics between formerly separate industries are taking place on several stages. Ideally, a convergence process first runs through science convergence (proxy: similar publications from different fields of knowledge) followed by technology convergence (proxy: patents, co-classifications), market convergence (proxy: hybrid products), and finally complete industrial convergence (Curran et al., 2010). At the beginning of every convergence dynamic (whether product- or technology-driven) is an innovation process that complements, develops or replaces products, resources, processes, or technology bases of a company. The introduction of a groundbreaking new technology can be seen as a driver of innovation processes. In addition to technological changes, socio-economic factors can trigger innovation processes and resulting convergence dynamics. In times of radical technological progress and changing global mega-trends, dynamics of convergence

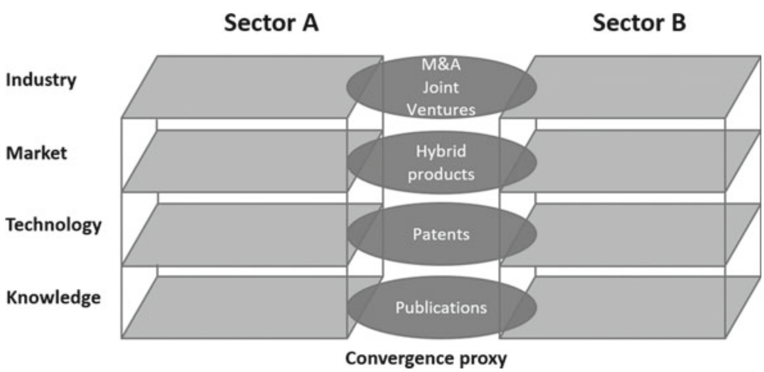

Fig. 1 Stages of convergence. *Source* Derived from Bröring & Craemer, 2020, p. 436

between different knowledge fields, technologies and industries are increasing at an even higher pace (Pennings & Puranam, 2001; Jeong, 2016).

Firms must overcome these challenges to strategically react in dynamic environments, enabling an adaptation of business models to exploit new entrepreneurial options in emerging inter-industry segments. Structural inertia, limited absorptive capacity, as well as cognitive distances inhibit the participation of firms in new inter-industry segments (Bröring & Leker, 2007; Duysters & Hagedoorn, 1998; Nooteboom et al., 2007). Prior research has examined the role of diverse cognitive frames within firms to sustain or break technological and innovative paths, given that cognitions are critical for firm decision-making and action (Thrane et al., 2010). Furthermore, organizations struggle to overcome their narrow search horizon and tend to focus on existing core competences to solve problems, resulting in constrained interpretation processes (Teece, 2007). Managers cognitions and dominant frames are deeply interrelated to the accumulation of organizational competencies by constraining and directing learning efforts, contributing to the organizational inertia of a company (Tripsas and Gavetti, 2000; Gavetti, 2012).

3 Challenges for the Opportunity Recognition in Converging Industries

Existing knowledge-, technology-, market-, and industry-gaps impair established firms to proactively identify entrepreneurial opportunities outside their own core business. A central barrier for the successful identification and development of entrepreneurial options is cognitive distance, which is defined by Nooteboom et al. (2007) as the heterogeneity of resources, organization, and perceptions between companies. Cognitive distance is found within and between sectors and results from heterogeneity of firms (industry-specific resources), different sensing capabilities and organizational focus, as well as from the diversity of competences and mental models, such as sense making, value judgments, and emotions (Nooteboom et al., 2007). Large cognitive distance implies novelty as an opportunity for firms, but simultaneously impedes sufficient mutual understanding. Entrepreneurship as the discovery, evaluation, and exploitation of opportunities for the creation of future goods and services (Shane & Venkataraman, 2000) creates cognitive proximity as a trade-off between novelty and efficient absorption (Nooteboom, 2000; Nooteboom et al., 2007).

Bridging of cognitive distances and overcoming competency gaps are pivotal for companies' innovative performance and their successful positioning in converging sectors (Sick & Bröring, 2022). In convergence settings, cognitive distance arises on the technology side as well as on the market side, making it more difficult to identify business opportunities.

Industry convergence, reflected by the integration of technology platforms and combination of product functions from different sectors, can lead to changes in

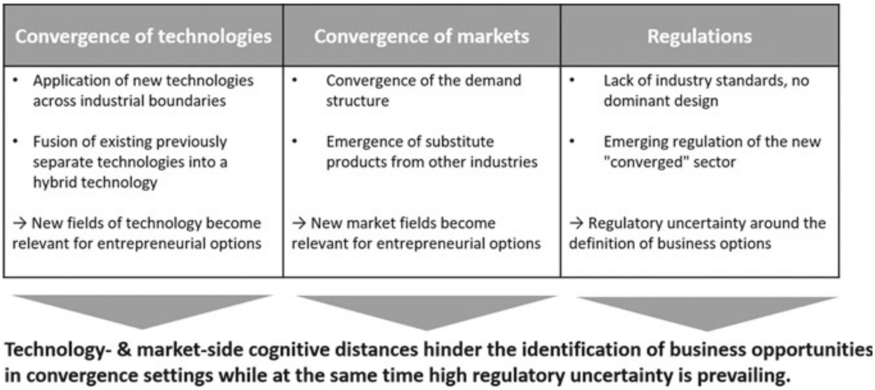

Fig. 2 Challenges regarding "opportunity recognition" in convergence fields. *Source* Derived from Bröring & Craemer, 2020, p. 434

entire industry structures. Missing industry standards and regulations as well as the limited comprehension of a novel dominant design leads to additional uncertainty making it more difficult to identify business opportunities (see Fig. 2). According to Alvarez and Barney (2005), the main challenge for established companies is to identify and exploit business opportunities before the future market is known. In times of convergence, companies must respond to competency caps and uncertainties about future business environments in terms of organization and resource allocation.

A key function is "absorptive capacity" as the ability to recognize the value of external knowledge, assimilate and integrate it successfully into production processes (Cohen & Levinthal, 1990). A high absorptive capacity enables companies to quickly and efficiently absorb know-how from formerly foreign sectors (Bröring et al., 2006). According to Cohen and Levinthal (1990), absorptive capacity increases with the amount of already accumulated know-how in the respective field of knowledge. It is difficult to identify entrepreneurial opportunities in converging industries and to enter cooperation with firms from other sectors due to path dependencies and the resulting cognitive distance. According to Cohen and Levinthal (1990) and Nooteboom et al. (2007), absorptive capacity can be increased through various channels such as investments in research and development, participation in cross-industry and innovation networks, involvement in alliances and cooperation with competitors, and changes in the organizational structure. Furthermore, the agility of a firm is described as a prerequisite for coping with uncertainties in a dynamic and innovative environment (Teece & Peteraf, 2016). In addition, Vecchiato (2015) identifies strategic agility and early anticipation of external changes as central to the creation of "first mover advantages".

4 Opportunity Recognition and the "Bridging Function" of Start-Ups

While current convergence literature explains the dynamics of converging sectors and its implications for companies, strategic management literature has scarcely discussed the role of competence-building and sensing capabilities (opportunity recognition) for technology-based start-ups in a convergence setting. Technology-based start-ups seem to play a crucial role when closing knowledge-, technology-, and industry-gaps between converging sectors and adapting to new business areas. Mature firms can take advantages by interacting with start-ups to deal with path dependency by creating more agile processes and advanced dynamic capabilities (Boccardelli & Magnusson, 2006). Start-ups appear to serve as a bridge for established companies to the "new sector" in a convergence field. Regarding the distinction between substitutive and complementary convergence, this results in different approaches for which start-ups play a central role. In the case of substitutive convergence, an open innovation process via cooperation and networks is elementary for the survival of companies, since the merging of several value chains can lead to a "phasing-out" of the own business model (Bröring, 2010). Faced with tendencies of complementary convergence, established companies can become active in the emerging field or keep focused on their old core business. In both cases, cooperation with start-ups appears essential to identify and exploit entrepreneurial opportunities.

We refer to Ardichvili et al. (2003) who propose a theoretical framework that identifies entrepreneurs' personality traits, social networks, and prior knowledge as crucial for the alertness to business opportunities (Fig. 3). The model is directly related to absorptive capacity (Cohen, Levinthal, 1990) as an expression of dynamic capabilities (Teece & Peteraf, 2016) and allows for several linkages between the literature of opportunity identification and convergence (Bröring, 2013; Clausen, 2013; Kim et al., 2015; Siedlok et al., 2010). The model defines the successful identification and development of entrepreneurial opportunities as an interplay of various factors such as personality traits (creativity, optimism), social networks (partnerships, inner circle), existing knowledge bases (markets, customers), and entrepreneurial alertness.

These factors (e.g., personality traits, alertness) are relevant for established companies, however advantages cannot be optimally exploited. We argue that smaller, agile start-ups therefore profit to a greater extent from these factors. Teece and Peteraf (2016) accordingly conclude that large, established companies can position themselves successfully in changing market environments, if they are led by "Entrepreneurial Managers" that are characterized by a specific entrepreneurial alertness and possess specific knowledge of markets and customer problems to effectively identify and exploit business opportunities. In this context, Teece and Peteraf (2016) highlight the role of start-ups and "corporate entrepreneurship" as key to the successful identification of opportunities. The need for established companies in converging sectors to absorb and accumulate external knowledge from concerned sectors consequently depends on the interaction with start-ups to identify novel opportunities and development of "Combinative Capabilities" (Kogut & Zander,

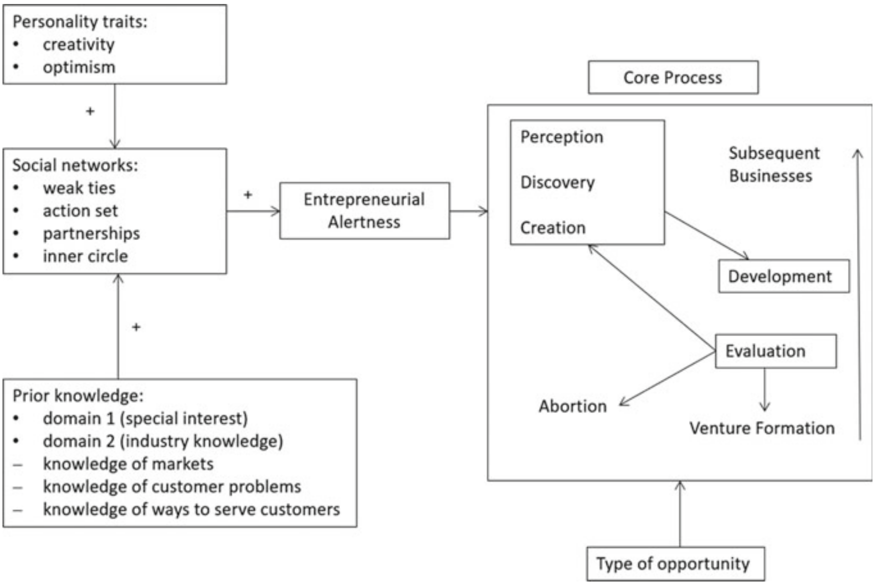

Fig. 3 Identification of business opportunities. *Source* Ardichvili et al. (2003), p. 118

1992). Start-ups can play a pivotal role for established companies in accumulating external knowledge in convergence settings as they enable to bridge competency gaps at the knowledge, technology, market, and industry level.

In the context of convergence, start-ups have clear advantages in terms of their "absorptive capacity" and agility over established companies due to lower path dependencies and learning capabilities due to more agile processes. Compared to established companies, start-ups generally have fewer resources. For investors, the existing knowledge base and its agile development represent a significant value for future returns. Young companies are highly dependent on the novelty of their business model, making rapid adaptation to changing industry dynamics elementary (Debrulle et al., 2014; Zahra & George, 2002). For founders, this creates great pressure to quickly build up a new knowledge base in changing market environments, even outside their own core competence. A high absorption capacity of external knowledge is therefore vital for start-ups (Deeds, 2001). Regarding the need for supportive personality traits (Ardichvili et al., 2003; Teece & Peteraf, 2016), start-ups benefit from the fact that these aspects are inherent in a successful start-up process. Since start-ups suffer from a lower bureaucratic burden and path dependency, they adapt faster to changes in the sectoral environment by assimilating external information and reorganize themselves more quickly than established market players (Zahra et al., 2006). This might result in a competitive advantage over traditional companies because of the ability to adapt quickly (Dess et al., 2003; Zahra & George, 2002).

The importance of start-ups for the identification of entrepreneurial options of established companies depends on the type of convergence as well as on how different converging sectors are characterized (see Fig. 4). High cognitive distance between sectors requires established companies to adapt in a flexible way and to absorb foreign know-how quickly. If established companies strive to enter emerging segments in case of complementary convergence, one starting point might be the acquisition of start-ups in the newly identified knowledge, technology, market, or industry fields. This enables a fast and efficient closing of competency gaps, bypassing path dependencies and inflexible processes. In this way, companies can acquire competencies and adapt business models outside their origin industry field (Freeman & Engel, 2007). Investments in start-ups can increase companies' absorption capacity. According to Cohen and Levinthal (1989, 1990), absorption capacity increases cumulatively with investment in R&D and the creation of teams with diversified professional backgrounds. Thus, start-up acquisitions are not only an investment in an innovative business model from another sector, but an enabler for the diversification of human capital, which increases accumulation of external knowledge in the future.

In the case of substitutive convergence, established companies must develop hybrid products outside their origin industry to survive. However, they are limited in their own resources, processes, and path dependency (Bröring, 2010; Sydow et al., 2009). An approach beyond the acquisition of start-ups to reduce cognitive distance between converging sectors lies in the commitment to open innovation and cross-industry innovation networks. This might lead to the formation of partnerships with stakeholders from business, science, and the start-up scenes that might result in an

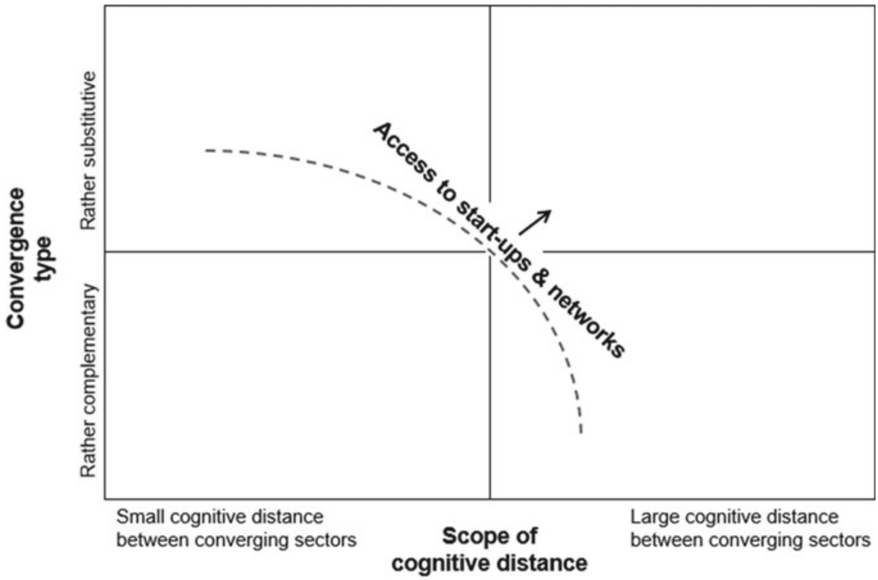

Fig. 4 Recommendations for action. *Source* Derived from Bröring & Craemer, 2020, p.441

exchange of know-how up and concrete joint innovation projects. Corporate venture capital plays a similar role. Established companies use these "strategic investment" in start-ups to gain access to new, foreign technological know-how (Röhm et al., 2018) to gain a foothold in converging fields. Meanwhile, building bridges between companies and start-ups through corporate accelerators can be seen as a hybrid approach (Kohler, 2016). In this process, companies support start-ups through mentoring, provision of office facilities or capital, to access business model innovations and know-how from other economic sectors.

Since established firms often reject to go beyond their current core competences (Leonard-Barton, 1992), network participation seems to be crucial to initiate collaborations that lead to innovation and economic growth (Camarinha-Matos et al., 2009; Levén et al., 2014). Especially, transition regions such as the Rhenish lignin mining area initiate processes in which heterogeneous firms (in terms of industry cultures, social capital, and goals) and different types of partners share information, resources, and responsibilities to jointly plan, implement, and evaluate a program of value creation activities (Levén et al., 2014; Nieto & Santamaría, 2007). Therefore, collaborative networks that integrate partners from different industry backgrounds should trigger knowledge-sharing processes by establishing approaches to motivate members sharing valuable knowledge, to prevent free riders and undesirable spillovers, and to reduce barriers associated with accessing knowledge from other domains (Dyer & Neobeoka, 2000; Kale et al., 2000; Sorenson et al., 2006). The interplay of different social integration mechanisms affects learning outcomes and firms' capabilities to bridge knowledge distances (Enkel et al., 2018).

The implementation of these processes requires a deep understanding of firm's strategic behavior and network activities to exploit opportunities at the interface of hitherto separated industries. Cross-sectoral networks such as "INNOSpace®2Agriculture"[1] might help to establish technology platforms that drive the development of novel inter-industry segments in emerging bioeconomy regions such as the Rhineland.

5 Cross-Sectoral Networks: The Case of INNOSpace®2Agriculture

We explore the INNOSpace®2Agriculture network as an illustrative case of various entrepreneurial opportunities arising in the hybrid industry zone between the hitherto separated industry fields of agriculture and space. The network comprises members located in the Rhineland and is connected to regional research institutes, accumulating knowledge about new technologies for a sustainable crop production

[1] Communication platform INNOSpace®2Agriculture: https://www.space2agriculture.de/

The objective of the network is to establish cross-industry networking, to initiate joint funding projects, to consolidate synergies and to identify new potential for technology cooperation and commercialization.

and digitalization in the agricultural sector. Based on desk research about network members on the official network website, we clustered all participating actors into company types (MNE, SME, Start-Up) and industry sector (including agriculture sector, hybrid industry zone with agricultural context or high-tech setting and space industry). Consulting companies, initiatives, associations, and research institutes were excluded.

The confluence of previously distinct knowledge bases (such as agricultural engineering, plant cultivation/protection, KI, robotics, sensor technology, satellite systems) implies novelty as an entrepreneurial opportunity and has the potential for technological change and creation of new technology applications (Hacklin et al., 2010). The dynamic of tinter-industry segments (interface of the agricultural and high-tech driven space industry) seems to be dominantly explained by the emergence of various technology start-ups (see Fig. 5). The diversity of knowledge bases in such a network is significantly shaped by many heterogeneous start-ups. However, the future development of hybrid industry zones is impeded by a lack of mutual understanding and depends on the communication skills and opportunity recognition capabilities of individuals, working in different types of enterprises.

The multi-national enterprises CLAAS and Deere and Company with agricultural industry background builds new ventures such as Claas E-systems and John Deere to exploit information technologies and take advantages of the digitization and automation. While Microsoft holds Azure FarmBeats for new applications of KI, Edge-Computing, and IoT in the agricultural sector. This has implications

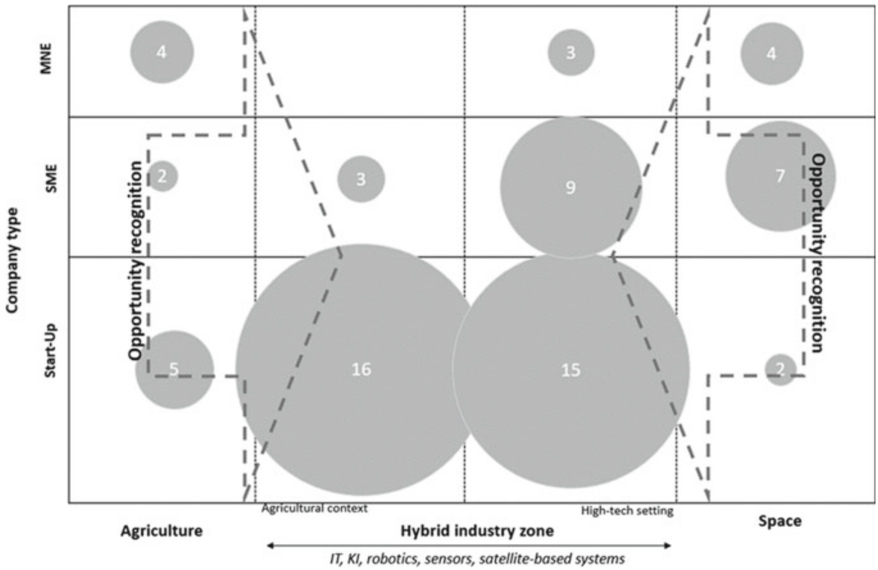

Fig. 5 Company types and hybrid industry zones in the "INNOSpace®2Agriculture" network. Circle size reflects the quantity of respective company type within the network. The number in the circle indicates the amount of company types in the respective industry segment

for the strategic positioning of multi-national enterprises in a new hybrid industry zone, which is currently dominated by start-ups. The establishment of new industry segments in Germanies brown coal regions depends on entrepreneurs and managers that are capable to interact with different firm types and to position their own business in dynamic fields that are driven by industry convergence. Our analysis of the INNOSpace®2Agriculture network implies that Start-Ups seem to be faster in realizing opportunities in new inter-industry segments, while larger firms are even more challenged to recognize opportunities in these emerging technology fields. Larger firms need to build agile competence-building processes by interaction with start-ups and engagement in in collaborative networks.

Interactions between heterogeneous players driving the dynamics of converging field such as “digital farming” (convergence of agriculture and IT) have already been successful without participation in such a cross-industry network. We highlight the collaboration between Bosch and the Australian start-up. The Yield (founded in Sydney in 2014) to illustrate the connection between cognitive distance and extent of convergence. As a traditional manufacturer of consumer goods and industrial technology, Bosch has a large cognitive distance to the field of digital farming and aquaculture. The Yield combines knowledge about aquaculture and the emerging field of the “Internet of Things” and, as a start-up, has specialized in the production of sensor technology and machine learning in the field of (autonomous) aquaculture production. As a small start-up the Yield is subject to lower path dependency and benefits from dynamic processes and an efficient absorption capacity. The Yield was able to quickly unite different fields of knowledge (aquaculture and sensor technology) and thus identify entrepreneurial opportunities in an emergent field and translate them into a successful business model. The high cognitive distance of Bosch to the world of “digital farming” is not only characterized by strong resource differences, but also by a lack of experience with organic farming systems such as aquaculture. In 2015, Bosch invested around 6.5 million dollars in the start-up to set up a platform for joint research and development with The Yield. Through this investment and collaboration, Bosch enters a sector that has strong complementary convergence dynamics. “Digital farming” increasingly requires the convergence of raw material production (here, e.g., aquaculture), mechanical engineering and information technology and sensor-based, autonomous, self-learning production systems. Accordingly, Bosch integrates and combines its own IoT-based products and product systems and offers them as product bundles (Bosch, 2019). The initial cooperation with the start-up company the Yield thus serves to reduce cognitive distance and thus strengthens Bosch’s dynamic capability to identify entrepreneurial options in the future field of "digital farming".

6 Conclusion

By drawing upon the historical case of the phasing out of coal mining which implies the transformation to a novel bioeconomy region, this book chapter highlights the dynamic integration of different sectors such as Farming and IT leading to various business opportunities. However, the recognition of these arising business opportunities and needed integration of hitherto different knowledge areas is challenged by cognitive distance. Convergence processes driving the transition of the Rhenish coal mining area will take place at different levels between previously separated sectors. This poses numerous challenges for established companies affected by the lignite phase-out, as they need to reduce cognitive distance and deal with uncertainties to exploit new business options.

The question of how established players can become aware of and overcome cognitive distance that impedes successful opportunity recognition in converging industries and invest in their “absorptive capacity” seems pivotal in the context of those emerging inter-industry segments.

Due to path dependencies and associated cognitive distance, established companies require the strengths of start-ups to recognize entrepreneurial opportunities in convergence settings. Entering a collaboration with partners from various industrial backgrounds follows the aim of the integrated bioeconomy for a sustainable development of brown coal regions. In the case of complementary convergence, established companies might focus on entering a new sector while retaining the core business. Therefore, they should close competency gaps at the knowledge, technology, market, and industry level by acquiring start-ups in the relevant sectors or making use of accelerator programs. Overall, established companies need to promote the involvement in cross-industry networks, open innovation, cooperation, and joint ventures to identify entrepreneurial opportunities at an early stage.

In view of convergence and strategic management literature, agile competence-building processes, flexible collaborative networks, and sensing abilities to guide prior knowledge accumulation seem to be crucial for start-ups to successfully position between two converging sectors. The questions of how to collaborate in distant knowledge fields (Gruber et al., 2013) and how to build larger collaborative networks and entrepreneurial ecosystems seem to be major challenges. In this regard, a technology perspective on emerging ecosystems (Markard & Truffer, 2008) as well as a knowledge creation perspective (Von Krogh & Geilinger, 2014) might be beneficial in academic literature. A cross-fertilization of convergence and entrepreneurship literature seems promising to understand opportunity recognition in distant knowledge fields (Ardichvili et al., 2003). Future research should focus on the impact of path dependent learning and the role of start-ups and corporate accelerators (Gruber et al., 2013; Kohler, 2016) to enable strategic renewal in times of convergence (Sick & Bröring, 2022).

Start-ups function as a bridge between separated industry fields, which previously dominated the specific brown coal region. As start-ups are highly dependent on the novelty of their business model, rapid adaptation to changing industry dynamics and fast absorption of external knowledge are elementary (Debrulle et al., 2014; Zahra & George, 2002; Deeds, 2001). Therefore, start-ups may have competitive advantages in terms of opportunity recognition capabilities compared to established firms. Larger enterprises can benefit from start-ups by acquisitions and cooperation depending on the type of convergence (substitutive or complementary). In case of the Rhenish lignite mining region, strategic investments in start-ups and corporate accelerators seem crucial to gain access to foreign technological know-how (Kohlert, 2016; Röhm et al., 2018). We suggest that start-ups and firm's participation in cross-industry networks such as the INNOSpace®2Agriculture play a key role to react to the dynamics of substitutive bioeconomic developments. This book chapter renders implications for the analysis of entrepreneurial landscapes in different sectors to predict business opportunities in future convergence settings that might help to uncover a new potential for sustainability transitions of European coal mining regions and beyond.

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Innovation Policy and Innovation Patterns of SMEs—Heterogeneity in German Manufacturing SMEs' Innovation Behaviour and Its Implications on Policymaking

Carsten Dreher, Oliver Som, and Martina Kovač

Abstract Research indicates that there are many pathways to innovation and knowledge appropriation for SMEs. However, to what extent is this heterogeneity in SME resources and organisational competences reflected by existing SME innovation policies? Within the VIVA-KMU project funded by the German Federal Ministry of Education and Research, 23 national and four European SME innovation policy instruments were analysed. The systematic analysis comprises documents of regulations, evaluation reports, calls and other publications. The findings illustrate that existing SME policy instruments still predominantly focus on the R&D-based mode of innovation. Other important innovation modes of SMEs, such as deep process expertise, customisation, tacit knowledge or non-technological innovation, are not considered. Additionally, most policy instruments do not meet the specific needs of SMEs in terms of agility, feasibility or the possibility of transferring existing technologies into new fields of application. By integrating existing empirical findings on the heterogeneous innovation patterns of SMEs in the German manufacturing industry and the findings on the existing SME policy landscape, the paper suggests several approaches to a targeted, demand-side-oriented SME innovation policy scheme.

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1 Introduction

Industrial SMEs are an essential pillar of innovation and technological performance and thus of the international competitiveness of German industry (Berlemann & Jahn, 2014; Som, 2012). The economic importance of SMEs for Germany as an industrial location is reflected in the fact that SMEs comprise more than 97.7% of all companies in the German manufacturing sector. According to the official definitions of the European Union, SMEs are defined as companies with less than 250 employees and less than 50 million annual sales or up to a balance sheet total of fewer than 43 million euros (European Commission, 2003). To consider the specificity of the German economy regarding the size structure of its companies, the group of medium-sized companies in the definition of IfM Bonn includes companies with up to 499 employees with the same criterion of annual sales volume or annual balance sheet total.[1] Based on this broader definition, SMEs comprise approximately 99.5% of all companies subjected to value-added tax in Germany with economic and legal independence. These definitions form the basis for the statistical-administrative delineation of the SME population in tax, employment, economic, technology and innovation policy.

Today, there is broad consensus in the economic and political debate that R&D-based innovation is the key driver for growth and competitiveness in developed economies, as the R&D intensity of an economy leads it to expand its technological knowledge (Fagerberg, 1994; Freeman, 1994; Freeman & Soete, 1997; Pessoa, 2010; Sandven et al., 2005; Saviotti & Nooteboom, 2000). Although the proponents of the traditional neo-classical paradigm of innovation perceive other non-R&D-based innovation patterns, they are not considered to have any meaningful significance in achieving economic competitiveness. The reason for this is the assumption that non-R&D-based innovation activities primarily focus on the small-scale improvement of existing products and the efficiency enhancement of processes at the end of the technological life cycle and, therefore, do not generate significant growth effects (Arundel et al., 2008).

Applying this traditional neo-classical innovation paradigm to the innovation behaviour of SMEs, they are assumed to have certain inherent structural disadvantages to reach innovativeness and competitiveness, e.g., lower financial and human resource resources and lower scale, synergy and learning curve effects (Welter et al., 2016; European Union, 2015; Immerschmitt and Stumpf, 2014; Pfohl, 2006). Expenditure on research and development (R&D), participation in innovation cooperation with universities and research institutes or investment opportunities in new machinery and equipment are well below those of large enterprises (Zanker et al., 2014a; Rammer et al., 2016). In addition, for example, approximately 55% of all innovative SMEs do not conduct in-house R&D activities (Frietsch et al., 2015). Another structural disadvantage of SMEs is their dependence on regional location factors. SMEs

[1] https://www.ifm-bonn.org/en/definitions/sme-definition-of-the-ifm-bonn (accessed on 03 January 2023).

are less able to compensate for location disadvantages (such as inadequate infrastructure, lack of networks for knowledge transfer and exchange, local/regional skills shortages in rural areas) than large enterprises. Therefore, regional factors are more important for SMEs than for large companies (Kay & Richter, 2010). As a result, SMEs not only have disadvantages in the generic generation of R&D knowledge but are also faced with more difficult access or development of knowledge spill-overs and transfers from universities, research institutes and R&D-intensive companies.

The intrinsic features of R&D-based innovation projects are, e.g., considerable risk, high uncertainty, less availability of external risk capital and externalities due to the characteristic of R&D knowledge as a quasi-public good. Hence, within the framework of market-based resource allocation mechanisms, private-sector enterprises do not provide sufficient incentives to carry out innovation activities to achieve economic prosperity and growth. Innovation economics addresses this problem as "market failure" (Barber, 2009; Gustafsson & Autio, 2011). Due to their specific characteristics, it is assumed that SMEs are considerably more affected by the different forms of market failure than large enterprises. As a result, their innovation activities (in the sense of R&D activities) remain below the socially and economically desirable level.

Based on the high importance of SMEs for growth and employment, German industrial SME policy has largely focused on mitigating the structural disadvantages and market failures of SMEs in innovation, e.g., granting state aid (BMWi, 2016; Welter et al., 2016). The primary guiding principle here is "precompetitive support", meaning that support measures shall not lead to any distortion or distortion of market competition (BMWi, 2016). The intended additionality (publicly funded results serve as an impetus for innovations for nonsubsidised companies via knowledge transfer) is intended to strengthen SMEs' efficiency and increase technological development in the industries and technology sectors involved. In addition, industry-wide or cross-industry networks should establish permanent research cooperation between research institutions and SMEs.

These assumptions are equally problematic for scientific analysis, the understanding of innovation behaviour and the derivation of an SME-oriented science, technology and innovation (STI) policy. It was discovered relatively early that a sizable proportion of manufacturing companies does not invest in their own R&D. For example, Cohen et al. (1987) show that more than a fifth of all major US companies at the time of their study did not have R&D activities. As early as 1984, Bound et al. found that 40% of US companies do not report R&D spending. As one of the first studies in Europe, Galende and Suarez (1999) showed for Spain that more than 70% of all companies located there did not conduct R&D activities. More recently, several studies have shown that approximately half of all SMEs that do not perform R&D activities at the time of the survey are still successful innovators, i.e., they successfully developed and launched a new product or process in the past three-year period (Arundel et al., 2008; Kirner et al., 2009; Rammer et al., 2011; Som, 2012; Frietsch et al., 2015; Rammer et al., 2016).

In many cases, the abandonment of R&D activities is not due to structural disadvantages but rather to a rational strategy decision (Som, 2012; Rammer et al., 2011; Som et al., 2010). Moreover, studies show that the waiver of R&D activities does not automatically lead to lower novelty and technological complexity levels. There are innovative firms without any R&D that successfully develop cutting-edge, knowledge-intensive high-tech products or use advanced manufacturing technologies (Frietsch et al., 2015; Som, 2012; Som et al, 2017).

This raises the question of whether, despite the deliberate renunciation of R&D activities, these companies are at all affected by market failures in the classical sense (and thus justify public support measures) or whether innovation policy needs a broader, evolutionary understanding of the innovation behaviour of SMEs to develop targeted, demand-side-oriented policy support.

The paper addresses this question by bringing up the extent to which the existing landscape of German and European innovation policy instruments meets the specific needs and requirements of the heterogeneous innovation patterns of German manufacturing SMEs. Therefore, the paper builds upon a recent empirical typology of SME innovation patterns in the German manufacturing industry based on representative, large-scale empirical data at the firm level. The typology was developed in a research project funded by the Federal Ministry of Education and Research (Som et al., 2017). Against this backdrop, the paper comprehensively analyses policy support schemes and documents on the German and European levels. It provides insights into whether and to what degree these SME policy instruments address the specific needs and requirements of SMEs' heterogeneous innovation patterns. Finally, based on its findings, the paper derives a range of possible approaches to how existing SME instruments to support innovation and technology development can be adapted and/or extended towards a demand-side-oriented, sustainable SME policy portfolio.

2 Heterogeneous Innovation Patterns of German Manufacturing SMEs

2.1 Conceptual Framework

The assumption of heterogeneous innovation patterns of SMEs can be reasonably derived from evolutionary economic theory, which argues that the competitiveness of firms is based on firm-specific routines and firm-individual heuristics instead of merely single, homogeneous R&D-based innovation strategies (Nelson, 1991; Nelson & Winter, 1982). Evolutionary or neo-Schumpeterian innovation research has always tried to link high diversity at the microlevel with a strong interest in taxonomic work (Peneder, 2010). The most prominent example goes back to Pavitt (1984), whose sectoral classification proved extremely influential and motivated numerous extensions and further refinements. Among them, the most essential taxonomies are provided by Marsili (2001), Hollenstein (2003), Hollanders and Arundel (2004), De Jong and Marsili (2006), Leiponen and Drejer (2007) and Srholec and Verspagen (2008).

One of the key arguments of evolutionary economics is that enterprises show considerable heterogeneity in their innovation behaviour and strategies, even within similar framework conditions of sectors or innovation systems (Nelson, 1991; Som et al., 2017; Srholec & Verspagen, 2008). Dosi (1988) argues that despite common intersectoral frame conditions of firms (such as technological opportunities, possibilities of technology acquisition or public support), a large, unexplained residual of intrasectoral, institution-specific innovation behaviour remains, which results from differences in firm-specific structures, proportions and innovation strategies. To this extent, the neo-classical assumption of the representative enterprise has to be abandoned (Grupp, 1998).

Nevertheless, heterogeneity itself does not yet provide a substantive explanation of *how* firms differ in their innovation behaviour. The empirical taxonomies of firms/SME innovation behaviour, such as Cesaratto and Magnano 1993; Hollenstein, 2003; Hollanders and Arundel, 2004; Leiponen and Dreijer 2007 or Srholec and Verspagen 2008, have answered this by analysing different, sometimes rather arbitrary, selections of variables available in the Community Innovation Survey (CIS). They include innovation performance (e.g., introduction of new products and services new to the market), inputs for innovation (e.g., R&D expenditure) and the way innovation is happening (e.g., make or buy).

As the competitive advantage of SMEs cannot be explained by the existence of internal R&D alone, it is necessary to look elsewhere for alternative sources of innovativeness and competitive advantage. In evolutionary terms, this means focusing on other resource variations that achieve similar innovation success and allow firms to survive market competition. Thus, it is necessary to choose an approach that allows for multiple, heterogeneous innovation inputs beyond mere R&D. Within evolutionary theory, authors such as Nelson and Winter (1982), Dosi and Marengo (1994) or Teece et al. (1997) have integrated this perspective by referring to the works of Penrose (1959) and the stream of organisational learning by Cyert and March (1992) or Simon (1991). Thus, within the evolutionary paradigm of this paper, the resource-based theory of the firm (Barney, 1991a, 1991b; Peteraf, 1993; Wernerfelt, 1984), as well as its modifications by the relational-based view (Dyer, 1996; Dyer & Singh, 1998) and the knowledge-based view of the firm (Grant, 1996; Kogut & Zander, 1992; Nonaka, 1994; Nonaka & Takeuchi, 1995; Spender, 1996), seems to provide an adequate framework. That is, to analyse *how* innovation patterns of manufacturing SMEs differ and whether and to what extent pattern-specific resource current SME innovation policy instruments address bundles.

For this reason, this paper builds upon the recently developed empirical taxonomy of manufacturing SME innovation patterns in the German industry provided by Som et al. (2017). The empirical data are derived from the German sample of the *European Manufacturing Survey* (2009), which provides representative cross-sectional data of 1484 German manufacturing firms. SMEs with fewer than 100 employees account for more than two-thirds of the sample (SME < 250 employees = 85%) (Jäger & Maloca, 2009). In a postal, standardised survey, detailed indicators are used to identify production strategies, the technical modernisation of value-added processes, the use of innovative organisational concepts and processes in production, innovation cooperation and impulses, questions of personnel deployment and qualification and the offering of new business models complementing the product range with innovative services. Therefore, the survey, in its coverage of business innovation in SMEs, goes beyond other datasets and is particularly suited to include all the dimensions of investigation relevant to the development of an innovation typology of SMEs. To date, the quality of the database has been acknowledged by several studies that have been published in internationally leading journals such as Technovation (Armbruster et al., 2008), Research Policy (Kirner et al., 2009), Industrial and Business Economics (Dachs et al., 2015) or Technological Forecast and Social Change (Bierwisch et al., 2014).

Applying an evolutionary perspective, the typology by Som et al. (2017) explicitly accounts for a maximum of firm-level heterogeneity by identifying the SME innovation patterns about their specific resources and competences instead of their achieved performance output or statistical groupings based on industry affiliation. We used the large strand of theory labelled the "resource-based view of the firm" (Barney, 1991a; Peteraf, 1993; Wernerfelt, 1984), which originates in an evolutionary perspective. Hence, the heterogeneity of SMEs' innovation behaviour is modelled in terms of firms' individual routines, capabilities, skills and experiences (Christensen, 2002; Massini et al., 2005; Nelson, 1991; Nelson & Winter, 1982; Teece et al., 1997). The identified innovation patterns of SMEs are thereby constituted by statistical cluster analysis based on a broad range of different tangible, intangible, internal and external resources and competencies as the constituting variables for the identified innovation patterns. Thus, the identified patterns are based on individual, pattern-specific bundles of resources and competencies, which provide an adequate framework for the analysis and the later discussion of the SME innovation policy measures.

Heterogeneous behaviour by firms with regard to innovation could also be viewed from the perspective of equifinality and the related multifinality in systems theory (Kruglanski et al., 2015). While equifinality depicts a situation wherein different behavioural configurations lead to similar results, multifinality describes the opposite situation when similar behaviours result in different results (Kruglanski, et al., 2013; Kruglanski et al., 2002). In the context of this paper, this means that firms might, on the one hand, achieve similar innovation strategies by means of different resource configurations (equifinality). For instance, the technology first-mover strategy can be based on high internal R&D investments or an open innovation strategy based on knowledge sourcing from external partners. On the other hand, similar resource configurations can result in different innovation outputs (multifinality). To exemplify, open innovation can be used both for product- or process-focused innovation patterns. To take this into account, the innovation typology developed by Som (2012) and Som et al. (2017) identifies heterogenous innovation patterns on the level of firm-individual resource configurations first before linking to different types of firms' innovation output and economic performance.

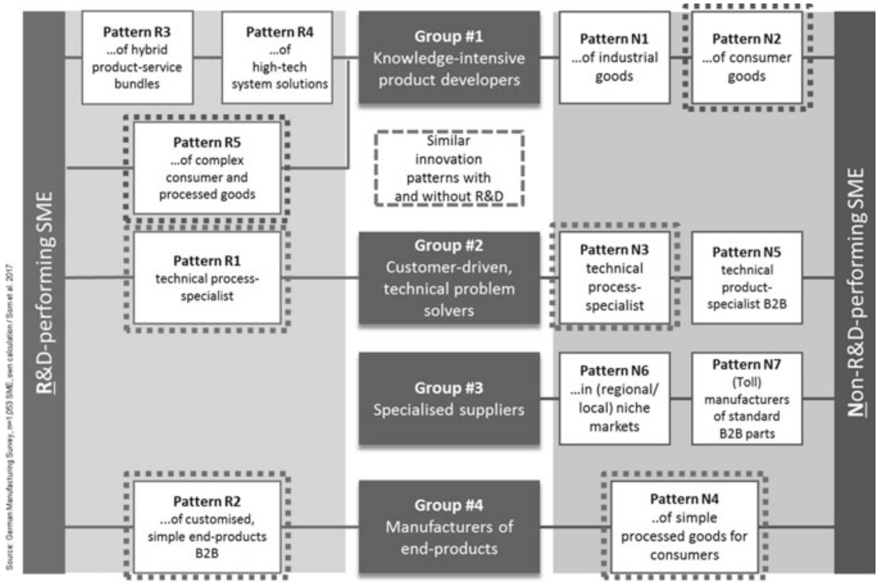

Fig. 1 Innovation pattern of SMEs in the German manufacturing industry (Som et al., 2017)

In the following paragraph, the identified innovation patterns of German manufacturing SMEs are briefly summarised.[2]

2.2 *Heterogeneous Innovation Patterns of German Manufacturing SMEs*

The statistical cluster analysis of the resource bundles of technological and non-technological competencies in the surveyed companies shows twelve specific innovation patterns of SMEs in the German manufacturing industry. These differ significantly from the resources used by the companies, their pursued technology and organisational strategies, the opening to external innovation partners and the use of different forms of knowledge. The group of R&D-performing companies can be divided into five innovation groups and non-R&D-performing companies into seven innovation models (Fig. 1).

In general, the results describe the innovation behaviour of manufacturing SMEs empirically along the selected resource dimensions that cover the entire, more holistic spectrum of the "Schumpeter-Understanding" of innovativeness. All operations of the analysis sample were successfully assigned to one of the R&D-based

[2] For a detailed description of all the innovation patterns (including additional case examples for each of them) see the project report by Som et al., (2017) which is provided upon request by the corresponding author.

or non-R&D-based innovation patterns. This finding supports the basic evolutionary assumption of the heterogeneity of corporate innovation behaviour, which is reflected along with different organisational resource bundles of company-specific competencies. These resource bundles include both technological (e.g., R&D, use of modern production technology and manufacturing processes) and non-technological competencies (e.g., customer service, innovative organisational and management methods, cooperation) and are based on different proportions of explicit (formal) and implicit (experiential, informal) knowledge resources. As expected from theoretical reasoning, none of these identified innovation patterns can be attributed solely to one of the considered innovation resources. Rather, the individual innovation patterns are characterised by a variable interaction of the different resources.

None of the patterns of innovation is constituted solely by structural features such as industry affiliation or company size—on the contrary: all identified innovation patterns—R&D-based and non-R&D-based—are affiliated to relevant proportions in all economic sectors and enterprise size categories. First, this supports the evolutionary heterogeneity thesis, implying that classifications based on statistical distinctions along structural characteristics of establishments do not permit homogeneous demarcations of working populations concerning their behavioural patterns (Kirner et al., 2009; Nelson, 1991; Srholec & Verspagen, 2008). Second, this underpins the explanatory value added by using a resource-based view perspective for identifying different innovation patterns. Following the concept of equifinality, the innovation typology shows that different innovation patterns might be based on similar resource configurations (e.g., similar patterns with and without R&D), which are transverse to statistical categories of firm size and/or industry affiliation. The estimation of the economic relevance of the innovation patterns using weighted data based on official statistical data from the German manufacturing industry reveals that all innovation patterns are economically significant in terms of the number of enterprises and their employees. Each innovation pattern comprises between 2400 and 6000 companies and between approximately 237,000 and 592,000 employees.

The twelve identified innovation patterns of SMEs in the German manufacturing industry can be summarised based on the following four groups:

Group 1—Knowledge-intensive product developers: The innovation behaviour in this group is characterised by a high degree of knowledge intensity. The focus is on developing new industrial and consumer goods, which often include high-tech components such as microelectronic components or new materials. In alignment with the high complexity of these products, customers receive comprehensive, product-accompanying services. The high level of knowledge is reflected in a high proportion of graduate workers, a high level of internal and external knowledge and impulses for innovation and frequent innovation collaborations with universities and other enterprises. The innovation-relevant knowledge is thus more formalised and of a scientific character, even if two of the non-R&D-based innovation patterns are included. This illustrates that the absence of R&D does not automatically imply low technology, knowledge or product innovation orientation. They achieve high sales shares with product innovations, often with innovations that make them first to introduce them to the market. Therefore, these companies achieve high sales on the market with product novelties and product-accompanying services, especially in the mechanical engineering, optics and measurement and control technology sectors.

Group 2—Customer-driven, technical problem solvers: This innovation pattern is characterised by an above-average use of modern production technologies, such as high-performance machine tools, industrial robots or automation systems. For their customers, these companies develop and implement complex and highly sophisticated manufacturing processes and product solutions, which are adapted to the customers' specifications and wishes. Innovation drivers are thus predominantly customers. Although proprietary ideas for innovation exist, they cannot always be promoted because of the high level of customer dependence and the resulting operational pressure on everyday business. An essential internal success factor for this type of innovation is the in-house process and knowledge of the employees in design, toolmaking or production, as well as for beginners and unskilled workers. If needed, targeted collaborations with external partners in research and development can supplement external knowledge. These include, for example, cooperation around new production processes or materials. Product-related services in the field of technical documentation and project planning complete the range of services. The small and medium-sized companies of this group achieve high punctuality and high-quality performance. In the value chain, these non-research-active SMEs are often parts and component suppliers. They are preferred in the automotive industry and the production of rubber and plastic products.

Group 3—Specialised suppliers: These innovation patterns are characterised by a high level of customer orientation, which is reflected in the excellent price–performance ratio and high-volume flexibility on the market. To achieve these goals, companies with these innovation patterns frequently use innovative organisational concepts and management methods in labour and manufacturing organisations. The development of own, new products is, if available, largely market- or customer-driven. The products tend to have medium-to-low complexity. On the other hand, the range of product-related services, such as packaging, logistics or sales, is of great importance. Both the share of employees in production and assembly and the share of low-skilled and unskilled employees are highest in this innovation pattern. Accordingly, innovation-relevant knowledge is more about implicit, experiential and application-related knowledge. If necessary, however, it is also possible to cooperate with external partners in innovation projects. These are often upstream and downstream value-added partners but occasionally, if needed, also R&D facilities. The companies of this group are often parts and component suppliers and standardised industrial production companies, which can equally be found in research-intensive and non-research-intensive industrial sectors. Therefore, these companies represent the "backbone" of German industry.

Group 4—Specialised end-product manufacturers: The companies in this innovation pattern are also characterised by rather small-scale product innovations aimed primarily at meeting demand in niche (industrial goods) and mass markets (consumer goods). The experience and user knowledge of their own, often semiskilled and unskilled employees are an essential source of innovation impulses. There is hardly any opening towards external partners, merely in the form of innovation cooperation with suppliers and customers. In the industrial goods sector, manufactured products are of low-to-medium complexity. The competitive advantage lies primarily in the price–performance ratio as well as customer-specific adaptation. Important industries are, for example, the textile and clothing industry (e.g., high-performance/speciality fibres) and the chemical industry (e.g., custom consumables). In the consumer goods sector, these companies are positioned above all by the high quality of their mostly simple products. Typical representatives can be found in the food and beverage industry (e.g., canned food manufacturers or private breweries).

3 Document Analysis of Innovation-Oriented Policy Instruments for SMEs

Innovation policy instruments have complex functional characteristics. The policy instrument analysis aims to examine the already existing innovation-oriented policy support for SMEs regarding their potential to address the individual innovation patterns of industrial SMEs. For this purpose, a comprehensive review of important SME policy instruments at the German and European levels was carried out, allowing different systematisations based on functional properties.

To describe innovation policy instruments, differentiated definitions and typologies have been presented in the past. These include typologies along the class of instruments (e.g., Borras & Edquist, 2013; Meyer-Krahmer & Kuntze, 1992), the direction of impact of the instruments in terms of demand or supply-sided instruments (e.g., Edler and Fagerberg 2017; Edler, 2007), the addressed functions in the innovation system (Smits & Kuhlmann, 2004) or the policy domain (e.g., Lundvall & Borras, 2005). All these systematisations show particular idiosyncrasies and are partly overlapping. A systematisation based on functional properties focuses on the instrument's characteristics to put them in relation to a specific context (for example, a concrete problem situation, a specific objective or a target group). This instrument analysis should show to what extent the existing innovation-oriented SME support of the federal government and the selected EU instruments addresses the resource and competence bundles underlying the previously identified innovation patterns.

For this, we use different systematisations of instruments, which provide information about the orientation of the considered SME-oriented instrument portfolio. This portfolio of instruments aims to influence companies' quality and quantity of R&D and innovation activities. Since we do not analyse the interaction effects of these instruments but only systematise based on the functional characteristics of single instruments, we speak of instrument portfolios. To investigate how the existing policy instruments address the different resource and competence bundles of the identified innovation patterns, they have been systematised in terms of the resources and competencies of companies promoted by the instrument (e.g., Barney, 1991a, 1991b; Dollinger, 2008; Galbreath, 2005). This analysis does not evaluate individual instruments' effectiveness or identify concrete gaps in instrument portfolios. Instead, this analysis intends to spot *fields for further investigation* and thus identify those areas in which existing instruments may hardly address the identified innovation patterns and their resources. Against this background, (1) a selection of relevant instruments and (2) a qualitative systematisation of these instruments based on functional characteristics were undertaken.

3.1 Selection of the Examined Instruments

The complexity of the whole system of public SME-oriented innovation support at the federal, state and EU levels makes it necessary to appropriately select across the range of different instruments to provide a nuanced analysis. To identify instruments, we used public announcements and official declarations of the instruments. Evaluation reports and other available materials, such as brochures or press releases, complemented the database. We took several steps to select the relevant instruments. A simple search in the funding database of the federal government and the EU provided a first overview of the currently used instruments. In Germany, a holistic SME strategy has been pursued within the Hightech-Strategy 2025. We selected those instruments strategically geared to the specific target group of SMEs at the federal level. However, due to mapping the SME-oriented funding landscape as comprehensively as possible, some instruments were also selected that are only indirectly aimed at SMEs.[3] This resulted in a selection of 23 instruments at the national level and four instruments at the EU level. The instrument selection aimed to map a vast range of instruments that are as diverse as possible to capture the instrumental diversity of innovation-oriented SME support. The instrument selection was discussed with external and internal experts from the German Ministry for Education and Research (BMBF) and the German Ministry of Economic Affairs (BMWi) during several expert workshops from 2016 to 2017.

3.2 The Innovation-Oriented Instrument Portfolio to Support SMEs

A broad mix of different instruments supports the specific target group of SMEs, having different emphases on their concrete objectives. Overall, the analysed innovation-oriented SME support covers the areas of R&D and technology support, start-up support, knowledge and technology transfer, innovation-oriented consulting

[3] Instruments such as cluster policies, technological program support, or instruments for innovation-oriented structural funding within the framework of the "*Unternehmen Region*" also have impact on SME.

services and the formation and management of clusters and networks. The 23 national funding instruments thus form a diverse set of support measures.

Thirteen of these instruments are administered by the Federal Ministry for Economic Affairs and Climate Acion (BMWK). They can be grouped as follows: The five instruments *"coparion"*, *"ERP/EIF-Dachfonds"*, *"ERP-Innovationsprogramm"*, *"KfW-Unternehmerkredit Plus"* and *"ERP-Startfonds"* are financing instruments and partly implemented by the Kreditanstalt für Wiederaufbau (KfW). *"INVEST"* and the *"Hightech Gründerfonds"* are also financial instruments. The first one subsidises venture capitalists; the latter is investing venture capital in young companies implementing promising research results. The *"Zentrales Innovationsprogram Mittelstand"* (ZIM) offers SMEs' individual (ZIM Einzel), cooperation (ZIM Koop) and network-oriented (ZIM Netz) funding opportunities for innovation projects. The *"Wissens- und Technologietransfer durch Patente und Normen"* (WIPANO) should improve the diffusion of innovations in the market. *"Industrielle Gemeinschaftsforschung"* (IGF) indirectly supports SMEs primarily through research funding from research institutes and universities. The targeted transfer of the research results into marketable products through business start-ups is the primary goal of the *"EXIST"* programme. In addition, the competition *"Digitale Innovation"* aims at start-ups in information and communication technology. Finally, innovation vouchers *"Innovationsgutscheine"* finance external consulting services for innovative business ideas.

We include ten more instruments of the Federal Ministry of Education and Research (BMBF). Among them, seven instruments belong to the group *"Unternehmen Region"*: *"Förderung von Zentren für Innovationskompetenz in den Neuen Ländern"*, *"InnoProfile Transfer"*, *"Innovationsforen"*, *"Innovative Regionale Wachstumskerne"* and *"Zwanzig20"* are aimed at promoting economic growth in Eastern Germany but address the specific group of SMEs. Both instruments *"Internationale Zusammenarbeit in Wissenschaft und Forschung"* and *"Internationalisierung von Spitzenclustern, Zukunftsprojekten und vergleichbaren Netzwerken"* promote international networking. *"KMU-innovativ"* facilitates access to technical programmes *(Fachprogramme des BMBF)* and thus supports industrial research and precompetitive development projects of SMEs.

At the European level, the instrument *"InnovFin-EU"* deals with funding for innovative SME projects. The *"European Cooperation in Scientific and Technical Research" (COST)* initiative aims to promote the European exchange of scientists. *"Eurostars"* also supports transnational SME research projects and the *"SME Instrument"* (SME mono/multi) is designed to help the further advancement of innovative SMEs whose concepts align with the objectives of Horizon 2020.

3.3 Systematisation of the Instruments Based on Functional Characteristics

We derived the functional characteristics of the policy instruments relevant to this research project from the literature (e.g., Bräunling & Harmsen, 1975; Edler, 2007; Edler et al., 2013; Garofoli & Musyck, 2003; Guy et al., 2009) and adjusted them for our objective. The systematisation aims to present the addressing of individual instruments to resources of SMEs and to obtain the broadest possible overview of the overall orientation of the instrument portfolio, thereby identifying current priorities and potential search fields. We want to highlight that the following statements refer only to the number of considered instruments in the instrument portfolio. No distinction is made about the importance of instruments concerning the volume of funds or the group reached by the different instruments.

The functional characteristics include traditional dichotomies, including (1) direct or indirect, (2) technology-specific or technology-open, (3) broad impact or targeted impact, (4) supply- or demand-oriented and (5) systemic or business-oriented instruments (see Table 1). In addition, (6) information on the addressed innovation phase and the level of innovation was compiled.

We distinguish whether the instruments promote the supply side in terms of the creation of innovations (manufacturers, networks) or instruments that predominantly consider diffusion on the demand side, e.g., the increased use of technology. At the same time, the instruments can address different phases in the research and innovation process. They can be placed on the continuum between basic research and the market launch of an innovation. Another feature concerns technology specificity. Some instruments are technology specific, i.e., only applicable for technology areas preselected by the grantor, whereas other instruments are technology-open.

Table 1 Examined functional characteristics (own illustration)

Support measures	Dichotomies/characteristics	
	Direct instrument Impact directly on the company	Indirect instrument Impact on target group through support of intermediaries between involved authorities (consultants, investors, banks)
	Technology-specific	Technology-open
	Broad effect A large number of companies is reached	Narrow effect A small number of companies is reached
	Supply-side oriented Producers of innovations (large/small)	Demand-side oriented Users of innovations (large/small)
	Business-oriented	System-oriented
	Basic research	Market entry

According to the guidelines, technology-open instruments are intended for all R&D-performing SMEs, regardless of their technological-thematic orientation. Thus, these instruments support companies without selection according to the technology field. They are often expected to broaden the general level of technology and innovation options as well as promote increased R&D activities across the board. An instrument can furthermore be classified in its broadness, determined by the number of potentially addressed and reached SMEs.

By considering the instruments to promote the formation and management of clusters, which involve and address SMEs as a specific target group, a further functional distinction can be made in the business or system orientation of the instruments. System-oriented instruments describe those measures that affect the cluster or groups of more than three companies and support their education, management or publicity through grants or subsidies. Business-oriented measures, usually administered in direct project funding, can be designed as individual or collaborative projects. As a rule, individual projects aim to promote a high level of R&D performance in selected technology areas. Each company is free to apply for grants for their respective R&D projects (under the guidelines for grant applications). Collaborative projects, on the other hand, are carried out in various organisational forms and involve multidisciplinary cooperation between various partners.

Applying these characteristics, it can be identified that overall, instruments are generally more application-oriented and focus on market entry, while only a few are involved in basic or application-oriented basic research (Fig. 2). The situation is somewhat different in the case of measures that do not have an exclusive SME-specific objective but that impact them. For example, regional or value chain-oriented programmes such as cluster support are of particular interest to SMEs because they integrate SMEs in a specific region through network organisers, network drivers or large enterprises.

Figure 3 shows a systematisation of the selected instruments along two different dimensions. On the one hand, a distinction is made as to whether the instruments are more business-oriented, addressing the input for innovation projects or the innovation capabilities for processing the innovation input. A similar distinction can also be made regarding system-oriented support, which addresses at least two and more innovation actors.

In doing so, a distinction between capabilities and input resources is also employed, which is defined as follows: "Capabilities […] refer to a firm's capacity to deploy resources, usually in combination, using organisational processes, to affect the desired end. They are information-based, tangible or intangible processes that are firm-specific and are developed over time through complex interactions among the firm's resources" (Amit and Shoemaker, 1993:35). As a result, capabilities are needed to combine input resources and properly coordinate them (see also Schreyögg & Kliesch-Eberl, 2007). This shows that only two are aimed at individual companies and support their ability to develop innovations among the instruments considered systematically.

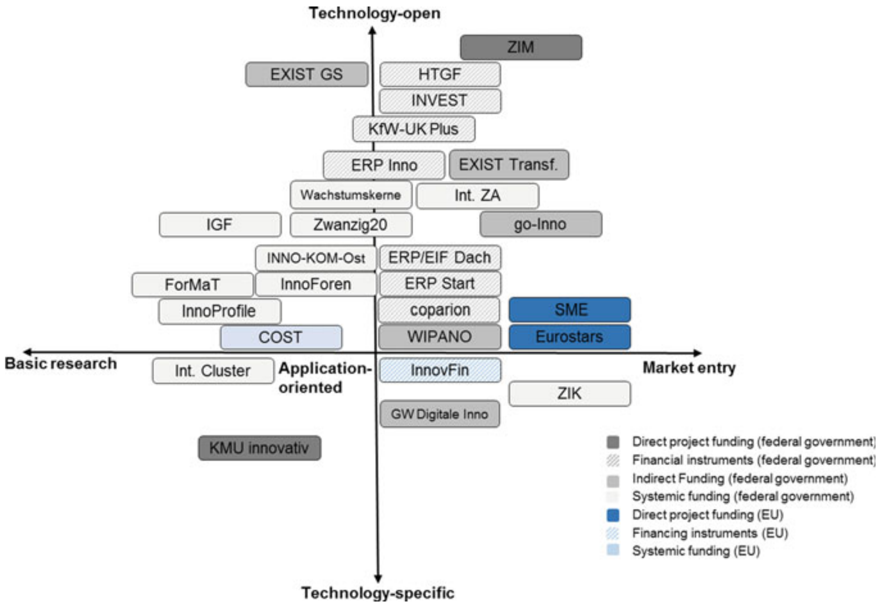

Fig. 2 Systematisation of the selected instruments along the innovation process and the technology specificity

Considering the fields of public innovation and technology support, which provide SMEs with essential resources for innovation processes, the focus lies on the flow of knowledge to technologies or markets, financial support, improving organisational and management skills and, most importantly, the ability to cooperate. Direct support, such as the targeted support of using new techniques, is currently not offered. In addition, except in the start-up sector and cluster competition or regional programmes, personnel training and development are less pronounced in R&D and innovation support programmes. Further systematisation, which would have provided important information on the direction of the instrument portfolio, would have been the classification of instruments according to the addressed degree of novelty of innovation projects. Here, differences in the funding requirements within the described instrument set are observed. However, such a systematisation based on a document analysis of the existing official announcements failed because they did not give a complete picture. The texts of the tenders and the programmes leave too much room for interpretation. Capturing such information in the future and including it systematically in strategy formation seem very meaningful, considering the diverse range of instruments. This could only be done as part of a detailed individual assessment of supported projects.

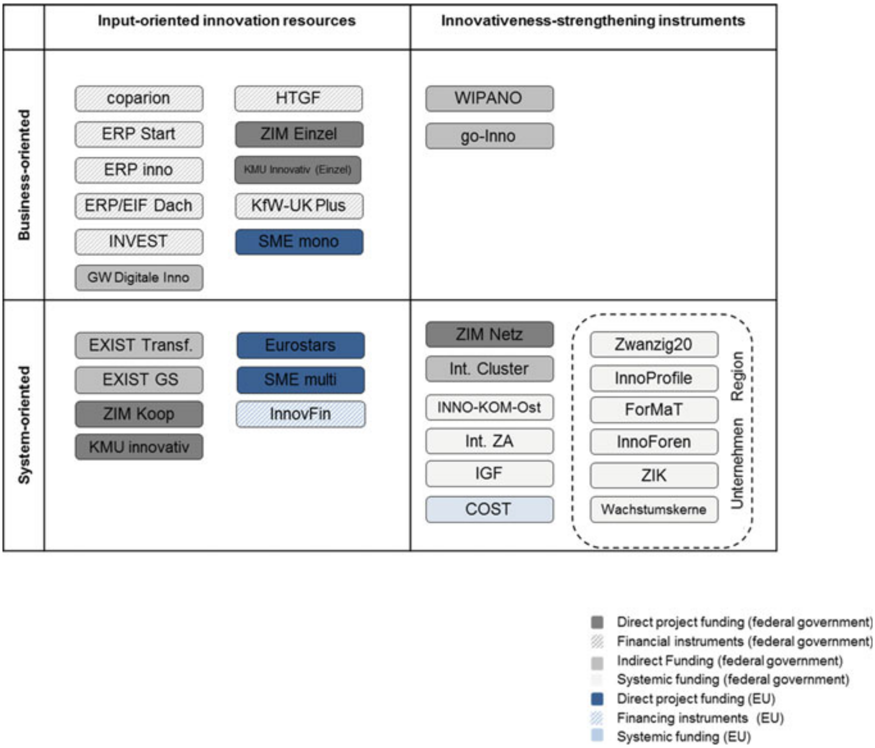

Fig. 3 Classification of the selected instruments according to their goal orientation and the resources provided

3.4 Instruments from the Resource-Oriented Perspective

In the following, we investigate which innovation resources are addressed by the respective instruments. To illustrate this relationship, an interpretive translation process based on the conceptual aspects of the resource-oriented approach had to be undertaken. The resource-based approach explains the differences in the economic performance of companies by suggesting that companies each have their individual and strategically valuable pools of resources that give them a competitive advantage (Welge & Al-Laham, 2008).

Different types of resources can be distinguished, which refer to material or physical resources (e.g., machine, construction) or immaterial personal (e.g., skills, abilities, contracts) and nonpersonal resources (e.g., patents, process flows) (Moldaschl & Fischer, 2004; Knaese, 2013). The following remarks outline common resources necessary for SMEs in their innovation behaviour. They are based mainly on the resource typology of Dollinger (2008). To use these resource types for a qualitative document analysis, proxy variables had to be defined to systematically compare the documents. This establishes a concrete connection between the instrument and identified innovation patterns.

We use the concept of material resources (infrastructure), which includes the support of material services and the use of premises and laboratories that are not owned by the company but provided for a limited time in the context of a support programme. Funding offers of this kind are more frequently found at the provincial level than at the federal or EU level and are only considered at specific points but are regarded as conceptually relevant. Financial resources that are made available for the primary material supply of employees as part of a support programme are also included in this category. As a proxy variable for this resource category, the support programme guidelines selected the payment of livelihood, material costs, personnel expenses or investments in equipment and laboratory equipment. An example of an instrument that addresses this resource is the *EXIST Founder Scholarship* or the reimbursement of personnel and material costs in collaborative projects of the BMBF.

Since all support programmes generally offer financial resources, the resource category “corporate finance” has to be defined more narrowly. This category includes the borrowing capacity of companies and their ability to raise capital. For the targeted support of this resource, political actors have different opportunities, such as the creation of tax advantages. However, the focus here is on support programmes that are not provided in the form of grants but in the form of participation, credits or loans. Therefore, the proxy variable in the guidelines is “participations” and “loans”, “credit”. The *ERP/EIF Dachfonds* is one example.

The resource “knowledge” is defined differently and includes technical knowledge and/or intellectual capital. The company may own the former, while the latter is personal. Within the framework of this study, knowledge resources mainly include technical knowledge, experience, IPR, customer requirements, market knowledge and market access knowledge. Therefore, traditional R&D funding instruments and network support, cooperation projects and clusters address this resource. Examples include *ZIM* and *KMU-innovativ.*

The resource “personnel” includes the knowledge, training and experience of the employees of a company. Regardless of whether there is a team of skilled, semiskilled and/or high-skilled employees, judgement and creativity are personal resources that benefit a company. Accordingly, instruments that aim at training and further education as well as new start-ups fall into this category. Therefore, as a relevant feature in the guidelines, the eligibility of natural persons and the explicit support of start-ups are chosen, for example, in the support programme “*Gründerwettbewerb Digitale Innovation”*.

The resource “network” is based on the definition of reputational resources (Dollinger, 2008:44), which emphasises the importance of the reputation of a company as an independent resource. Brand loyalty and loyalty play a role between the producer and the consumer and within the entire value chain. In particular, SMEs rely on networks and contacts, which are essential resources. Instruments that promote, for example, the German industry, take on public relations, attend trade fairs or forums and hold regular conferences or meetings belong to this category of resources. Examples include the instruments “*Internationale Zusammenarbeit in Wissenschaft und Forschung*” or “*Innovationsforen”*. Highly competitive instruments with a high image effect are particularly effective, such as the “*Spitzenclusterförderung*”.

“Organisation and management” of a company are essential intangible resources. In particular, a company’s cooperation, conversion, foresight and planning capability depend on its organisational, communication and decision-making structure. Therefore, instruments fall into this category, which, in line with the definition of organisational resources (Dollinger, 2008:46), provide consulting services for a company and, for example, allow for patent counselling or the conduct of market analyses. The respective guidelines show that consulting services and market analyses are at the centre of the “*WIPANO*” and “*go inno*” support programmes.

Based on these briefly outlined definitions, we provide an overview of which the respective funding instruments address specific resources. A distinction has been made between primary and secondary resources that are derived from the guidelines to provide a comprehensive overview. Some of these were only implicitly derived from guidelines, which is why further documents (such as evaluations and brochures) were used to identify them (Table 2).

Overall, the analysis of resources shows that the SME instruments examined at the federal and EU levels address different resources and innovation actors. The considered instruments mainly address the development or inflow of technological knowledge and the financing of personnel capacity and/or technical equipment for R&D. Furthermore, new networks for innovation are increasingly considered. Less relevant are measures that support people, such as training or the thematic strengthening of SMEs’ ability to transform and plan. Direct instruments (in different and widely diversified funding formats in the form of individual, collaborative and network funding) are predominant. The goal is usually to create innovations (in the sense of new developments), while the diffusion or recombination of existing solutions is not in focus. The focus of business-oriented instruments is primarily the provision of input-oriented innovation resources (such as financing), while system-oriented instruments considering skill and competence building are the exception among the examined instruments.

3.5 *Main Findings—Systematisation and Analysis of Existing SME Promotion Instruments*

The analysis of the 27 innovation-oriented instruments offered by the BMBF (10), the BMWK (13) and the European Commission (4) until the end of 2018 for SMEs revealed several observations. Most measures considered by the federal government and the EU are technology-open. Technology-specific measures are primarily implemented within the framework of "*KMU-innovativ*" or in the participation of technology programmes ("Fachprogramme") of the BMBF and other resorts. The considered funding instruments are generally more application-oriented and focused on market entry. There are comparatively few measures for SMEs involved in basic research or application-oriented basic research, i.e., where disruptive developments are being prepared.

Table 2 SME innovation policy instruments and addressed resources

	Staff	Organiz. & Management	Knowledge	Infrastructure	Network	Financing
ZIK		○	●	○	●	
InnoProfile	○		●		●	
Inno-Foren			●		●	
Wachstumsk.			●		●	
ForMat	●		○			
Int. ZA					●	
Int. Cluster		○			●	
Zwanzig20			●			
KMU-innovativ			●		○	

Legend: ● = Primary resource that is addressed by the instrument (the instrument primarily addresses the specified resource in its objectives). ○ = Secondary resource that is addressed by the instrument (the instrument addresses the specified resource in a second (subordinate) objective).

(continued)

Table 2 (continued)

	Staff	Organiz. & Management	Knowledge	Infrastructure	Network	Financing
Coparion						●
ERP Dach			○			●
ERP Inno				○		●
KfW-UK Plus						●
ERP Start						●
INVEST	○					●
HTGF		○				●
ZIM		●	●	○	○	
WIPANO		●	●			
IGF			●			
IGF Cluster			●		●	
IGF Cornet			●		●	
EXIST-Transf	●		●			
EXIST-GS	●			●		
GW Digital	●				●	
Go inno		●				
INNO-KOM			○	○	●	

Legend: ● = Primary resource that is addressed by the instrument (the instrument primarily addresses the specified resource in its objectives). ○ = Secondary resource that is addressed by the instrument (the instrument addresses the specified resource in a second (subordinate) objective).

(continued)

Table 2 (continued)

	Personal	Organiz. & Management	Knowledge	Infrastructure	Network	Financing
COST			●		○	
Eureka			●			
Eurostars					○	
SME		●			●	
InnovFin						●

Legend: ● = Primary resource that is addressed by the instrument (the instrument primarily addresses the specified resource in its objectives). ○ = Secondary resource that is addressed by the instrument (the instrument addresses the specified resource in a second (subordinate) objective).

The situation is somewhat different for instruments that do not have an exclusive SME-specific objective but that may impact them. In this context, regional or value chain-oriented formats such as cluster support should be of particular interest to SMEs because these regional approaches involve the existing SMEs of the region in the value chains through network organisers, drivers or large focal companies. In this way, SMEs with innovation patterns beyond R&D are also reached. The resources addressed by the funding instruments are preferably the inflow of technical knowledge and the financing of personnel capacity and/or technical equipment for R&D. The creation of new networks as a reputational resource for innovation is mainly within the BMBF programmes. Comparatively, less attention is given to measures to promote human resources or strengthen SME strategy change and planning capacity. In addition, no indirect measures with an SME focus are in the policy instrument portfolio, especially no demand-oriented measures that support the application of new technologies, for example, in coping with certain technological or organisational hurdles. To raise the efficiency of the SME-oriented instrument portfolio, the results of this policy document analysis suggest that the innovation behaviour of German SMEs will have to be viewed in a more differentiated way in the future. In particular, innovation patterns beyond R&D need to be taken into account in more detail to enhance the innovation capabilities of SMEs.

4 Policy Implications by Mirroring Heterogeneous SME Innovation Patterns with Existing German Innovation Policy Instruments

4.1 Implications by Using the Typology of SME Innovation Pattern Groups

The findings of this study allow a differentiated assessment of the innovation behaviour of German industrial SMEs. The results make it clear that the existing SME definition based on statistical characteristics (e.g., company size and sales volume or balance sheet total) and univariate typologies (e.g., R&D intensity) is not sufficient for meaningful analysis and evaluation of the innovation behaviour of SMEs. Both research-intensive and non-research-intensive (or even nonresearching SMEs) contribute equally to the performance of the German industrial innovation system through different functional innovation patterns. As the analysis of existing SME policy instruments has shown, they only partially target the specific features and diversity of different SME innovation patterns. Based on the identified heterogeneous innovation patterns of German manufacturing SMEs and the policy analysis, several more detailed observations can be made. A particular advantage of this innovation typology is that it better maps the different innovation patterns of the "Hidden Champions"—the widely unknown world market leaders among small and medium-sized companies (Simon, 2009) whose innovation patterns often rely on deep customer knowledge and a strong in-house technological capacity originating in practical and experienced-based know-how (Rammer & Spielkamp, 2019) as represented by the innovation patterns of "*knowledge-intensive product developers*" or "*customer-driven technical problem-solvers*".

The policy implications will be discussed for each of the four summarised innovation pattern groups (1) knowledge-intensive product developers, (2) customer-driven technical problem solvers, (3) specialised suppliers and (4) manufactures of end-products.

Knowledge-intensive product developers

Knowledge-intensive product developers are the leading target group of the existing innovation-oriented SME instruments analysed. Companies of this group rely on a high degree of their own R&D activities and are characterised through knowledge-intensive and often formalised innovation processes. In their early and start-up phases, these SMEs are reached by most national financing instruments, such as INVEST, HTGF or ERP-funding schemes. A high possibility of external cooperation between industry partners but also in terms of science-industry cooperation allows them to benefit from system-oriented instruments strengthening innovativeness (such as IGF or ZIM Netz) as well as input-oriented instruments (such as KMU-innovativ or ZIM-Koop). Basic and applied-basic research activities of this group are addressed with KMU-innovativ. Furthermore, companies that are active on a European level can benefit from programmes such as the SME instrument, which targets breakthrough innovations of highly innovative SMEs with market-creating potential.

In summary, it can be stated that the group of knowledge-intensive product developers, which represent approximately a quarter to a third of all SMEs, are the primary target group of many of the analysed SME instruments. They are the "ideal or role model SME" for innovation policy makers meeting all general assumptions usually connected to SME innovation behaviour. Nevertheless, it might still be difficult to find suitable funding schemes for software development or service activities (as part of innovative business models), which are not captured by the current R&D paradigm.

Customer-driven technical problem solvers

Many of the SMEs of this group do not have their product development and position themselves on the market exclusively through their process excellence. The technical process specialists, which represent the R&D-performing SME of this group, are well reached by many of the R&D-based instruments targeting financing, knowledge or network bottlenecks.

However, many SMEs are strongly driven by customers, i.e., innovations are often initiated by customer requests in the form of small-step improvements and incremental product innovations. These inquiries and the resulting innovation projects are generally short- to medium-term and often time-critical. Systematic innovation activities in the sense of the development and implementation of own ideas and products, which were not directly initiated by customer orders, can be found less often in the innovation patterns of this group. Thus, there is usually less a lack of own ideas for implementation but instead a lack of institutionalised and professional processes of forwards-looking corporate innovation management.

SMEs with these characteristics hardly correspond to existing support offers and instruments for SMEs. This is partly due to the design of the funding programmes themselves. For example, the instruments are primarily aimed at developing market innovations, i.e., new products that have not yet been offered on the market by any company and that, due to the level of innovation involved, have a strong precompetitive character. Many SMEs do not consider themselves in this terminology, which is often accompanied by terms such as "high-tech" and the novelty claim associated with this in the allocation of subsidies.

A further reason is the frequently long project duration of three years, enabling longer and more complex analysis and development steps. Often, these periods are too long for customer-driven problem solvers among SMEs, as their customers cannot or do not want to wait so long for the new solution. In this context, applications by SMEs are often perceived as too lengthy and, due to the strong level of competition, ultimately too uncertain in many programmes.

Specialised suppliers

The SMEs of this group are characterised by a high level of customer orientation. They position themselves on the market with products having medium-to-low complexity, an excellent price–performance ratio and high-volume flexibility. In doing so, they do not rely on formalised R&D but rather use implicit, experiential and application-related knowledge. They constitute a group of rather internally oriented (closed) innovation patterns and, therefore, can hardly be achieved through the existing transfer channels of scientific research institutions. New technological knowledge is primarily tapped through corresponding impulses from (major) customers. Thus, they are hardly addressed by many of the existing R&D-based funding schemes. Network-oriented funding schemes may include more of them if these SMEs are brought in by their clients into the funding schemes. A few of the other identified instruments are useful, such as ZIM or go-inno support on organisational concepts and management methods, which are essential innovation drivers for the SME within this group.

Manufactures of end-products

Many of the SMEs in these innovative patterns do not have the necessary organisational and personnel framework conditions to benefit sustainably from funding measures and, in particular, project funding. The first reason for this is undoubtedly the lack of professional structures and routines in strategy development, handling of intellectual property rights and cooperation and innovation management. As a result, the income from such projects with high degrees of novelty cannot be adequately acquired or can be largely eroded by additional efforts, unintentional knowledge outflows and inefficiencies due to a lack of processes. Thus, from the point of view of their organisational framework conditions and their culture of innovation and knowledge, many SMEs are literally not "eligible" for demanding project funding programmes in the sense of not being sufficiently prepared. If this leads to disappointments and negative experiences, further activities in support programmes are generally avoided.

Additional observations

There is a dominant focus on stimulating SMEs' R&D activities, which does not correspond to half of all SMEs' innovation patterns and thus should be not assumed to trigger broad mobilisation effects. On the other hand, the existing administrative frameworks of application and eligibility criteria (e.g., submission of commercialisation strategy) counteract these efforts.

Not least, the time logic of many existing programmes does not meet the short-term needs for innovative solutions of many SMEs. As the challenges and case studies, several innovation patterns show, it is precisely the increasing technical complexity and the need for change in internal processes as well as the increased time pressure that makes it difficult for small and medium-sized enterprises to plan and implement projects in the classic funding project design of two, three or four years. Usually, these projects require shorter runtimes but larger-volume approaches. The funding instruments largely ignore postquestion stimuli that contribute to the development of management and organisational skills or enable the use of new technologies to be able to position oneself successfully in the long term.

There is currently a much-differentiated range of instruments on the supply side, whereas in the broad demand-oriented measures, fewer instruments are explicitly used for SMEs. Instead, it can be said that, on the one hand, policy makers are trying to achieve innovation and growth policy goals and, on the other hand, to address as many SMEs as possible, which are "caught between the seats" in their target logic. Hence, a rethinking of the SME innovation policy objectives and the instrument portfolio is necessary.

4.2 Reconsidering Objectives (and Dilemmas) for SME Innovation Policy and Consequences for the Instrument Portfolio

Before the implications for innovation policy derived from the present analysis results are explained, the underlying premises of the recommendations must be mentioned:

Based on the estimated relevant economic importance of each innovation pattern based on a cross-sectional view, it can be assumed that—as things stand today in Germany—all identified innovation patterns of SMEs with their individual resource or competence bundles contribute to the performance of the industrial innovation system in Germany in different ways and to different degrees. The aim of the innovation policy recommendations is, therefore, among other things, to address observed heterogeneity in the different innovation strategies of SMEs. The genuine consideration of the specific innovation patterns of SMEs against the background of a "new mission orientation" is of particular importance for innovation policy. For example, in their current strategy papers, the BMBF and BMWI emphasise that "it is not only a question of financial support but also of individual and needs-oriented offers" (BMBF, 2015; BMWI, 2016), which should lead SMEs overall to more innovation performance. Therefore, a discussion of innovation policy options should take place against the background of the concrete objectives of state intervention and the heterogeneous patterns of innovation.

In the context of future challenges, many industrial SMEs are confronted with considerable or even disruptive dynamics of change, which partially or even largely devalue or reform their currently successful resource and competence bundles. As a result, it is to be expected that new obstacles and barriers to innovation will arise, which can no longer be described in detail with the findings of market failure that are now customary for the legitimation of state intervention. These may also require new approaches at the instrument level that are not yet, or only partially, compatible with existing regulatory guidelines and administrative structures of the funding landscape. The innovation policymakers have already recognised some of these aspects (among others also after the interim reporting from this project) and have been included in the debates. Possible objectives for the further or new development of SME promotion instruments are based on the growth policy objectives of public innovation and technology policy and essentially comprise three dimensions:

- Increase in the number of innovation-active SMEs across the board (quantitative).
- Increasing the degree of ambition and novelty of the innovation activities of innovation-active SMEs (qualitative).
- Accelerating the transfer and diffusion of new solutions in SMEs.

Objective 1: Increase the number of innovative SMEs (quantitative)

Most of the innovation patterns identified for SMEs are not primarily geared to differentiation via new products or even market innovations. This does not mean that the development of products (e.g., new product ranges) does not play a role, but it does mean that unique selling points in production and manufacturing processes, such as quality, flexibility or the price–performance ratio, differentiate companies from their competitors. In addition, there are also innovation patterns, some of which companies do not even have their product development and which position themselves on the market exclusively through their process excellence. Furthermore, many of the innovation patterns of SMEs are strongly driven by customers, i.e., innovations are often initiated by customer requests in the form of small-step improvements and incremental product innovations. These inquiries and the resulting innovation projects are generally short- to medium-term and often time-critical. In the sense of the development and implementation of own ideas and products, which were not directly initiated by customer orders, systematic innovation activities can be found less often in these innovation patterns. However, there is usually not a lack of own ideas for implementation but instead a lack of institutionalised and professional processes of corporate innovation management.

A further reason is the frequently long project duration of three years, enabling longer and more complex analysis and development steps. However, these periods are too long for customer-driven problem solvers among SMEs, as their customers cannot or do not want to wait so long for the new solution. In this context, applications by SMEs are often perceived as too lengthy and, due to the strong level of competition, ultimately too uncertain in many programmes. In addition, it can be assumed that in economically busy and profitable periods with full-order books, existing resources and competencies will be concentrated in the operating business and innovation projects will (must) be postponed both at the customer's and at the company's levels. In this context, a decline in SME participation in innovation may well be due to the current excellent economic situation in the German industry.

These points illustrate a particular dilemma of innovation promotion. On the one hand, due to the duration of many funding measures, especially in the context of collaborative research, short-term solutions are often developed and implemented too slowly or too late. For some of the SME innovation patterns mentioned above, this may mean that they do not participate in project funding measures and show little interest in the existing formats. The funding policy focuses on knowledge transfer, and the efforts to link SMEs in many funding formats more closely with science and scholarship further reinforce the problem. At the same time, more radical and medium-term innovation projects whose concrete demand is not immediately available require targeted positioning in new markets and business areas. However, finding precisely these opportunities in the form of new market niches and fields requires the ability to evaluate new technologies and market opportunities and the general transfer of existing forms of knowledge into entirely new fields of application. This represents a particular hurdle for many SMEs and requires an increase in the overall adaptability of SMEs.

In addition, many of the SMEs in these innovative patterns do not have the necessary organisational and personnel framework conditions to benefit sustainably from funding measures and, in particular, project funding. The first reason for this is the lack of professional structures and routines in strategy development, handling of intellectual property rights and cooperation and innovation management. As a result, the income from such projects with high degrees of novelty cannot be adequately captured or can be largely eroded by additional efforts, unintentional knowledge outflows and inefficiencies due to a lack of processes. Thus, from the point of view of their organisational framework conditions and their culture of innovation and knowledge, many SMEs are not "eligible" for demanding project funding programmes in the sense of not being sufficiently prepared. If this leads to disappointments and negative experiences, they avoid further activities in support programmes.

Objective 2: To increase the level of innovation and innovation of innovation-active SMEs (qualitative)

As the analysis results show, a number of SME innovation patterns are already driving the development of new products and market innovations to a high degree, such as the product developers of knowledge-intensive product-service bundles or the providers of high-tech system solutions. SMEs with these innovation patterns rely on a high degree of their own R&D activities but represent only approximately one-quarter to one-third of all SMEs. Most SMEs innovate primarily with incremental improvements to existing products and processes, which are often geared to customer-specific needs and niche markets with low market volumes (Sandven et al., 2005; Hirsch-Kreinsen, 2008). This often guarantees high short-term innovation success (in the sense of high sales with new products) but implies that innovation-based growth of these SMEs is dependent on the growth of customers or their markets and that it is challenging to develop new markets and customer groups from within. To overcome the resulting path dependencies and in part also lock-in effects (Zanker et al., 2014) in the innovation behaviour of SMEs, as well as to open up their growth potential for these companies, the question of how existing innovation activities in SMEs can be raised to a higher level of demand and novelty also arises for innovation and technology policy. There is also the possibility that future, sometimes disruptive changes will more or less gradually devalue the existing resources, skills and knowledge base of some SME innovation patterns. The meta-competence for the early identification of such developments, the exploitation of new strategic business areas and markets and the adjustment of the innovation resources and competencies that are available within and outside the company ("dynamic capability") up to the radical reinvention of the entrepreneurial business model will therefore gain importance in the future.

The challenge is twofold. First, time logic is a particular obstacle to ambitious innovation projects and thus also to the efficiency of innovation policy instruments. This can be attributed primarily to the coordination and synchronisation difficulties between different private and public innovation actors. Economy, science and politics are each structured by a specific temporal logic (Rollwagen, 2015). The long-term time horizons of science (through scientific methods) and politics collide with the short-term time horizons of the industrial exploitation of many SMEs. This time obstacle also became apparent in the qualitative company surveys and case studies of the present work. Second, existing funding regulations, application procedures, linear project processes and proof of the commercial exploitation of the developed solutions often stand in the way of demanding innovation projects with high degrees of novelty. Especially in the context of increasingly dynamic technological and economic conditions, it is increasingly difficult to define the economic exploitation prospects of a radical innovation at the time of application. As a result, existing funding programmes tend to reinforce the incremental innovation pattern of many SMEs in their administrative and funding law framework conditions. This is also the case for the SME-specific "KMU-innovativ" or "ZIM" programmes, whose approval criteria also tend to favour incremental innovations with already clear marketing prospects and which make it difficult for SMEs to leave their "comfort zone" towards more radical innovation.

Objective 3: Accelerate the transfer and diffusion of new technological and non-technological solutions in SMEs

The analysis of future challenges in the context of qualitative business cases with SMEs from different innovation patterns makes it clear that SMEs in different key technological areas are facing the challenge of building up future market potential and application competencies. Dynamics and trends in production technologies have the highest strategic relevance, especially for highly production- and process-oriented innovation patterns such as process specialists (with and without R&D), as these SMEs achieve their competitive advantages through this. However, various structural barriers hinder market introduction and diffusion on the demand side, for example, due to the high entry or conversion costs, lack of network effects or a lack of information and awareness on the part of customers (Edler et al. 2008). In particular, more internally oriented (closed) innovation patterns of SMEs, such as manufacturers of products, can hardly be achieved through existing transfer channels of scientific research institutions. As the analysis has shown, new technological knowledge is primarily tapped through corresponding impulses from (major) customers.

As the present studies have shown, many SMEs face various obstacles to innovation. This includes, for example, the lack of access to markets. Organisational innovations in these areas, in particular, are an essential lever for the innovative capacity of SMEs. However, unlike technological solutions, new organisational concepts and solutions for coping with growth crises or improving innovation management cannot easily be transferred between companies. Moreover, even with the appropriate capacities, SMEs generally do not succeed in perceiving the entire breadth of existing research results or good practices from other pilot companies or in making the results independently usable. As a result, organisational solutions are often sought in vain or newly developed using external consultants for already adaptable solutions in other companies, industries or application contexts.

Policy recommendations

SMEs and their innovation patterns, the foreseeable socioeconomic challenges and technological trends as set out in the context of the "new mission orientation" and in the Federal Government's High-Tech Strategy must be considered. In light of the existing portfolio of SME promotion instruments, three concrete starting points for the design and development of promotion instruments can be identified, which are reflected in the various recommendations for measures:

- Frequently encountered resource and competence bundles of SMEs in the sense of recurrent resource constellations and competence focal points in the innovation behaviour of SMEs, which can be interpreted in the form of strengths and weaknesses.
- Frequently encountered innovation modes of SMEs in the sense of specific innovation activities that can be identified across several innovation patterns.
- Pattern-specific characteristics in terms of strengths and weaknesses of the heterogeneous innovation patterns of SMEs.

Following the three objectives mentioned above, recommendations for design and measures will be discussed, which can be derived from the results of this study.

The proposed measures range from:

- Further developments in terms of content in the form of existing or new funding instruments (e.g., inclusion of architectural and non-technological innovation).
- The constellation of actors in collaborative research consortia (e.g., cross-industry innovation, integration of value creation partners) to.
- Structural changes in the instruments' application, approval and implementation modalities (e.g., agile approaches to project management). Thus, they represent a holistic approach to policy design.

The measures for which priority is given to the identified innovation patterns were also listed. The table in the Annex gives an overview of all measures concerning their contribution to the three central objectives and the innovation patterns that are mainly addressed. This should also make clear that many of the measures are complementary to each other and can therefore be integrated consistently within the framework of a further developed SME promotion policy.

5 Conclusion and Outlook

The results show that the innovation behaviour of small and medium-sized enterprises can be empirically recorded and comprehensively described along the selected resource dimensions covering the entire range of Schumpeter's understanding of innovation. All firms in the analysis sample were successfully assigned to one of the R&D-based or non-R&D-based innovation patterns. This finding supports the basic assumption of the heterogeneity of firm innovation behaviour, which is reflected along different organisational resource bundles of firm-specific competences. These resource bundles comprise both technologically oriented (e.g., R&D, use of modern production technology and manufacturing processes) and non-technologically oriented competences (e.g., customer service, innovative organisational and management methods, cooperation) and are based to varying degrees on explicit (formal) and tacit (experience-based, informal) knowledge stocks. Due to the evolutionary analysis design based on different resource networks, the analysis was also able to show that the innovation behaviour of R&D-driving SMEs is by no means homogeneous with regard to their resource and competence bundles. The five R&D-based innovation patterns make it clear that this group of companies also has completely different resource bundles and behaviour patterns, some of which are similar in character to those of non-R&D-driving SMEs. Hence, the theoretical framework based on evolutionary economic theory to explain heterogeneity and the resource-based view at the firm level to operationalise different dimensions of heterogeneity in firms' innovation behaviour proved to be a feasible basis and has been widely supported by the empirical findings. As innovation policies target different resources (e.g., financial, knowledge, networks, human, machinery and equipment), the resource-based view appears to be particularly useful to develop an innovation typology of firms' innovation behaviour for the purpose of policy analysis and policy design.

The analyses show that in the future, the innovation behaviour of German SMEs will have to be viewed in a more differentiated way and that innovation patterns beyond R&D will also have to be considered and possibly paid more attention to. This particularly accounts for the context of an ongoing transformation towards mission-oriented innovation policies that focus on the solution of grand societal challenges with their cross-industry, ecosystem and technology-open characteristics (Borrás & Edler, 2020; Kulmann and Rip, 2018; Wittmann et al., 2021). For this purpose, the presented analytical framework does not aim at substituting existing innovation typologies at the industry (e.g., Peneder, 2010) or firm level (DeJong and Marsili, 2006; Leiponen & Drejer, 2007). Instead, it is intended to enlarge the design and analysis of innovation policy by a new conceptual perspective that accounts for heterogeneous innovation patterns and their individual resource base.

It should be emphasised that the heterogeneity of the empirically identified innovation patterns does not initially justify an immediate need for (additional) funding. Instead, the identified innovation patterns of SMEs enable a comprehensive and meaningful description, interpretation and prognosis of the innovation behaviour of different SMEs in the German manufacturing industry for the first time. Starting from their respective "innovation DNA" in the form of a specific interplay of different tangibles and intangible resources and competencies, detailed identification of their respective strengths and weaknesses is possible. It has also been reported that innovative and successful companies can be found in all innovation patterns.

The benefit for the policy discussion in general and the innovation and technology policy in particular results from the fact that these innovation patterns are affected to varying degrees by innovation barriers and barriers due to their individual "innovation DNA". The findings on innovation patterns thus allow diagnoses of different, individual problem and demand situations that go far beyond the understanding of "market failure" as a homogeneous assumption valid for all SMEs.

For the development of funding policy instruments, this means that the entire SME population can never be reached in a "one-fits-for all"-scheme or that specific instruments always consciously or unconsciously exclude a larger or smaller part of the SME landscape. Instead, the results on innovation patterns add value for policymaking in targeting, developing and/or extending existing supportive actions employing objectives, logic and target groups. Thus, different innovation patterns are achieved differently by different measures. Should, for instance, R&D be stimulated in SMEs, then support measures should primarily address the innovation patterns of "knowledge-intensive product developers" and, in part, "technical process specialists". In contrast, SMEs that differentiate themselves primarily through technical and organisational processes or that are active in markets that do not allow the generation of Schumpeter pensions would be neglected by such R&D-oriented instruments. The question of the use and design of funding policy instruments thus decides against the background of the pursued objective. As a result, the policy recommendations developed have been assigned to innovation policy goals and offer starting points for achieving these goals. This raises the question of whether, as the BMWi writes in its programme paper "From Idea to Market Success", the goal must be "to have the right funding instrument for each company" (BMWi, 2016, p. 2). If one follows this consideration, further questions arise quickly as to whether such a "microcontrol" can be legitimised in the public policy in addition to the barely representable administrative expenses. However, it should be remembered that each of the identified groups includes between 2400 and 6000 businesses with 237,000–592,000 employees.

As with every study, this study suffers from several limitations. Ultimately, the results obtained here are just a snapshot in one country (Germany). That concerns the innovation patterns identified as well as the portfolio of innovation policy instruments observed. Nevertheless, the findings of the analysis support previous (mostly qualitative) studies (e.g., Sandven et al., 2005; Santamaría et al., 2009). Additionally, the conceptual and analytical approach of this study (i.e., the innovation pattern typology) has already been successfully applied by the authors to other innovation systems (e.g., Egypt, Slovenia, China and Brazil). The results from these projects confirm that, being based on traditional mainstream economics of growth, most innovation policy support schemes are primarily focusing on the stimulation of R&D, neglecting the growth potentials of non-R&D-based innovation patterns to a great extent.

Furthermore, the resource-based view as a theoretical foundation has been criticised for its simplicity and only explaining competitive heterogeneity (e.g., Kraaijenbrink et al., 2010; Priem & Butler, 2001). In particular, it does not cover the level of capabilities (opportunity detection, filtering, decision-making, unlocking external resources) or meta-capabilities of resource configuration such as the dynamic capability of firms (Teece et al., 1997; Eisenhardt and Martin, 2000), which are regarded as prerequisites and drivers of evolutionary processes (Dekkers, 2005). Although the findings can be robust hypotheses for a functional interaction of different innovation patterns, they ultimately can only be answered by further research on the dynamics and the interaction of the patterns in the context of the industrial innovation system.

Thus, further research is needed to answer whether and how much heterogeneity of innovation patterns in SMEs is functional in terms of innovation performance and thus the growth of an economy, which in turn could justify support because of maintaining a certain level of heterogeneity. A necessary further question would be whether there are "ideal innovation patterns" for SMEs in the context of future challenges towards which companies can or should develop. In particular, possible dynamic migration paths between the different innovation patterns and their respective resource DNAs should be considered against this background. In particular, "switchers" would have to be studied specifically (e.g., switching between R&D and non-R&D-intensive "twin patterns") to identify which of the resources and competences have played a particular role in achieving dynamism and adaptability in small and medium-sized enterprises. Here, future research should add a capability perspective to explore which and to what extent the patterns are characterised by certain (dynamic) innovation capabilities.

It is also important to note that little is yet known about the functional interplay of the patterns. The pattern structure points to a specialisation in the innovation system based on the division of labour (analogous to evolutionary ecosystems), but it is still largely unclear how this ecosystem functions or how it reacts to external disturbances/interventions.

In addition, a comparison of the identified innovation patterns of small and medium-sized enterprises with other, existing and new innovation indicators would be helpful. As an indication and to underline the need for research, it should be noted that innovation patterns can be found in many sectors, including so-called high-tech sectors. Moreover, there are enough small and medium-sized enterprises that do not conduct any research and development at all, even in so-called high-tech sectors. Thus, the reality of differentiating innovation patterns can only be incompletely assessed with the previous indicators. This leaves the question of for which innovation patterns, for example, the patent indicator, remains meaningful and for which new indicators must be developed to be able to make an appropriate assessment of innovation activity.

On the economic level, this analysis raises the question of how regulatory policy can be argued in the future if structural factors such as sectors and size play no role in innovation behaviour or patterns. Economic policy justifications based on company size would be prohibited in the future on the basis of the present differentiation of innovation patterns. Aspects of company adaptability, (technology-) dynamic and systemic considerations from evolutionary innovation economics are likely to be given much more weight in the debate on the sense and purpose of state intervention.

Finally, from an innovation policy perspective, the analysis of the policy instruments had to leave open the question of the desired and achieved level of innovation of the supported projects of the SMEs. This would have required a more detailed analysis of the funded projects, which was not possible within this project's scope. This would certainly be an important question for future evaluations and the question of the addressed and reached resources. Furthermore, this analysis raises the question of how innovation policy can be argued in the future if structural factors such as industries and size do not influence innovation behaviour or patterns. However, bundles of resources and competencies are relevant. In the future, economic policy justifications based on the company's size would be prohibited without the differentiation of innovation patterns. The aspects of business adaptability, (technological) dynamic and systemic considerations from the evolutionary innovation economy will become much more important in the debate about the meaning and purpose of state intervention. In many cases, however, there is still a lack of clear-cut operationalisation and criteria.

6 Annex

No.	Option for action	STI goals: Goal 1: Increasing the number of innovation-active SME (quantitative)	STI goals: Goal 2: Increasing the degree of novelty of SMEs' innovation actitivies (qualitative)	STI goals: Goal 3: Accelerating the transfer and diffusion of new technological and non-technological solutions among SME	Innovation pattern, R&D-based: Customer-driven technical process specialist	R&D-based: Manufacturer of simple endproducts B2B	R&D-based: Developer of knowledge-intensive hybrid product-service bundles	R&D-based: Systems provider of customized high-tech systems-solutions	R&D-based: Developer of complex consumer and processed goods	Non-R&D-based: Knowledge-intensive developer of industrial goods	Non-R&D-based: Knowledge-intensive developer of consumer goods	Non-R&D-based: Customer-driven, technical process specialist	Non-R&D-based: Manufacturer of simple processed goods B2C	Non-R&D-based: Technical problem-solvers for products	Non-R&D-based: Specialised supplier in (regional) niche markets	Non-R&D-based: (Toll-)manufacturer of standardised industrial goods
(1)	Extending the criterion "novelty" for getting access to STI funding by SME	++	+		++	+	+	+	+	++	+	++	+	++	++	++
(2)	Introducing a „starter kit" for SME which are new to public funding schemes	++		+	+	++						+	++	++	++	++
(3)	Stronger consideration of non-R&D-based patterns of innovation	++	+	+	+		++	++		++	++	++	+	+	++	+
(4)	Closing the funding gap in the middle-to-lower segment	++			++	+			+	+	+	++		++	++	+
(5)	Implementation of agile approaches in the administration of SME funding schemes	+	++		++		+	++		++	+	++			++	
(6)	Provision of an instrument for supporting SME in apllying for funding of innovation projects with higher novelty/radical novelty		++	+	++	+				++	+	++		+	++	+
(7)	Promoting open Innovation with partners outside the own market and technological regime		++	+	++		++	++	++	++	++	++		+	++	+
(8)	Funding of services and software developers to implement digital busienss models		++	++	++		++	++	+	++	+	++		+	+	
(9)	Extending the integration of up- and downstream partners in the value chain	+		++	+	++			++			+	++	++	++	++
(10)	Demand-oriented redesign of transfer channels from "science-to-industry"	+		++	++	+			+			++	+	++	++	++
(11)	Strengthening SMEs' innovation competence and absorptive capacity	++	++	++	+	++						+	++	++	++	++

STI goals: ++ = high contribution / + = considerable contribution

Innovation pattern: ++ = strong relevance / + = relevance for innovation pattern

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Ecosystem Practices for Regional Digitalization: Lessons from Three European Provinces

Vincent Boly, Laure Morel, Brunelle Marche, Davy Monticolo, Mauricio Camargo, and Marianne Hörlesberger

Abstract The aim of this research is to obtain better understanding of ecosystems that foster digital evolution at the regional scale. The research focuses on the actions achieved by territorial ecosystem with the different existing financial procedures and political strategies in place at different stages (European community, national, regional and local). These practices help the description of what is really undergone by local stakeholders individually and collectively to improve the digital maturity of their territory. The quadruple helix concept is used to formalize the set of stakeholders involved in the collective dynamics of digitalization. An empirical observation campaign in three European regions (Grand Est in France, Styria in Austria and Värmland in Sweden) helps to provide a description of the nature of digitalization ecosystems, their practices and internal collaborative dynamics. The composition of the ecosystem is described and underlines that there is no real specialization between the members of ecosystems and their beneficiaries. Thirty-six practices have been identified and analysed, taking into account local ambitions. Finally, the type of interrelations (formal/informal and pecuniary/non-pecuniary) have been established.

1 Introduction

Digitalization represents a major change in terms of its impact on society and businesses (Tihinen et al., 2016) as it aims at transforming traditional processes, tools, objects and trades through digital technologies in order to make them more efficient (Schneider & Sting, 2020). Digitalization is a "socio-technical process of applying digitization techniques to broader social and institutional contexts that make digital technologies infrastructural" (Tilson et al., 2010). As such, it is one of the main drivers of change on the global and regional scale. It can act as a catalyst for transition in every

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dimension of the economy, social life and the environment and represent one of the main drivers in imposing change in our lifestyles and organizational and economic models. In addition, digitalization represents a lever of development and attractiveness for many regions (the creation of new jobs such as computer scientists, engineers, network experts, new, more flexible and autonomous forms of employment, new modes of collaboration and cooperation and the elimination of repetitive tasks, among others) (Degryse, 2016). Therefore, all the components of the regions are concerned as users: local authorities, companies, universities, citizens, etc. Indeed, local authorities must review their traditional responsibilities, including urban planning, mobility (Zuti, 2018), economic development, tourism (Ziyadin et al., 2019) and servitization (Vendrell-Herrero & Wilson, 2017). At the technological level, companies are not only changing their products, their production techniques, their supply chains and their sales techniques, but also their organizations from human resource management up to senior management (De Carolis et al., 2017; Remane et al., 2017; VanBoskirk et al., 2017). At the academic level, pedagogy has undergone a very rapid transformation and research is undergoing transformations directly related to digitalization. Regarding this, mention can be made of participatory research and open data (Yarychev & Mentsiev, 2020). Citizens have also adopted multiple new uses: social networks, digital leisure, links with the administration, etc. (Nordlund et al., 2019).

Digitalization is a prominent goal for all these actors. A diverse array of initiatives has been proposed and implemented with the aim of facilitating digitalization development. These initiatives vary according the stakeholder (policy-makers, industries, academics—including education, citizens). A study of digitalization at a given scale requires an understanding of how the actors in this space, grouped together in a system called the quadruple helix (Carayannis & Campbell, 2010), exchange knowledge in different domains, including digitalization. Indeed, the main constituent element of the helical system is knowledge, which changes to innovation and know-how. It has implications for smart co-evolution of regional innovation, and it has been applied to innovation ecosystem (Lew et al., 2018; Vallance, 2016). Digitalization for a specific region can therefore be considered as a result of the actions of a quadruple helix in individual and associative ways. Thus, in order to better understand a region's initiatives in terms of digitalization, it is necessary to have a systemic vision of the practices implemented at territory scale. However, there is no universal practical manual for implementing digitalization. Therefore, this paper seeks to explore the following two questions: What practices are contributing to the digitization of a given spatial scale? Is there an ecosystem based on the quadruple helix that drives digitalization at the regional level?

The objective of this article is to provide researchers and practitioners with an overview of local digitalization initiatives, practices and decision-making approaches mobilized by stakeholders mastering the digital transformation. In this paper, we explore the diverse ways in which different stakeholders stimulate "digitalization" and how they implement it at the regional scale. For practical reasons, we chose the regional scale for analysis because it allows a more detailed study to consider the specificities of a given area. Indeed, differences can be observed between regions in terms of digitalization, so it could be hypothesized that the most innovative areas implement specific practices to stimulate transformation. Thus, this research focuses on the identification of people and structures that foster the digitalization of provinces and regions (nature of the digitalization ecosystem), the description of their stimulation modes (ecosystem activities) and, finally, how they all interact (ecosystem internal collaborative forms).

The situation is paradoxical as, at the same time, this quadruple helix is also representative of the users (Arnkil et al., 2010). Therefore, each individual is both a user of digital technology and can be an actor in digital transformation. Therefore, within the quadruple helix it is necessary to distinguish the different roles played by stakeholders: decision-makers, beneficiaries, influencers and/or influenced actors (non-users among others). This is done through interviews.

Since the impacts of digitalization are multiple, it is difficult to qualify the degree of novelty. The discontinuities generated in all sectors in the sense of (Garcia & Calantone, 2002) define it as a multiplicity of ruptures. The sciences of innovation are therefore called upon to understand this complex evolution and propose methods for managing transition set in motion. Of course, these studies cannot be performed without a multidisciplinary dimension, since digitalization raises ethical questions (Bruynseels, 2020).

This description of the innovation ecosystems includes an understanding of the role of decision-makers belonging to the ecosystem and their interrelationships. One aspect relates to the practices of this ecosystem, i.e. actions carried out by private or public organizations and individuals that mobilize resources with a specific goal of digital transformation for identified beneficiaries. Our approach is local and seeks to describe at the micro-level the modes of action of local actors, focusing on activities. The aim is to better understand how the complexity of digitalization is approached locally. For achieving these objectives, initiatives provided by three different provinces have been studied: Styria in Austria, Värmland in Sweden and Grand Est in France. These regions were selected because of their economy based on traditional industries (wood, steel, automotive, energy), the existence of national and regional digital transformation programs and the presence of teams ready to collect data. Rather than taking a comparative approach that would require an analysis of the different administrative contexts, attention is given more to the modes of action implemented according to different spaces and culture.

In this paper, the scientific background focuses mainly on the concepts of digitalization and ecosystem to better understand how different stakeholders act for digitalization. Then an empirical study of three European provinces is proposed based on the description of these geographical areas and their innovation ecosystem history. The results of the census of the practices engaged by regional stakeholders are presented: the description of these practices and the nature, interrelation and objectives of the ecosystems managing these practices. All the outcomes are analysed using digital maturity models.

2 Innovation Ecosystems and Digitalization

2.1 Innovation Ecosystem: A Regional Entity

An innovation ecosystem can be viewed as a meta-organization integrating innovation actors in the form of networks with diverse forms (Carayannis & Campbell, 2009). The following ecosystems are distinguished (Oh et al., 2016).

- Industrial: composed of companies working in open innovation mode. In order to maintain their competitiveness, network-specific innovation capabilities have become a lifeline for many companies (Valkokari, 2015), highlighting the creation of shared knowledge (Ketonen-Oksi & Valkokari, 2019). As a result, these ecosystems are composed of members who are interested in the same topics of study: industrialists, centres of expertise, and research (Järvi et al., 2018)
- Regional: composed of various actors in the same region, their main characteristic is the geographical area of intervention. These ecosystems are characterized by links between actors with different specialties (technical, financial, legal, etc.) and entrepreneurs.
- Virtual: contributors of various kinds such as individual developers, companies or institutions are brought together via the Internet. These ecosystems are based on social networks where contributors participate in the design of products in the form of a community of creators, or by letting companies exploit their creation. This takes the form of groups of individuals building and updating digital or hardware products (e.g. the Linux community), companies developing call for project sites and setting up collaborative design processes downstream (e.g. Lego) (Bogers et al., 2019) and companies sourcing ideas or skills or better understanding needs on the Internet (Hitchen et al., 2017).
- Networks of new companies: these are groups of high-tech companies or creators who have had experience in an incubator and who collaborate either through exchanges of experience (Witt, 2004) or by moving to forms of co-design or business partnership.

Innovation ecosystems give rise to economic activities and support economic development over the long term, which requires regular adjustment. This development takes the form of innovation and new technologies. Within these ecosystems, there are flows of data, knowledge and finance, as well as material flows such as intermediate design objects or product flows (Kasmi, 2019; Kasmi et al., 2019). Finally, an innovation ecosystem is composed of evolving sets of actors, activities, and artefacts, and institutions and relations including complimentary and substitute relations that are important for the innovative performance of an actor or a population of actors (Granstrand & Holgersson, 2020).

Innovation ecosystems are particularly involved in Oh et al., (2016).

- Digitalization. The central role of information and communication technologies (ICT) in new products and services, and in connecting innovation actors, is recognized.
- Open innovation. Borrowing, licensing, open-sourcing, crowdsourcing, and alliances that allow ideas from diverse sources to be combined into new products and services.

Thus, in the context of regional digitalization, the study at the local level of ecosystem practices requires an understanding of what these ecosystems are (the nature of the members and their interrelationships), their roles and the tasks they perform.

2.2 Quadruple Helix

The initial triple helix model was formulated to explain local phenomena and thus the context in which changes occur in regions. Taking up the challenge to enrich the evolutionary perspective with sociological and methodological reflections, the triple helix model states that universities, industry and government act conjointly for the transformation of regions (Leydesdorff, 2012). Certain authors (Carayannis & Campbell, 2009) proposed to add key stakeholders in terms of the end user, the public and civil society. The objective was to obtain a more human-centred model, highlighting that innovation has to serve civil society and the people. The quadruple helix is a kind of user-driven innovation model that adds a fourth helix, leading to a quadruple helix ecosystem (Miller et al., 2018). Financiers are also considered by this model (Höglund & Linton, 2018). Thus, characterizing the members of the quadruple helix represents a means of describing the nature of the so-called ecosystem acting for digital change.

2.3 Innovation Ecosystems and Digitalization

Innovation ecosystems assume a wide range of challenges to transform their regions. The literature includes models that specify the objectives of digitization assumed by ecosystem members. They help to define the itinerary of digital transformation taken by organizations (Bumann & Peter, 2019). Mostly developed within companies they are also useful for understanding the digital strategy of ecosystems. Bumann and Peter (2019) proposed a digital maturity model as a reference to describe the initial situation and the desired future for the target to be digitized (Andersen & Jessen, 2003). The digital maturity model is therefore representative of the role that the digital ecosystem tries to adopt and, as a result, is consistent with the research aim of obtaining better understanding of their modes of functioning (Fig. 1).

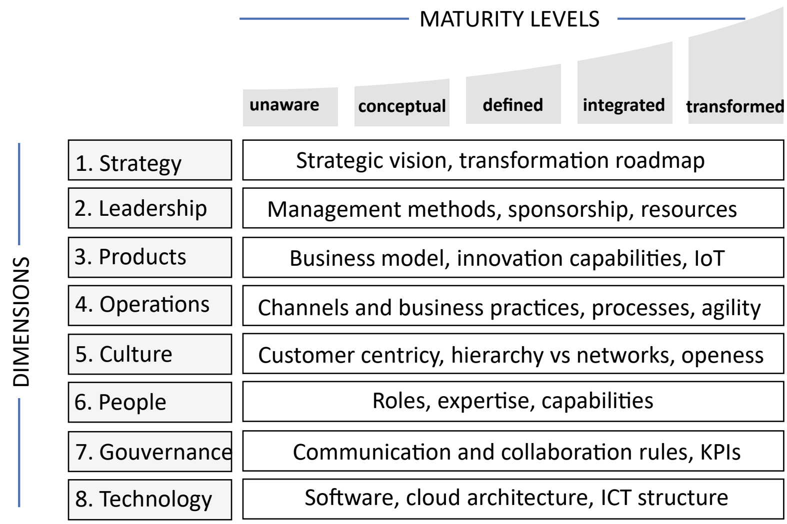


Fig. 1 Digital maturity model to represent the present situation and objective of ecosystem practices (From: *Digital transformation report 2014,* Eine empirische Studie, Neuland une analyvision un transformation)

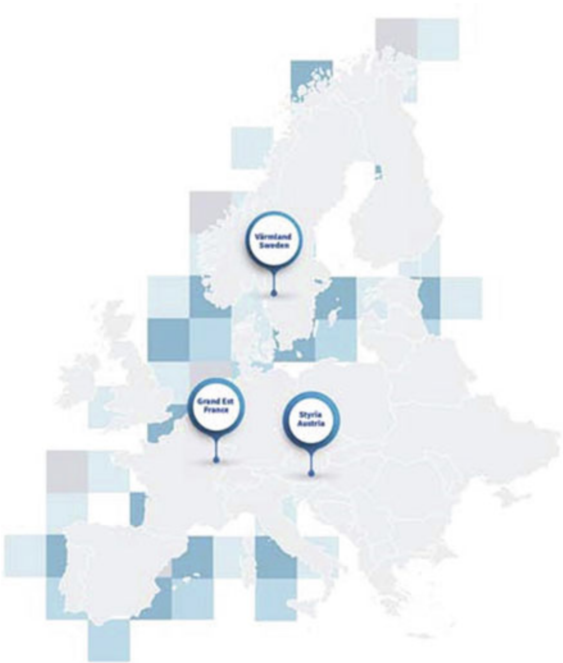
The "dimension" indicates the expected effects of the ecosystem action: this corresponds to the change the beneficiary should benefit from. It may involve helping the beneficiary to integrate digital technology into its strategic policy, to change its internal management, to train staff or to opt for technical support (logistics, manufacturing process or products). In addition, an increasing "level" is set, ranging from complete ignorance by the beneficiary to their expertise and autonomy. This level describes both the present situation and that targeted.

Finally, for a micro-level analysis of the digital transformation of provinces, the quadruple helix and the digital maturity models make it possible to construct a representation of the functioning of innovation ecosystems. At the same time, we must consider the conditions under which these innovation ecosystems carry out their actions.

3 A Descriptive Study of Three European Regions

An observation campaign in three European regions was conducted in 2021 to describe the functioning of regional innovation ecosystems in favour of digitalization. This work has received the support of the European Community H2020. The

Fig. 2 Regions involved in the exploratory research



three selected provinces (Styria, Värmland and Grand Est) are all regions with a strong traditional economy (automotive industry, wood sector, agriculture, materials sector, among others), and a strong political will to join the movement towards digital transformation (Fig. 2).

Styria is a federal province ("Bundesland") of Austria, located in the south of the country, with a population of 1.25 million in 2019, representing 14% of the Austrian population. Traditionally both a resource-based and industry-oriented provinces, Styria has become a European region with high technology companies and hosts the automotive industry and the electronics industry (semiconductors and electronic components) situated around the provincial capital Graz. In 2017, Styria´s expenditure on R&D amounted to 2.3bn EUR (GERD, intramural R&D expenditure), representing 4.88% of the regional GDP—quite a substantially higher share in comparison with the national figure of 3.05%. Business expenditure in Styria was 1.7bn EUR in 2017, equalling 74% of total R&D expenditure in Styria and representing 3.6% of regional GDP. Thus, the business sector is dominant in the performance of R&D and underlines the technological strength of Styria.

The Värmland region is part of the NUTS2 region of North Central Sweden. Värmland is facing important challenges, such as slow population growth, a low level of education, low wages and a low level of employment compared to the Swedish average. The population of the region was 281,482 inhabitants in 2019, representing a rise of 2.8% since 2014. Värmland borders Norway and the Oslo region and is thus a border region in the EU. Värmland's industry is concentrated in a few dominant sectors and is well organized in cluster initiatives and networks. The biggest industries are wood pulp and paper (approx. 4000 employees), steel and engineering (10,000 employees), IT (2000 employees) and tourism (3000 employees), which has the highest growth. The total regional expenditures on R&D (GERD) have been decreasing since 2013 and amounted to 0.39bn EUR in 2017 in North Central Sweden, representing 1.2% of the regional GDP—a share substantially lower in comparison with 3.37% at the national level in Sweden.

The Grand Est region is a large administrative region in Eastern France with 5.5 million inhabitants (representing 8.3% of the total French population in 2018). The regional capital is Strasbourg, a city of European-wide political importance that hosts the seat of the European Parliament and the Council of Europe (including the European Court for Human Rights and the European Pharmacopeia Commission). Materials, mechanics, textiles, chemistry and agri-food industry (including agriculture/viticulture) constitute the backbone of the region's industry. The materials and processing sector in Grand Est represent 15% of the national production of materials and 18% of scientific jobs in France. Digital transition presents a major challenge for this industry. The government share of R&D is lower than the national average (7.54 vs 13.06%). As a result, R&D expenditure is mostly driven by the higher education sector which accounts for 39.74% of the total R&D expenditure, almost twice as much as the national level (20.88%).

The campaign was based on interviews conducted with the same interview medium by the AIT Austrian Institute of Technology, Montanuniversitaet Loeben, Karlstadt Universitet, Materalia, Grand Est innov and the authors. Each of these structures followed interview guidelines and a video tutorial. Appendix 1 sums up the topics discussed during the interviews.

The institutions contacted were chosen on the basis of the following criteria: financing by regional or national funds for digitization. The duration of the interviews was between 2 and 3 h. Interviewers directly feed a specific database managed by an open-source content management system for universities. The database is a 36 × 68 matrix containing qualitative data like the function of the interviewee or the type of the quadruple helix members he/she collaborates with. Some data are yes/no answer to question about any relation with universities. One objective is the identification of digitalization practices, so, for each line of the matrix (data given by one particular interviewee) we consider that a "practice" is observed when the following information is collected simultaneously: a certain activity, a related decision-maker, a specific set of beneficiaries, a specific targeted digital goal, a related specific budget or funding and related specific resources like competences. As a consequence, when an interviewee describes one of its tasks with all these descriptive items, we considered that a digitalization practice is cited. The objective is to remove routine activities like permanent training in a university or basic digital development activities in companies providing services. Data treatment is not statistical as the aim is noted to be representative (if possible), but trends are extracted compiling similarities between practices.

4 Results

4.1 Ecosystem Practices in the Three Provinces

The first finding concerns the existence of digital transformation strategy plans in each region. Formulated in a participative way, they mobilize quadruple helix representatives. Regional public funding allocation therefore directly depends on this global policy. Värmland smart specialization integrates smart energy and photovoltaic development, the heavy vehicle sector and a forest-based economy. Grand Est dedicates much effort to develop artificial intelligence, while Styria wagers on Industry 4.0 and smart component production. In common, these regions integrate social objectives and ethics in their plan, including inclusion, gender equality and welfare. These plans received the support of the EC through the smart specialization strategy S3 procedure. Thus, these innovation ecosystems manage their activities in a political environment characterized by both national, European and regional policies. Moreover, each region has academic laboratories and research centres. Research programs focused on digitalization deal with a broad spectrum of topics: technologies (sensors, robots, etc.), data processing, virtual reality, cyber security, information and communication systems as well as sociological and philosophical aspects of the digital world (e.g. privacy protection).

A list of 36 practices has been established thanks to the interviews (Table 1) considering the list of criteria given in the above section. It constitutes a sample of activities managed by these regional ecosystems. The reader is reminded here that the goal is not to be exhaustive (if possible?) but to address the precise description of certain key actions undertaken in the provinces in order to grasp the entrepreneurial character of each region, the vision of the actors of the problems to be solved to achieve digitalization and their interrelationships.

Different domains are targeted:

Strategic plan: Each of the three regions (Styria, Värmland and Great East) has established a strategic plan at the regional government level. These plans were developed in a participatory manner. Guidelines are defined as well as financial incentives. Some particularities can be found in these plans, such as the Grand Est, which emphasizes artificial intelligence. In each region, this strategic program aims to provide framework conditions and co-funding initiatives. Infrastructure development is part of this program. Improving broadband infrastructure (fibre) to give Internet access is fundamental, and the European Community has set standards followed by Styria, Värmland and Grand Est. Another strategic dimension relates to access to educational tools: *Lycée 4.0* is organized in Grand Est. A plan to deploy digital educational action has existed since 2017. It provides all secondary school students (public, private, professional, agricultural, technical), i.e. approximately 200,000 students from 353 secondary schools (from the second to the final year), with a digital tool (computer). Access to thousands of digital educational resources is also provided via the ENT Digital Workspace with access to “My Digital Office”. The ENT represents the

Table 1 List of 36 digital practices

1	72 h to develop Agile projects to foster digital innovation: a training module shared between students and company executives. The university identifies companies with digital problems. Executives of these companies attend specific training modules relevant with their needs in parallel with students. They all work also on the company problems
2	Institut des services et industries du Futur de Troyes is an institute that brings together academics, companies and public institutions in order to reflect and develop digitalization solutions, prepare a future economy and train managers and citizens. It has four mains tasks: education, research, discussion between stakeholders and demonstrators
3	Platform Industrie 4.0 private association: mutualization of equipment and human resources. All relevant stakeholder groups design and improve the framework conditions for implementation and promote exchange (projects, technology-related), mutual learning of the members, human-centred approach to digitization. This platform has a territorial operation area, helping companies to find relevant digital technologies
4	Cooperation network: research, science, open innovation, cooperation, technology and knowledge transfer, RRI, digitization in cooperation. Company mutualized financial resources to hire and share a team dedicated to digitalization. These are SME or big companies that cooperate with their suppliers
5	Disabled testing group: a public institution manages an acceptability assessment group composed of physical disabled people, people with mental or social problems. They express their reaction when trying to use new numeric tools under study. The strategy is the same tools for everyone. For example: city information website for collective transportation information
6	AIP PRIMECA/SMART: factory of the future platform: the aim is to develop a factory/school where students and industrial employees improve their skills in the field of parts' production in a context of digitalization. The platform allows agile, reconfigurable production and the use of recycled raw materials. It also focuses on the regeneration of "old" products. On this platform, they are robots, cobots, automated machines, lean tools, automated workshops, and sensors. The concept of a product storing its own data is developed
7	New academic courses and new digital academic organization: Transformation to digital learning (teaching, examination, communication with students) to develop skills in the field of the future factory. The development of new module is a process integrating technology surveys, enquiries by experts and companies, collaboration with researchers
8	Regional master plan for the fibre network to reach the defined European standard of 100 Mbit, in the region of eastern Obersteiermark. The basis is national and regional regulation, land initiative (new company of the state of Styria, to support broadband), old fibre works 100 MB, the EU demands 100 MB

(continued)

Table 1 (continued)

9	Lycée 4.0.: Since 2017, a plan to deploy digital educational action: provide all secondary school students (public, private, professional, agricultural, technical), approximately 200,000 students—353 secondary schools from the second to the final year) with a digital tool {computer) to access educational resources replacing textbooks, school books, in order to familiarize themselves as best as possible with the uses of digital technology, to benefit from modern working conditions, responding to today's educational challenges and helping to facilitate their professional integration. Access to 3000 digital educational resources. 8000 references, including 3500 manuals via the ENT Digital Workspace access "My Digital Office". The ENT represents the strategic tool and the unique communication channel of the region for families and pupils. The student becomes the owner of the computer at the end of his/her schooling. It is the only region in France to apply this approach for the target in question
10	Serious Games. The idea of creating the Serious Games follows the policy to deploy a "Factory of the Future" plan from 2016 at the national and regional levels. The Chamber of Industry and Commerce (CCI) is fully committed to this plan. As part of the regional "Factory of the Future" plan, supported by the region for business development, the Alsace CCI launched a major survey at the end of 2015 to identify companies with cutting-edge know-how and technologies that are able to transform a company into an industry of the future. 170 solution providers were identified, with cutting-edge expertise in ten areas: productivity; agility; human factor; deadlines; digital; customer relations; business model; energy; design; modelling. This game was thought up during a working group led by the CCI, with the regional companies offering technological solutions (community) with the aim of making themselves better known and also to spread awareness of the stakes of their technologies for companies. This game is a technological showcase of the industry of the future accessible to all people (company, student, public player, citizen, etc.), and no age is required to become familiar with the technologies. It allows starting from a problem (human, organizational, product, management, strategy, etc.), based on real business situations that entails finding an associated technology according to a business project or the development of a theme. The local solution providers are referenced in a directory by technological brick, and therefore, the company can identify providers' solutions after the game to move forward on its project: www.offreursdesolutions.fr. It is a private initiative built by partner companies, supported and labelled by the Alliance Industrie du Futur at the national level (AIF). An atypical innovation, this platform is hosted by the CCI (no risk of product stoppage)

(continued)

Table 1 (continued)

11	Simplon school. Short Description: Project DNA digital training school (training organization) based on an inclusion model serving people who are far from employment, people with disabilities, refugees, women, young people without diplomas, newcomers, etc.) and the most disadvantaged regions while promoting as much as possible gender, age and social and geographical diversity: “make digital technology a real inclusionary lever to reveal different talents that are not well represented in digital technology and digital technical professions (basic, CNF, etc.)”. Simplon.co’s positions concern the code for all, gender parity in the digital world and the Social and Solidarity Economy, the battle for youth employment, the revitalization of regions including working-class districts, rural areas and overseas territories. Eighty-two factories (“social franchises”)—training centres including 20 abroad (15 countries), no presence in Sweden or Austria to date—located in rural territories, overseas and not only in working-class districts and large conurbations. Distinction: genuinely open to all {regardless of age, no diploma requirements) and entirely free of charge for learners, it is also one of the key players which, since its inception, has been integrating a central concern regarding the representation of women in these professions which are not very feminized. Value, impact of the project: over the last two years, driven by the maintenance of a very high level of skill needs in the digital field, Simplon.co has multiplied its social impact by four and trained more than 5600 people worldwide in digital professions with a positive exit rate of 75% (6 months after training). International development is ongoing
12	Online platform for companies in Bruck an der Mur: homepage for companies which have little or no digital media or no online platform which is financed by the initiative. Among targeted companies are many retail shops and craftspeople. A centralized tool is developed to help companies getting a website to promote their activities but also to propose services like “click and collect”. One manager is hired to update and maintain the system
13	Workshop in Styria—workshops throughout Austria with companies: Identify IT competencies of employees for companies and develop through workshops those competencies that are important, e.g. accounting software, IT security, etc. This activity managed by a public organization is based on diagnosis proposed to companies, and, then meeting where companies can identify suppliers, partners and experts corresponding to their needs. Proximity is prioritized
14	Digital Material Valley Styria (DMVS): to support industrial companies through projects to carry out digital transformation. It combines six technical institution specialized in digitalization and metallurgy. DMVS provides support for digital technological development projects mainly for SMEs. It also published books to train company executives with many company examples
15	Project “Voladigital™ from the University of Technology Graz: Understanding and using the competence requirements of digitization. Development of a training platform and the creation of a training concept for SMEs for digital practices. The objective is to create a training concept where participants can flexibly acquire theoretical content on a learning platform and apply this knowledge. This practice is based on the concepts of learning factory. A survey with Styrian SMEs is carried out in the first step, and an online platform is then developed and tested
16	Regional political involvement: Role of a regional manager responsible for the implementation of the strategy concept that applies throughout Styria at the regional level (Bruck-Mirrzzuschlag). New mission in the region consisting in updating data about digital strength and weaknesses of the territory, cartography expertises and development of partnership between companies having digital needs and digital suppliers. Quantitative objectives are defined in terms of number of company involved and people impacted

(continued)

Table 1 (continued)

17	The Wood Region: a cluster dedicated to the development of additive manufacturing. Companies of the paper pulp domain mutualized financial and human resources to develop activities using additive manufacturing. It focuses on sustainable additive manufacturing with biocomposite as material. They use large and small size 3D printers, as well as equipment for developing new bio-based materials, processing wood and working with lamination and other finishing. The aim is to find new markets for wood pulp
18	Industrie 4.0 (national funding program): this is a non-repayable grant for enabling digital change in the production sector: analysis, investments, consulting and training for employees. It is a continuous assistance process proposed to companies with financial support. Companies find funding for expenditures and investments in the same program
19	Toolbox (a tool for family businesses): in response to the question of how family businesses can shape their future responsibly, CAMPUS 02 has developed an overall model with which this particular type of business can be optimally prepared, accompanied and supported for digital change. This model considers all the components of the overall situation, leaves the decision-makers responsible at the centre of the digital transformation project and uses the instruments developed specifically for family businesses to ensure sustainable business development. Thanks to these developments at CAMPUS 02, entrepreneurial families and owners can now find answers to many questions more easily in a practice-oriented manner and with the aim of being successful in a digital world. The model has already been tested in practice and can be successfully applied in future to accompany the digital transformation processes of family businesses
20	HiWay: A new SME working as a provider of data lines. Resulting from a territorial diagnosis and collaboration with different partners, this new company provides technological means and services for the initial partners and other customers. Its activities are proposing high level database, information system management, updating of commercial, financial and technical data and specific data extraction
21	Fit4internet: a program aiming at an increase of digital competence in Styria. As data science deals with analysing large amounts of data and deriving information from it, new competencies are required. This Internet tool is a quiz giving an overview of the knowledge about data science in everyday and professional life and proposing area of improvement. It is dedicated to employees but also people preparing a professional reconversion
22	Higher Technical Education (Engineer) on Information Technology (IT) and SMART Production, education in secondary school segment. This new module is targeting students preparing a long education cursus. It concerns the "hard" domain of digitalization mainly IT-OT, information systems and sensors integrated in the production line. The aim is to provide technical companies in candidates with high competencies
23	Science education, new study programs, bachelor study on "Industrial Data Science™ and integration of digitalization courses in an already existing study program of mining and tunnelling (specialization in digitalization), sensor technologies, computational networks, cloud computing, big data analysis, artificial intelligence applications in engineering, computational learning, computational simulation, new technologies in automatization
24	Pilot action for more higher qualifications and research resources for young people, science education (RRI), PHD initiative, new pool of PHD positions, approx. 30 positions, knowledge cluster in the region, become a hot spot in science education and research, more initiatives, more projects and infrastructure pilot action for the academic knowledge work market in digitalization initiatives

(continued)

Table 1 (continued)

25	Robottyftet—An organization whose goal is to support the Industrial SMEs of the Varmland region through different initiatives in their robotization process. This practice is totally dedicated to new automation technologies. It provides advices, helps finding the right equipment and supports implementation in the domain of robotization
26	Be Digital: a program of the compare structure to assist companies. This practice focuses on designing the environment helping companies to use digital tools and approach as a routine. Through an assistance in specific project, the aim is to transfer a know-how about software, digital design methodologies, test protocol elaboration to evaluate the acceptability towards panel of users, promotion by Internet among others; the aim is to help digital transition. Some digital spaces are provided in order to help companies without any initial investment
27	Rythmes et Sons company—Digitalization of the production process: This practice explains the how a traditional SME (production of flight cases) digitalized its process of production through the introduction of digital tools, the integration of a young engineer (training period, short time contract, full-time job) and cooperation between a laboratory and the company for the transfer knowledge. The project was funded by the Alsace Region (Region Grand Est) using the program Hommes resources (50% of the gross salary of the people hired funded through a grant for a period of 6 to 18 months). Setting up and following up the project were delegated by the Regional Authority to the Regional Innovation Agency, Grand E-nov
28	ACES: research and coordination program in the field of additive manufacturing. This program focuses on large size 3D printers mostly dedicated to the building domain. It gathered academic and private companies to develop a new industrial value chain starting from the raw material to the final product. This value chain design program integrates the development of new technologies but also addresses logistic problems
29	The Regional Executive Board and Regional Council have formed a long-term development of digitalization strategy that defines both the whats and hows. Focus on both innovative new practices, cost-efficiency and value for the people of Varmland. In terms of regional development, we have a regional development strategy and a smart specialization strategy. Within S3, we have pointed out digitalization as one of the main drivers for change
30	Implementation of an open-collaboration platform for the manufacturing- and innovation ecosystem. This platform is a suppliers/customers marketplace, where companies may find a provider in the field of software, digital equipment and services. The aim is the acceleration of the digitalization of the industry
31	Digitalwell Arena: program aiming at the development of digitalization in the field of wealth. This program is dedicated to hospital (doctors and administration), based on interviews and workshops diagnosis are done and training modules are managed. Moreover, investment in digital tools is proposed. An extension is planned to assist individual doctors
32	Fabrique Collective de la Culture du Libre: this is an initiative aiming at developing the use of freeware. A specific space with equipment welcomes people to teach them how to use freeware in different domains: office automation, data search and also working functionalities such as accounting. The objective is to propose an alternative to “basic” products managed by big international companies

(continued)

Table 1 (continued)

33	Artificial intelligence plan (Grand Est). The President of the Grand Est Region, Jean Rottner, presented the artificial intelligence regional plan at "360 Possibles event" (27 June 2019). This plan has five objectives over 5 years: (i) boost business competitiveness, (ii) support scientific excellence, (iii) support the development of start-ups, (iv) develop regional skills on the topic, and (v) ensure transparent, ethical and inclusive AI. The last point is directly linked to the DIGIT RRI project. This plan is part—and this is its great strength—of a genuine European dynamic, and the link with Germany (Three landers: Baden-Wurttemberg, Saarland, Rheinland-Pfalz), Belgium (Wallonia), Luxembourg and Switzerland {from Basel to Zurich} to federate businesses and academics within a real valley of European artificial intelligence
34	Axon Fab Lab: private company Fab Lab to foster the design of innovative products and employee training. This company decided to invest in a Fab Lab in order to elaborate prototypes before selling parts to the aeronautic companies. It also replaces some polymers injection processes by additive manufacturing. But also, the Fab Lab is open in the evening and during the week end to the employees and their family to their own needs and to educate people to new technologies
35	Digital fabrication (Fab Lab): a third place dedicated to digital applications open to the public. This Fab Lab is open to a large variety of beneficiaries: individuals, companies, students and job seekers. It is only dedicated to digital processes including virtual reality and Arduino
36	Innovation management structure: it proposes funding and assistance for project leaders in the field of digitalization and assesses the innovation capacity of the region. This program is dedicated only to decision-makers in companies. It is a training program joined with funding to support the expenditures of the participants during the project (only the time to market period is considered and no investment is covered).

strategic tool and the unique communication channel of the region for families and pupils. The student becomes the owner of the computer at the end of his/her schooling.

Training: there is a wide variety of offers targeting students at every level of education (from primary school to higher education). In addition, many initiatives are more inclusive concerning no diploma individuals (Région Grand Est and Värmland) or migrants (Styria). This takes the form of a new curriculum as well as new pedagogical approaches like the simultaneous training of students and company employees (Région Grand Est).

Technical platforms: two types of spaces are developed. First, Industry 4.0 platforms are where companies, academics and students can test and get experience in the many dimensions of digitalization (robotics, automation, IT-OT, etc.) as well as cloud computing of technical and marketing data, circular economy and energy savings. They are managed by industrial clusters (in the three provinces) and universities (Région Grand Est). Secondly, Fab Labs is developing prototyping and parts production. They target citizens and maker communities. There are also company Fab Labs (Styria and Grand Est) and academic institutions (in the three regions with a special mention for the Lorraine Fab Living Lab run by one university in Région Grand Est that mixes training, research and Living Lab approaches at the disposal of cities). Most have the objective of spreading digital culture, while others carry out research and training activities.

Clustering: this is an important trend, as stakeholders launch new legal entities where pooling is possible. This involves creating spaces for dialogue, project development, lobbying and setting up shared technical support and advice. The members are companies or a combination of private and public institutions (including academic establishments). The challenge is to gather all the necessary skills around the theme of digitalization and to coordinate training, consulting and material investments. The goal is also to give visibility to the support process. Different forms of clusters may be observed. One example in Grand Est is the *"Institut des services et industries du Futur de Troyes*" where the University of Troyes has taken the initiative of setting up this type of cluster in its employment area. A group of French companies has launched an open-collaboration platform for the manufacturing and innovation ecosystem. Its purpose is to stimulate open innovation between all kinds of stakeholder. Like the platforms of large innovative companies, this tool tries to generate a dynamic of creativity, information exchange and collaboration in the region. Participatory research practices are increasing faced with the complexity of societal issues, and the University of Graz (Styria) has set up a participatory research practice. This is an open model where focus groups are set up to develop research topics and guide scientific policy. This Connecting approach called *Ideas4research* has been implemented in various fields: medicine, culture and architecture. Ethical issues are addressed. In parallel, Grand Est has developed an important participatory research program on forestry. Moreover, the three provinces have set up holistic practices where the whole sequence from start to digitization is integrated: calls for consultants to frame projects, training, study of solutions and investment. These measures provide financial assistance and create repayment conditions that strongly limit the risks for the beneficiaries.

Integration of users in public service design: the practice of integrating users from the upstream stages of innovative projects has shown its value in terms of better adaptation to needs, greater acceptability, help in comprehending the future innovation according to different visions and adopting a more agile approach. In Grand Est, the City of Nancy's digital development department is organizing focus groups dedicated to people in difficulty, in the framework of designing its online services. People with physical disabilities or experiencing social integration problems participate in the design work with the developers. The aim is not to make specific tools but, on the contrary, to ensure that the same services are accessible to all.

Pooling services: in particular, web marketing assistance. The promotion and sale of products and services online represent an important market regardless of the size of the company. Initiatives are implemented to provide online sales assistance for small companies that do not have the means to create, maintain and renew a marketing site. https://wirtschaft-bruckmur.at/ is an initiative of a community in Styria that aims to promote service companies and businesses in its region. The companies benefit from the tool and from the engineering.

Promotion of free software: the aim of this practice is to help the population and companies of all kinds (start-up, retailers among others) to master free software, limit the distribution of their personal data on large commercial sites and be able to live "digitally" at a lower cost. Training is provided for citizens in media libraries, with associations, small companies and business creators. Technical advice is also available thanks to computer specialists. In the Grand Est, the town of Vandoeuvre les Nancy has launched the *"Fabrique Collective de la Culture du Libre*" (Collective Factory of Free Culture).

Research: following national and regional research programs, research laboratories adapt their scientific programs to integrate the challenges of digitalization. The regions have set up processes to orient research towards digitalization (formulation of political priorities), stimulate work (funding) and assess the impact of these devices on the region. This is the case in Värmland via the innovation management agency (*Vinnova*). The Montanuniversitaet in Styria has launched a *program for 30 Ph.D. positions* in the field of knowledge. The *Institut des services et industries du Futur de Troyes* has also mobilized funds for research, whether technological or in other fields: management, cognition, etc.

All these practices are managed by regional innovation ecosystems; they give a description of the activities driving digital transformation at the regional level. They cover the scope of technology and social impacts of digitalization in view to supporting people and private/public organizations unaware or victims of the changes brought about. They also have the ambitious objective of developing local expertise.

4.2 Description and Interrelations of Ecosystems

The practices supporting digitalization are carried out by a wide variety of actors. Within the total panel of interviewees, the lead of the practices is assumed by: (a) nine academic institutions are involved. These are territorial universities having their own domains or research and training. They provide human resources in the form of either teachers or researchers. Some have recruited project managers. This is accompanied by investments in computer equipment. In some cases, they are organized as technical platforms, (b) ten public institutions that provide guidance, communication, funding and participate in strategy, (c) two production companies apply digitalization and transfer their experience to other companies and suppliers, (d) three service companies provide guidance and (e) twelve private associative (cluster organization) or charitable entities which help a wide range of users.

In conclusion, public and private actors intervene either directly or by creating specific legal entities to carry out digitalization support practices.

The functioning of the actors is based on partnership. Only one practice is carried out totally in-house. One hundred and sixty-three partners are involved in the 36 practices. It can be observed that

- Academic establishments work with institutions and companies in addition to collaborations with other universities. They are very much in demand as partners although 11 out of 36 actors do not collaborate with universities.

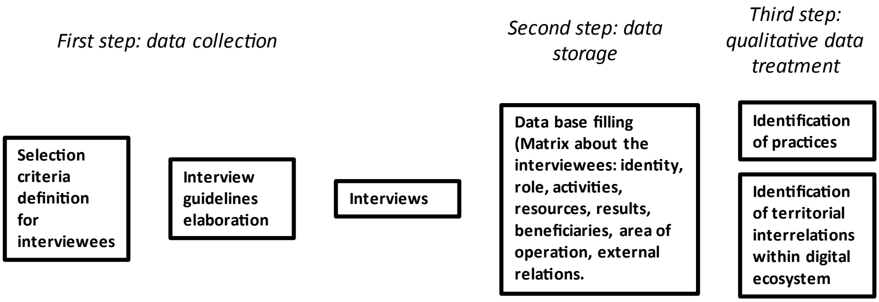


Fig. 3 Qualitative data treatment process

- All public institutions work together with other public institutions in the field of digitalization.
- Companies do not collaborate directly with social associations.

The form of the partnership has been also studied

- The academic institutes work on a contractual basis and pecuniary contracts most of the time.
- Public institutions work essentially in non-pecuniary relations.
- All other actors work in a contractual and pecuniary context.

Overall, and as a reminder, no statistically representative approach is targeted (the distribution of the types of actors within the ecosystems of the three regions not being known at the outset). A hundred and sixteen partnerships are the subject of a formal contract versus forty-seven with an informal agreement. Figure 3 shows that pecuniary relations are mainly formal, and half of the non-pecuniary relationships are formal.

This corresponds to several situations; essentially, the partners work within the framework of a project paid for by the project leader. Sometimes it is a subcontracting relationship.

4.3 Beneficiaries

Figure 4 gives the outcomes of the survey of the people targeted by the practices per type of stakeholder.

It gives the number of times a particular beneficiary is cited for one particular practice and domain. Stakeholders propose practices that address a wide spectrum of users. Only seven can be considered as more specialized with a maximum of five target categories. The consultancy companies and researchers are targeted by stakeholders that try to assist them in the field of technology exclusively. Companies and entrepreneurs are the recipients of stakeholders that try to assist them not only in the

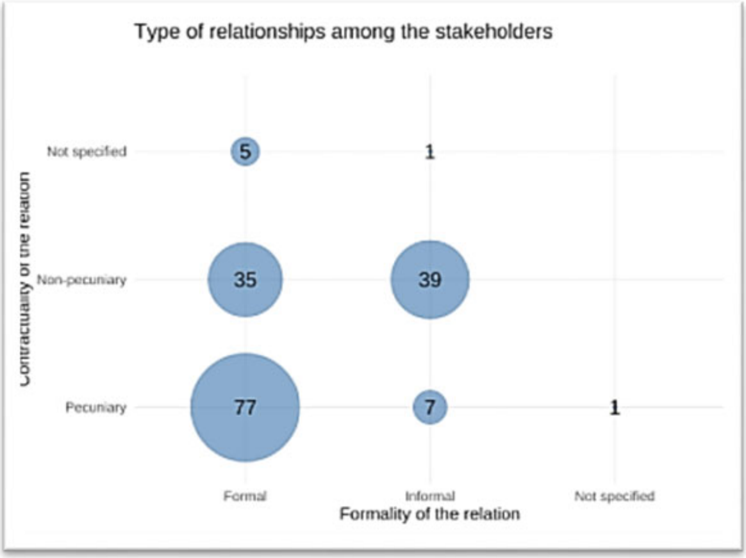


Fig. 4 Type of contracts between stakeholders

domains of technology but also work (organizational aspects) and employment. Not surprisingly, public institutions and associations are targeted when the digitalization process has a general regional impact. It is noteworthy that citizens constitute a major concern in different domains: general education, technology and professional abilities.

Moreover, data analysis shows that

- Academic institutions work for many king of beneficiaries (students, company, public institutions, other academic structures, among others). However, citizens sometimes do not have access to certain services. There is a very strong trend towards industrial clients.
- Public institutions can be divided into two categories: those that are open to all and those that are highly specialized.
- Production companies rarely target students (except for internships). They are mainly active in the world of work but may have a broader scope if they are mutualized entities (spaces with employees).
- The "other" structures are very diverse (including clusters), although they rarely target students.

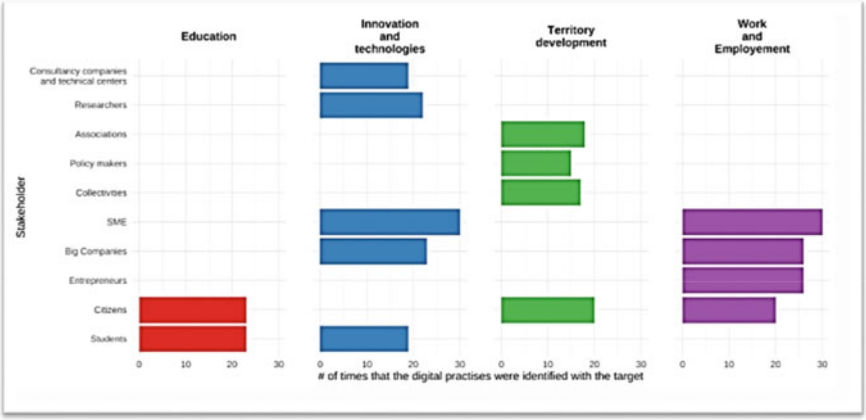


Fig. 5 Beneficiaries per practice and per targeted domain

4.4 Objectives of Ecosystems Members

The digital maturity model helps to identify the progression expected from the beneficiaries of the practice. The following figures show for each practice:

- The nature of the objectives (Fig. 5): strategy, individual leadership, technical evolution of the products, the internal organization of the organizations (operations), the culture of digitalization, the skills of the individuals, the governance, the production technology,
- The starting levels (Fig. 6). This is the diagnosis of each practitioner regarding the current situation.

As a reminder, the increasing levels of maturity are unaware (in dark red colour in the figure)/conceptual (in red colour in the figure)/defined (in orange colour in the figure)/integrated (in green colour in the figure)/transformed (in dark green colour in the figure).

Figure 5 facilitates understanding of the stakeholder's ambitions, while Fig. 6, which shows the current digital maturity diagram, indicates the vision of the stakeholders about the present situation in their provinces. The greener the boxes, the greater the ambition, on the other hand, the redder the boxes, the less the dimension is taken into account.

The following elements can be concluded, following the x-axis in Fig. 5.

In terms of strategic thinking: 29 practices out of 36 aim at the in-depth analysis of the beneficiaries ("transformed" or "integrated"). The goal is to help them to understand and to define the future profile of their digitized activities. Beneficiaries must acquire a very clear vision of what their business should become (individuals), their operations and products (companies and associations) and the requirements of online services (citizens). Seven practices are not at all interested in this dimension.

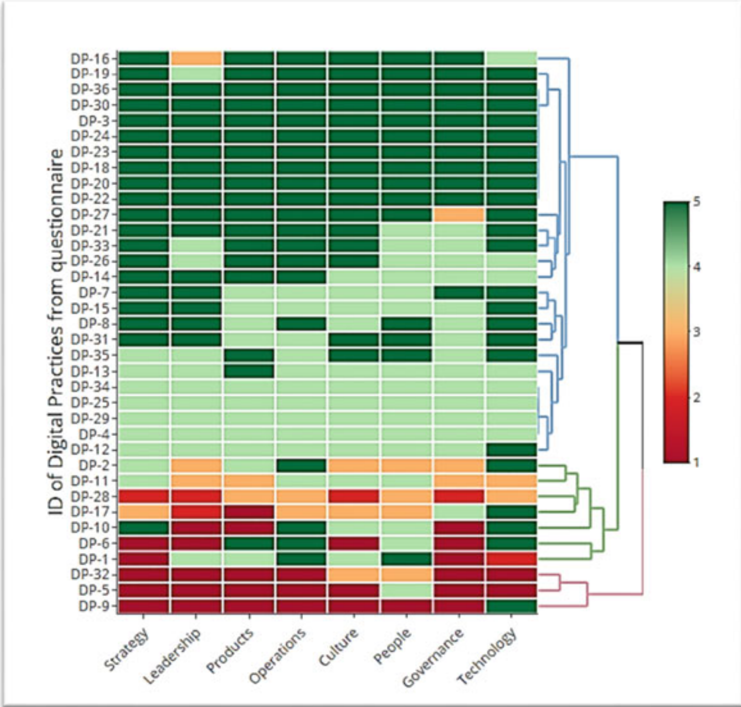


Fig. 6 Expected digital maturity level for each practice and each dimension

Twenty-six practices aimed at improving the mastery of digitization by organization leaders. The current situation (Fig. 6) starts from a low to medium initial situation (21 initial situations deemed "unaware, "conceptual or defined"). In addition, 15 initial situations are judged "integrated" or "transformed". It can be hypothesized that two categories of leaders must be distinguished. Those who generally understand that digitalization will have an impact on management and go before boards, while others have difficulty in defining the nature of these changes and must be proactively sensitized by the ecosystem. We note that the practices are aimed at taking leaders to "a higher level". This may seem modest. Five practices were not interested in this dimension.

The ambition concerning the technical transformation of products is considerable: 18 practices seek to ensure that the beneficiaries are fully capable of modifying their products and services. However, the initial situation is quite low, since only two initial "integrated" levels were identified. Thus, many practices integrate a "hard" and technological dimension of digitalization.

Twenty practices aim at the maximum level concerning the control of internal processes (operations) of organizations. The starting situation is disparate, with ten initial evaluations considered "conceptual" and 15 with an "integrated" or "transformed". Thus, there are two kinds of practices in this field: upgrading and specialization.

Sixteen practices presented the maximum targeted level in the cultural dimension. The others are less ambitious. Twelve practices start from the observation of strong initial weakness on the part of the targets (12 practices less than or equal to "conceptual"). This confirms situations known as the "digital divide".

The "people" section relates to individual skills. The actors consider that the initial situation is very varied; they face audiences with very strong differences in terms of digital skills. On the other hand, the ambition of the stakeholders is considerable for everyone,

Governance seems to be a more difficult subject for ecosystem actors to deal with. The aim of practices is almost systematically to move the beneficiaries from one level to another.

Technology is the subject of special and priority treatment. Only a few practices do not seek to make their beneficiaries' technology evolve very strongly. Despite a very disparate initial situation, the ambition is maximum. In this case, the technique that covers the way objects, services and cultural works are produced for companies, craftsmen and public service associations is at the heart of concerns.

We note that, overall, the practices are very strongly aimed at providing support in the technical dimensions of digitization: digitization of products and services, support for the digitization of organizations (supply chain management, control of operations, evaluation, etc.) and production techniques (material or services). It is in these areas that the target levels are the highest.

It can be considered that the majority of practices integrate the culture and skills related to digitalization. However, the objective of raising awareness among individuals and transmitting a new culture to them is approached more cautiously by the actors (Fig. 7).

In Fig. 6, the greener the boxes, the more favourable the initial situation is, conversely, the redder the boxes, the lower the initial level is.

Globally, stakeholders point out obstacles in every domain. But this diagram confirms that the diagnosis of people's capacities is controversial: the gap between highly competent and non-aware people seems to exist in each region. Moreover, stakeholders consider that the current level of internal operations (organization) of companies and public establishments is the most critical variable. Practices that address management (leadership and governance) pose problems for ecosystems because the progression targeted is low (only one level of maturity). Two hypotheses exist: the beneficiaries are not applicants for training and/or advice, or the actors are not very capable of addressing these aspects. This poses a problem because digitalization changes professional situations and therefore the hierarchical links and overall management of the women and men.

Finally, the skills of developing visions for individuals and strategic policies for organizations can be seen as a practice driven by specialists.

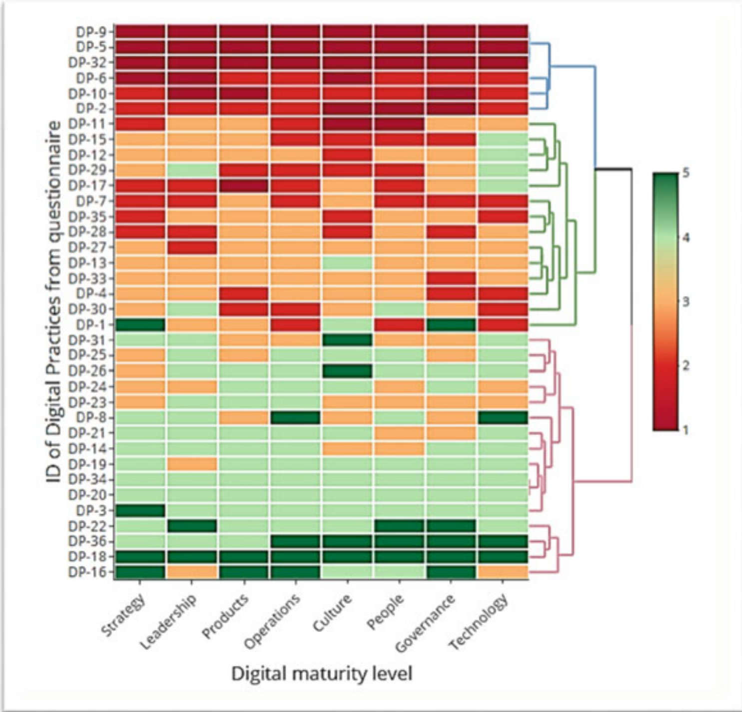


Fig. 7 Current digital maturity diagram for each of the practices and each dimension

5 Conclusion

Thirty-six practices were studied, showing the diversity and considerable involvement of regional innovation ecosystems. This list may be considered as a microanalysis of three regional digital ecosystems, consisting then in an empirical contribution. This research gives practical elements to describe the genuine processes in place in territories. It focuses on the tasks managed by the ecosystem stakeholders and the interconnection between them. It gives a specific insight about the digitalization dynamic of territories complementary to approaches focusing on evaluation (Sovetova, 2021). The main outcomes are: Who really stimulates digitalization, how and with which partners? It gives a description of what is done with the financial tools developed at different political stages: from The European Community to the local authorities (Von der Leyen, 2019; Viesti, 2022). The regional ecosystems aim to impact education to increase the digital ability level of people in order to: avoid the digital failure, to increase employees competencies and have an impact on employment. Our research shows that education is often integrated in the digitalization practices with the exception of some activities of private providers. Ecosystems also work on a global awareness about the opportunities and threats of a digital world meaning that some stakeholders are targeting specific beneficiaries, but most of them have also more global missions (impact on citizen). They stimulate the emergence of services and technical platforms facilitating the digital transformation in a mutualized way. Finally, they try to have a political impact by participating to the digital strategy of their region. This is an important finding: in each of the observed region, strategy definition is an open process with workshops integrating a large spectrum of stakeholders. Each member of the ecosystem acts mainly with partners. Our research shows the complex nature of the interrelation at the territory level. The ecosystem tries to cover the global life cycle of the digital transformation from diagnosis to implementation, technical support funding and evaluation. The research did not integrate a comparison between these practices or with other digital practices. Moreover, it seems difficult to make such a comparison as our study points out the complexity of regional innovation ecosystems and the obviously very different local contexts. However, as the interviews revealed that some of these practices tend to become permanent, it appears that our practice panel was composed of "good practices". In future work, a long-term observation campaign may give some insights on the assessment of the long-term impact of these practices. It could also be interesting to study the evolution of ecosystem composition and of the collaboration within these sets of stakeholders involved. One other question to be treated is also: Can we consider these practices as "best practices" for anticipation, reflexivity, responsiveness and inclusion? Considering the concept of Responsible Research and Innovation of the European Community (rri-tools.eu), is it possible to evaluate if all these practices have an impact on: gender equality, open data development, user integration, scientific education and governance and ethics.

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Appendix 1: Summary of the Topics Discussed During Interviews

- Name of the organization. Any person giving information may remain anonymous.
- Category: academic, public institutions, production company, service company, community.
- Influence/expertise: the area in which the actor can make decisions.

- Permanent and general professional goals: the objectives that the actor wants to achieve in order to fulfil his or her professional role. This could be a mission about job creation, performance in a particular economic sector, social challenges in a specific area.
- Main resources/means available to the actor. This concerns equipment, expertise and budgets.
- Main constraints: elements over which the actor has no power. This could be finance, quality of equipment and problem of expertise availability.
- Driving force for action: the indicators that the actor wants to improve. To understand the strategy of the stakeholder, its own assessment criteria used to measure its goals achievement are important.

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Innovation Capacities and Living Labs in Europe: A Competency-Based Approach Derived from a Systematic Literature Review

Raphaël Bary, Laure Morel, and Valentine Labouheure

Abstract The aim of this chapter is to clarify what competences are needed for individuals to innovate within European living labs. Living labs are user-centric and open-innovation approaches that aim at enhancing the acceptability of new products and services. In Europe, the concept has been adopted in particular as a way of reinforcing citizens' well-being by involving them in the early phases of living lab projects. Moreover, living labs are also seen as a way to improve the innovation capabilities of organisations. However, to date, research focusing on innovation capabilities at an individual level is scarce. Hence, in this chapter, we first present the concepts of co-creation and open innovation, and the living lab, before showing the link between organisation and individual capability. We then conduct a systematic literature review using the Web of Science and Scopus databases to understand the components of individual innovation capabilities in the context of European living lab approaches. We extracted 11 publications that we analysed to obtain a classification of categories of individual innovation competences. The study reveals some differences from broader previous studies on individual innovation capability, namely the importance of social competences and that of meta-competences such as adaptability, as well as the essential role of facilitators. This review is a first step towards evaluations of living labs. It could serve as a checklist for practitioners as well as for researchers. Moreover, it offers a better understanding of the importance of co-creation to enhance Europe's innovation capacity.

Keywords Individual innovation capability · Living labs · Co-creation · Open innovation · Innovation capacity of organisations

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1 Introduction

It is now well established that collaboration between partners from various institutions has a positive impact on innovation capacity (Dekkers et al., 2019). Moreover, while differences between European nations are real, as shown in (Lundvall, 1998, 2007) National Innovation System, approaches such as "co-creation", "open innovation" and "collaborative innovation" have garnered interest and shown positive results among these same nations, and could be seen as a way to foster innovation in Europe (Greco et al., 2015; Salmelin, 2016). More specifically, the living lab approach has been adopted as a way to innovate in many European countries. This approach considers users as "co-creators", that is, as active members in innovation processes: a role that concerns both operational work on the project and participation in defining the modalities and objectives of the collective work. It can thus be considered as a user-centric and open-innovation approach. Living labs first appeared at the beginning of the 2000s, at Massachusetts Institute of Technology. The American concept functioned as a test bed, an environment put in place to test the usability of new technologies. What differed from traditional test bed approaches, however, was its level of realism: users would test new technologies within a familiar environment. When the concept reached Europe, it evolved towards even more realism and a greater involvement of users in the early phases of the innovation process (Leminen et al., 2017). This evolution led to the creation, in 2006, of the European Network of Living Labs (ENoLL), which concentrates on topics that go beyond innovative product development, such as citizens' wellbeing.

Research has already shown the benefits of living labs for organisational innovation capacity (Schuurman et al., 2016). Nevertheless, little in the way of research has focused on what kind of competences are needed at an individual level to manage open innovation processes successfully (Hosseini et al., 2017). This phenomenon can be explained by the lack of a clear definition of individual innovation capability within an innovation process in general, and in a co-creation context such as living labs more specifically. Therefore, one first step would be to characterise what constitutes innovation capability at an individual level. This could help us better understand the link between individual innovation capability and organisational innovation capacity development in such an innovation space.

Therefore, this study aims at investigating what constitutes individual innovation capability in European living labs. To answer this question, we will first shed light on the co-creation and open innovation concepts, as well as their connections and evolutions. This step will lead us to an introduction of the living lab as a co-creation and open-innovation approach to improve European innovation. Then we will highlight the link between individual and organisational innovation capacity by defining both terms. Finally, we will conduct a systematic literature review of the competences needed to make a living lab approach successful. In other words, this study aims at answering the following question: "What elements define individual innovation capability within a living lab approach from a European perspective?".

2 Co-creation and Open Innovation as a European Commonality

2.1 Open Innovation: Definition, Evolution and Critics

Over time, views on innovation have evolved. These changes have led to concepts such as co-creation and open innovation. Initially, innovation was seen as being driving by technology advancement (techno-push), then by market demand (market-pull). Later on, in the 1990s, the view changed to combine both perspectives (techno-push and market-pull), to finally reach an interactionist perspective in which external actors, and especially users, become central to the process. This is today's view of open innovation (Ortt & Van der Duin, 2008). These evolutions have also led, among others, to:

- A transition from a product innovation *for* users to an innovation *with* users, involving their experiences in terms of knowledge and competences (Rayna & Striukove, 2015).
- A change in user involvement techniques: from questionnaires to focus groups (von Hippel, 1986) and, today, towards methods that imply greater user involvement in the need, problem and solution-finding process. Living labs are very good examples of these methods (Fig. 1).

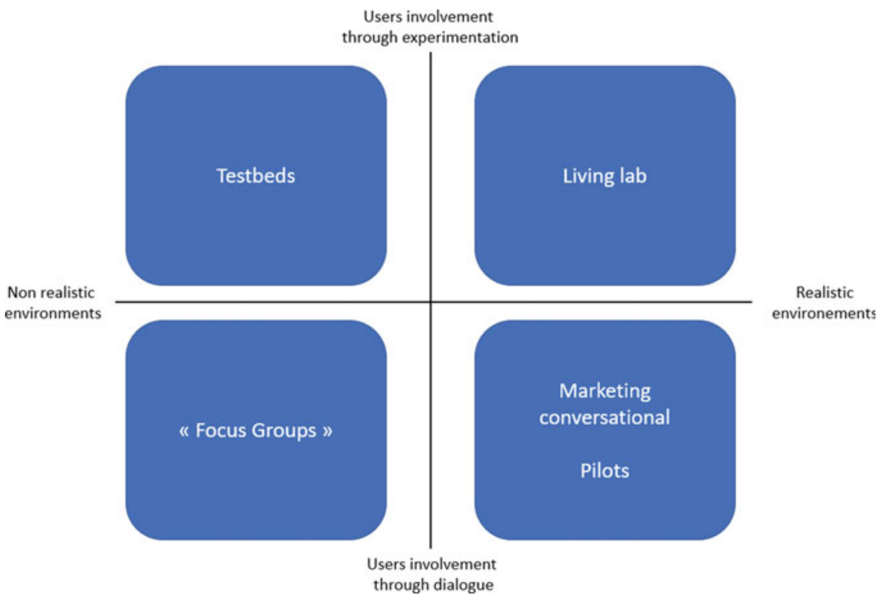

Fig. 1 The distinctive character of living labs. Dubé et al. (2014)

With respect to open innovation, the term first appeared in (Chesbrough, 2003), who defines it as “a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market as the firms look to advance their technology” (Chesbrough, 2006, p. 2). Since then, the concept has evolved:

- from inside-out innovation (or inbound open innovation), which consists of the integration and mobilisation of external resources to increase the company’s knowledge;
- to outside-in innovation (or outbound open innovation), which aims at accelerating the new technology creation process by outsourcing the company’s ideas directly on the market;
- to coupled innovation (Enkel et al., 2009; West et al., 2014), defined by Enkel et al. (2009, p. 313) as “co-creation with (mainly) complementary partners through alliances, cooperation and joint-ventures during which give and take are crucial for success”.

Consequently, we have progressed from a “firm to one” relation—with crowd-sourcing as the main method, which (Howe, 2009) defines as a contest between members of a large community where only one idea will remain—to a “firm to several” relation, which is most commonly adopted today and which involves the consideration of multiple actors’ ideas and points of view (Rayna & Striukova, 2015).

However, since the concept first appeared it has been subject to some noteworthy criticism. One criticism is that open innovation already existed long before 2003 (Dekkers et al., 2019; Trott & Hartmann, 2009). Among others, a great example of this is (Tidd, 1995) concept of “open networks” identified among Japanese companies in the mid-1990s. The concept resembles Chesbrough’s open innovation, as it is an open network of companies, suppliers and customers and contrasts with closed networks or organisation alliances that are described as less effective models of innovation. This last point actually calls into question (Ortt & Van der Duin, 2008) classification of the field evolution of innovation, as it appears that open-innovation-like models already existed in the 1990s. Trott and Hartmann (2009) support this idea when they qualify open innovation as “old wine in new bottles”, thus stressing the need to acknowledge previous work on the subject by giving further examples, and criticising Chesbrough’s thoughts on open innovation. Examples include the linear vision of the innovation process, as well as the opposition to closed innovation, a model that had in fact started to disappear from the corporate world before Chesbrough’s publications. Nevertheless, what remains from these counterexamples and criticisms is the need for collaboration and interaction in an innovation process (Tidd, 1995; Trott & Hartmann, 2009). In this respect, a similar idea existed under the umbrella term of co-creation.

2.2 Co-creation: Definition, Evolution and Link to Open Innovation

Prahalad and Ramaswamy (2004, p. 8) define co-creation as follows: "Co-creation is about joint creation of value by the company and the customer". The concept of co-creation emerged in Northern Europe at the beginning of 1970s in the fields of management and design. It first appeared under the term "participatory design", and aimed at making employees an active part of the company's decision process (Sander & Stappers, 2008; Koning et al., 2016). However, most commonly known theories on co-creation come from the business and marketing research fields (Sander & Stappers, 2008; Nájera-Sánchez et al., 2020). Until the end of the twentieth century, closed innovation was the dominant view (Chesbrough, 2003, 2006), in line with the Schumpeterian productor perspective. In 1998, Lundvall wrote, "until recently the analysis of innovation was with major exception of Schumpeter's contributions, a rather minor and little controversial speciality in economics (…)" (ibid, p. 409). In fact, before the beginning of the twenty-first century, including users in the innovation process was expensive, due to a lack of advanced technology (von Hippel, 2011). The advent of Web 2.0. marked a shift in this perspective. It offered new possibilities for creating communities of innovators that some users would join through new collaboration and sharing tools. These were visionary users, referred to as "lead users" (von Hippel, 1986). This elitist vision—which saw only a few specific users as capable of innovating—persisted until the beginning of 2000s and the introduction of (von Hippel, 2005) "user-centric" theory. This theory evidenced a transition towards a more democratic view of individual innovation capability, where all kinds of users are considered as potential innovators (Sander & Stappers, 2008).

Nevertheless, this variety of definitions and evolutions of both open innovation and co-creation are at the root of an ambiguity in the scholarly literature. Tekic and Willoughby (2019) explain how this confusion stems from the complexification of the two concepts: open innovation first focused on product enhancement and contrasted with the closed innovation model, before opening its process up to a greater variety of actors, such as universities. Moreover, these authors concluded that open innovation and co-creation should be seen as "adopted cousins", meaning that the two concepts were similar and appeared in the same period of time but in different fields of study. To clarify these concepts, (Tekic & Willoughby, 2019, Discussion, para. 1) distinguish the terms as follows:

- "co-creation is a concept concerned with involving individual external contributors in a company's innovation projects, when
- open innovation is a concept concerned with involving a wide variety of actors and stakeholders in a company's innovation projects, including both individual external contributors and partnering organisations".

In conclusion, both concepts have been defined as relevant to reinforcing the organisation's innovation capacity. A good example of current approaches embracing both ideas are living labs.

3 Living Lab as an Open-Innovation and User-Centric Approach to Improve European Innovation

3.1 Living Lab as a User-Centric and Open-Innovation Approach

ENoLL defines living labs as “user-centred, open innovation ecosystems based on a systematic user co-creation approach, integrating research and innovation processes in real-life communities and settings”. However, as the living lab is a recent concept, authors do not yet seem to agree on a common definition: it has been defined as a system, an environment, an approach or a method (Ballon et al., 2018; Kareborn & Stahlbröst, 2009). In this study, we consider the living lab as an approach. Kareborn and Stahlbröst (2009) identified five principles which characterise the living lab approach: empowerment of users, openness, spontaneity, realism and continuity. Skiba et al. (2012) specified these principles and translated them into collaboration, use analysis and integration in the design process, and experimentation in a real environment. This shows that co-creation is the level of user involvement that the living lab approach aims at.

One final characteristic of the living lab is its project phases, which several authors have defined, for example (Schuurman et al., 2016, p. 8): “(i) contextualisation, (ii) selection, (iii) concretization, (iv) implementation and (v) feedback”. In response to Trott and Hartmann’s (2009) criticism of open innovation’s linear vision of the innovation process, the living lab process is iterative. In other words, it repeats itself as often as needed until the product or service has been commercialised or diffused, as proposed by Kareborn and Stahlbröst (2009) through their FormIT process (see Fig. 2).

3.2 Living Lab Typologies: From an American “Test Bed” to a European “Co-creation” Concept

While these characteristics enable us to clarify the concept, various typologies of living labs remain. For example, in reference to the evolution of the living lab from an American testbed to a more open and realistic European concept, one distinction is to be found in today’s literature on living labs. It is to be found in the terms “American living lab approach” and “European approach towards living lab” in (Schuurman & Marez, 2009), and refers more specifically to a regularly cited typology from (Følstad, 2008), who differentiates “living labs as test beds” from “living labs for the research context and co-creation”. Other typologies can be found, such as in (Schuurman et al., 2013) who, among ENoLL living labs, distinguish those driven by “utilizers”, “enablers”, “providers” and “users”. Furthermore, the collaboration or

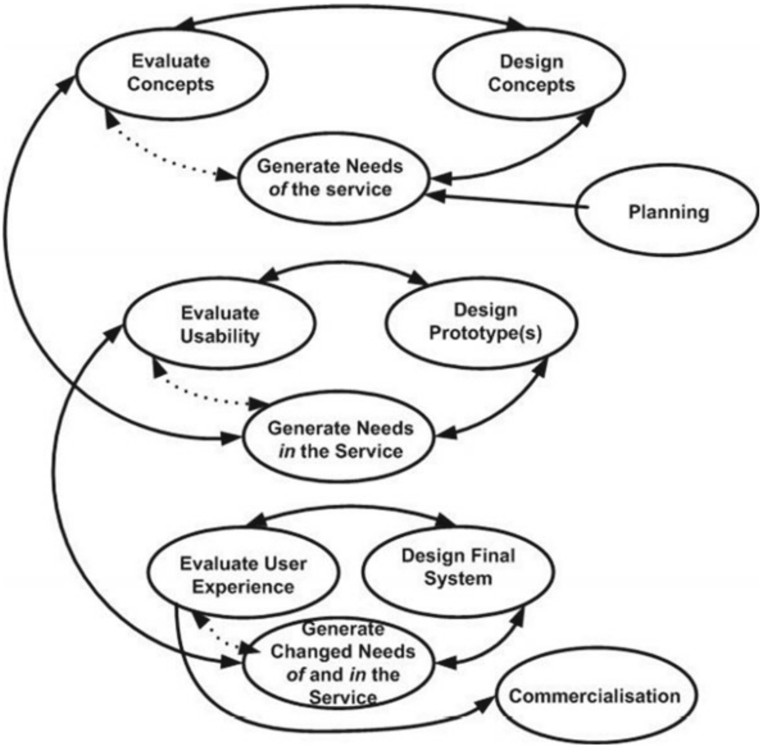

Fig. 2 The FormIT process for systems development. Kareborn and Stahlbröst (2009)

"openness" principle has also been defined as a quadruple helix concept or a public–private-people-partnership (4Ps) (Leminen et al., 2017), thus adding civil society as a participant institution into the (Leydesdorff & Etkowitz, 1996) university-industry-government triple helix proposal. However, the living lab has also been defined as adopting a quintuple helix model, especially within projects dealing with issues such as smart cities or sustainability, as is often the case of urban living labs (Baccarne et al., 2015). The quintuple helix model adds in sustainability issues by integrating the socio-ecological helix into the quadruple helix model (Carayannis et al., 2012). This may raise questions about the living lab typologies, and could create a distinction even within living labs "as a research and co-creation context". Nevertheless, the existence of a plurality of living labs and perspectives on the topic is at the root of difficulties in better understanding the concept and its potential impacts (Ballon et al., 2018). Among the few publications that focus on the matter, (Schuurman et al., 2016) showed the positive impact of living lab approaches for the innovation capacity of organisations, especially SMEs. However, the individual level of innovation capability required for living labs to be a success has not yet been investigated.

4 From Organisational to Individual Innovation Capability

4.1 The organisation's Innovation Capacity

The innovation capacity of organisations was a little-researched topic until the beginning of the 2000s (Dekkers, 2011; Enjolras et al., 2018). Since then, it has become a central concern of many publications. We can define an organisation's innovation capacity as follows: "Innovation capacity is defined as a firm's continuous improvement of capabilities and resources in order to explore and exploit the opportunities of new product development to meet market expectations". Pierre and Fernandez (2018, p. 25). Therefore, the term capability is applied here to individuals, whereas capacity is used for organisations. Investigations on this subject have enabled the creation of evaluation tools which offer companies the ability to improve their innovation capacity. For instance, at the beginning of the 2000s the French ERPI laboratory of Lorraine University developed the Potential Innovation Index (PII), a tool to evaluate SMEs' innovation capacity which has continuously evolved since then. PII also works as a benchmarking and recommendation tool. It is based on a multi-criterion questionnaire, maturity scales (five levels for each criterion) and self-evaluation by the companies involved (Boly et al., 2000; Corona Armenta, 2005; Morel et al., 2012; Galvez, 2015; Enjolras et al., 2018). More generally, today's evaluation of an organisation's innovation capacity concentrates on the firm's internal routines (Zawislak, 2013). In this view, entrepreneurs are seen as active actors of change (Enjolras et al., 2018).

The vision derives from the evolution of innovation capacity in terms of practices and processes, especially the introduction of open innovation (Enjolras 2016, 2018). Several studies have established evaluation frameworks for the innovation capacity of organisations in an open innovation context (Hosseini et al., 2017; Steiner, 2013). Moreover, (Hosseini et al., 2017), among others, have stressed the need to consider individuals in evaluations of organisational innovation capacity.

4.2 From Individual Capability to Organisational Innovation Capacity: The Importance of Organisational Learning

This seems relevant, as the link between organisational capacity and individual innovation capability has been found by several authors, and could be better understood through the concept of organisational learning (Feldman & Pentland, 2003; Kim, 1993; Stata, 1989). Organisational learning is defined as "a collective phenomenon of competence acquisition and elaboration, which modifies (…) situations and situations management". Koenig (2015, p. 297). It is based on two levels, the denomination of which differs in the academic literature: level 1 and level 2 learning, single loop and double loop learning (Argyris & Schön, 2001), adaptation and unlearning (Hedberg, 1981), learning by exploitation and by exploration (Levitt & March, 1988).

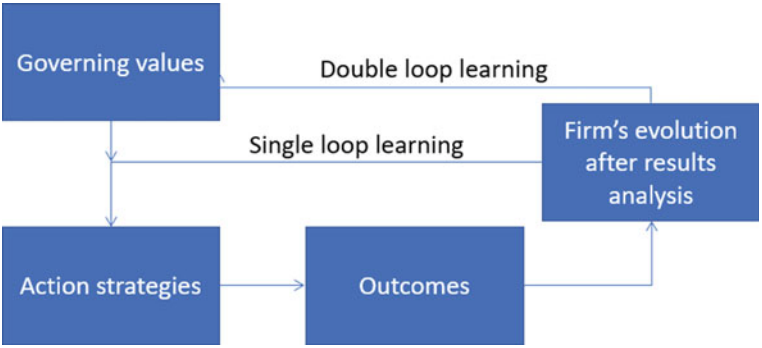

Fig. 3 Single loop and double loop learning. Adapted from Argyris and Schön (2001)

Argyris and Schön (2001) single loop and double loop learning are the terms used in this study, with single loop learning as changes and adaptations that are made in order to reach the expected results but without modifying organisational action values (generally at an individual level), and double loop learning as changes that question and challenge organisational action values (at a collective or organisational level) (Fig. 3).

Among those authors who have recognised individuals as the main component of an organisation's innovation capacity, (Feldman & Pentland, 2003), with the introduction of "organisational routines as a source of flexibility and change", acknowledge the importance and capability of individuals to switch from one level (single loop learning) to another (double loop learning). According to them, organisational routines have a twofold definition: (1) an ostensive definition, which is an abstraction of what the routine represents at a collective or organisational level; and (2) a performative definition, which represents the materialisation of the routine through individual actions. Unlike its ostensive counterpart, the performative view of routine is characterised by its novelty. In fact, each action depends on its context and environment, but also on inter-relations with the people and tasks included or not in the routine. As a consequence, even the most repetitive task will never be executed twice in the exact same way, but will rather need a certain degree of adaptability from the individual concerned (Feldman & Pentland, 2003). This concept shows the importance and, especially, the capability of the individual to progress from a performative level to an ostensive level of organisational routines, or from individual learning (single loop) to organisational learning (double loop). Kim (1993) goes even further in this sense by stressing the need to explain individuals' mental models in order to facilitate organisational learning. Organisations do indeed learn via their individual components. Individuals' capability to explain their mental models (to reflect on their actions) could thus be a key point of organisational learning. Stata (1989) agrees with this idea when outlining the difference between individual and organisational learning. Organisational learning depends on mental model exploitation and sharing between the members of an organisation. In addition, the memory of the organisation

Fig. 4 Impact of individual innovation capabilities on organisational innovation capacity. Adapted from Feldman and Pentland (2003)

cannot exclusively depend on individual memory. In this respect, the author stresses the need for teamwork as an important factor of organisational learning, mainly based on each individual's openness and objectivity. Furthermore, he identifies teamwork in small groups as a great training tool for organisational learning as it enables learning in action and limits reluctance to change, unlike individual training (Fig. 4).

Consequently, the importance of organisational learning, or learning to learn to enhance firms' innovation capacity and performances, which has been stressed many times (Lundvall, 2007; Patel & Pavitt, 1994), also emphasises the need to concentrate on individual innovation capability. Moreover, it shows the importance of involving the individuals concerned in the innovation process. In this way, they can improve their autonomy and their capability to progress from single loop learning to double loop learning, which brings us back to the relevance of co-creation and open innovation approaches. Nevertheless, while this process has proved efficient in enhancing innovation capacity at the organisational level, its implications at the individual level remain under-researched.

4.3 Individual Innovation Capability

This is a surprising observation, as we have seen that the relevance of the human factor has long been stressed in the scholarly literature. Consequently, it now seems necessary to focus on what constitutes individual innovation capability, especially in open innovation contexts (Hosseini et al., 2017; Enkel et al., 2017). Studies have already attempted to define and classify elements that constitute individual innovation capability. These studies have been in the fields of engineering, training and education (Beausoleil, 2019; Chatenier et al., 2010; Hero et al., 2017; Keinänen et al., 2018) for example, or in social psychology, with an interest in measuring innovative behaviour in a working environment (De Jong & Den Hartog, 2010; Lukes & Stephan, 2017). One possible definition of individual innovation capability is given by Beausoleil (2019, p. 86): "Innovation-related competencies are generally described as knowledge-based capabilities, aptitudes and skills integrated within organisational innovation management activities and systems". Beausoleil adds that "Competence and competency generally denote a person's ability to understand or perform a certain task". This last remark shows the need to understand the term "competence". Though there is currently no general agreement on its definition, the term competence has been for a prominent topic in a large number of studies. Many have described it as knowledge, aptitudes and skills turned into action (Escrig, 2019; Kahn & Rey, 2017; Le Boterf, 1995; Perrenoud, 1997). A literature review on this topic is not, however, the purpose of our study. For the sake of simplification, we refer here to (Chatenier, 2010, p. 272) definition of competence as "a specific set of attributes, combining functional competence (knowledge and skills) and behavioural competence (metacognition and attitudes) (…). Consequently, competence is defined as the integrated set of knowledge, attitudes and skills of a person". Moreover, for the sake of clarifity, we use the terms capability and competences interchangeably. Nevertheless, the diversity of definitions and perspectives on human innovation capability means that its components are not easy to understand. This is why more research on the topic is still needed (Hero et al., 2017).

5 Key Elements of Individual Innovation Capability: European Living Lab Study

Considering the above, our research aims at answering the following question: what elements define individual innovation capability in a living lab approach from a European perspective? To address the focal research question, a systematic review was performed between July and September 2021. The advantage of this method is that a systematic literature review "aims to minimize bias through exhaustive literature searches of published and unpublished studies and by providing an audit trail of the reviewers decisions, procedures and conclusions" (Tranfield et al., 2003, p. 209). Therefore, we conducted a systematic literature review in line with the extant literature on this method (Butler et al., 2016; Green et al., 2006; Greenhalgh & Peacock, 2005).

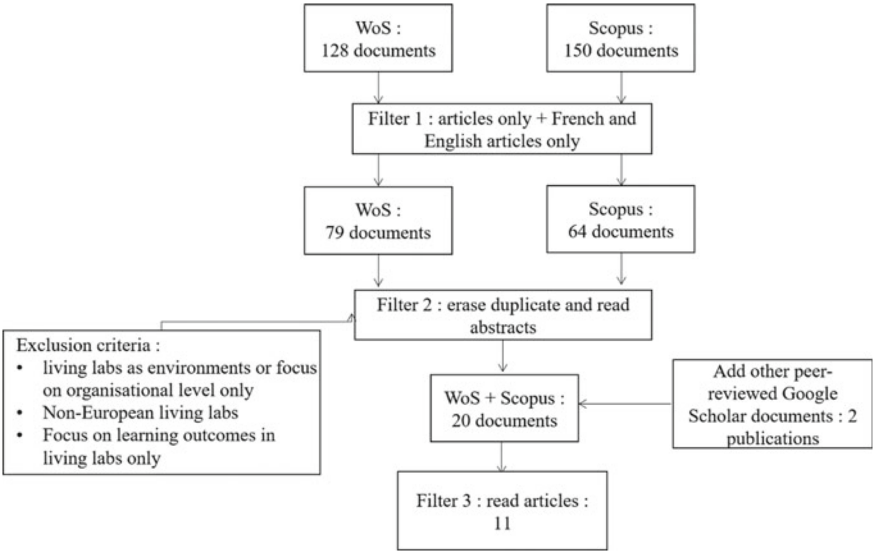

Fig. 5 Process of the systematic literature review on individual innovation capabilities in living labs. *Source* Our research

We focused on peer-reviewed documents from the Scopus and Web of Science databases, as the topics of living labs and innovation are mainly to be found in these databases. Following the advice of (Greenhalgh & Peacock, 2005), we also relied on our personal knowledge in the document search phase. Therefore, we included relevant documents from the Google Scholar database. No time frame was applied, as the living lab literature is quite new. The different steps and filters applied are summarised in Fig. 5.

The first exclusion criterion was to consider only articles dealing with the necessary individual competences in a living lab. However, this exclusion criterion led to few results. Therefore, we extended our inclusion criteria by including studies dealing with living lab success factors and lesson learned that could lead to an interpretation of the individual competences required to succeed in a living lab. Therefore, our search was conducted on both databases (Scopus and Web of Science) using the following query:

> Title= (“living lab” OR “living labs” OR “living laboratory” OR “living laboratories”) AND topic= (learning OR learnings OR learn OR competencies OR skills OR competences OR competence OR “innovation capacity” OR “success factors”)

We found a total of 128 publications in the WoS database and 150 in the Scopus database. A first filter selected articles only and only those in accessible languages for us: English and French. Then, following (Hossain et al., 2019) example, we downloaded the results from both databases in the form of CVS files (79 for WoS and 64 for Scopus), and started reading the titles and abstracts. We deleted duplicated documents and selected relevant ones using our exclusion and inclusion criteria.

Then, following the systematic literature review procedure, we applied our inclusion and exclusion criteria to select relevant publications. The exclusion criteria were publications concentrating solely on living labs as environments or at the organisational level and not on living lab methodology, publications dealing with non-European living labs, and publications focusing solely on learning outcomes in living labs. Moreover, following (Hero et al., 2017) example, we did not use the research discipline as an exclusion criterion because of the multidisciplinary character of innovation. Lastly, articles focusing on the learning impacts of living lab were borderline for exclusion, for example in the case of educational projects using a living lab approach. In fact, these studies could provide us with some idea of the required competences in living lab projects, but did not quite fit into our research goal of defining individual innovation capability within a living lab approach. This stage was carried out by only one reviewer, which may be one of the main limitations of this study.

Eleven documents remained from this last phase. From these, we gathered the methods used and provided the reader with a short statement of each study objective and contributions in respect to our literature review. This information can be found in Table 1. Then we searched for the required individual competences in the selected documents and listed them in a table. Once we had listed every competence from each article, we summarised and classified them following (Hero et al., 2017) table. This process was iterative.

Finally, our analysis of the documents gathered is data-driven and our results are presented using a narrative synthesis based on (Green et al., 2006).

6 Findings

6.1 General Remarks

The publications included come from 8 different sources, with a majority of articles from *Technology Innovation Management Review* (5 occurrences), one conference paper (*The OpenLivinglabs days conference*), one from *Computer Standards & Interfaces*, and others dealing with politics, sustainability and social innovation (publications in *Social Frontiers, Politics and Space, Sustainability,* and *The innovation Journal: The Public Sector Innovation Journal*).

Among the results we can distinguish between: (1) studies focusing on living lab management at different levels (Van Geenhuizen, 2018, 2019; García-Guzmán et al., 2013; Äyväri et al., 2019). For instance, (García-Guzmán et al., 2013) focus on the management of relations between a software company and other participants in a living lab, when ‘Äyväri et al., 2019) identify competences of living lab orchestrators at three different levels, namely macro (constellation), meso (project) and

Table 1 Selected documents description

References	Publication objective and contributions	Method used
Äyväri et al. (2019)	Identify skills for living lab orchestrators (networks + activities)	Literature review
Juujärvi et al. (2013)	Identify success factors for urban living labs	Single case study
Edwards-Schachter and Tams (2013)	Identify barriers to make users co-creators and reaching living lab goals. Make recommendations on how to overcome those barriers	Multiple case study
Hakkarainen and Hyysalo (2013)	Identify living lab barriers to reaching innovation goals	Single case study
Hakkarainen and Hyysalo (2016)	Show facilitators' different tasks and roles in a living lab and how encountered problems can be solved	Single case study
Van Geenhuizen (2018)	Evaluation of living lab at environmental and operational level: identification of living labs' key performance factors	Multiple case study
García-Guzmán et al. (2013)	Management of synergies between living lab participants in the context of ICT innovation	Multiple case study
Van Geenhuizen (2019)	Identify key learning in urban living labs	Multiple case study
Veeckman and van der Graaf (2015)	Improvement of bottom-up management in smart city initiatives: identify skills needed for greater user inclusion	Multiple case study
Gago and Rubalcaba (2020)	Identify employees' soft skills needed in a living lab	Multiple case study
Stahlbröst and Host (2017)	Show the impact of reflection on action for users' involvement and for managers in a living lab	Single case study

Source Our research

micro (methodology) levels. From these studies, we only focused on project- or methodology-level competences, as they are related to living labs as an approach; and (2) studies directly dealing with the competences required to succeed in a living lab approach.

In the second category, some publications explore the barriers, obstacles and challenges to co-creation in living labs and present the required individual competences in the form of recommendations and lessons learned to avoid these difficulties (Hakkarainen & Hyysalo, 2013, 2016; Edwards-Schachter & Tams, 2013; Veeckman & van der Graaf, 2015). For example, (Edwards-Schachter & Tams, 2013) identify power struggles between participants as a major barrier to empowerment, and find that the capability of facilitators to understand and balance participants' powers within the collaboration is a key living lab success factor. Along the same lines, (Hakkarainen & Hyysalo, 2013) present the required competences in the form of lessons learned from a longitudinal single case study. They identify collaboration challenges in a living lab project and ways to overcome them. Furthermore, (Veeckman & van der Graaf, 2015) focus on the challenges encountered in bottom-up initiatives in the context of a smart city project. In their research work, motivation, ability and satisfaction emerge as key elements for participants in a living lab approach.

The other publications specifically aim at identifying (1) the competences required to innovate in a living lab, or (2) the success factors from which these elements are deduced (Äyväri et al., 2019; Juujärvi et al. 2013; Stahlbröst & Holst, 2017; Gago & Rubalcaba, 2020). Good examples of the first category are the studies by Äyväri et al. (2019) and (Gago & Rubalcaba, 2020), which list living lab facilitators' key competences and characteristics. As for studies dealing with success factors, (Stahlbröst & Holst, 2017) focused on the importance of reflexivity in a living lab, and identified specific required competences such as the capability to adapt to specific situations. Lastly, (Van Geenhuizen, 2019) performed a literature review of living lab performance factors and conducted six case studies to complete this work.

Nevertheless, noteworthy common points in most studies are their use of single or multiple case studies as a research method, except for (Äyväri et al., 2019) who used a literature review, and their focus on the role of facilitators (also referred to as managers or orchestrators) in living labs (Äyväri et al., 2019; Juujärvi et al., 2013; Edwards-Schachter & Tams, 2013; Hakkarainen & Hyysalo, 2013, 2016; Stahlbröst & Host, 2017; Van Geenhuizen, 2018*;* Veeckman et al., 2013; Gago & Rubalcaba, 2020). For instance, (Äyväri et al., 2019; Gago & Rubalcaba, 2020; Edwards-Schachter & Tams, 2013) define facilitators' capability as key to successful user integration. Hakkarainen and Hyysalo (2016) go even further in this direction, presenting the different tasks that a living lab facilitator should be able to perform to guarantee the success of the living lab, and how their roles may change along the project phases, for instance switching from facilitating to technology configuring. Stahlbröst and Holst (2017) and (Juujärvi et al., 2013) also concentrate on living lab managers' capability to involve users, as do (García-Guzmán et al., 2013). The latter study, however, aimed to develop a management model to improve collaboration between ICT companies and users in a living lab. Only (Veeckman & van der Graaf, 2015) and (Juujärvi et al., 2013) focus on the competences of various participants. For example, (Juujärvi et al., 2013, p. 26) state that all participants involved need to be able to "tolerate uncertainty, search for knowledge from diverse sources and people, and think critically".

6.2 *Classification of Individual Innovation Capabilities in a European Living Lab*

6.2.1 Main Competences and Differences with the Broader Classification

In addition, this literature review allowed us to determine the key competences required for individuals to succeed in a living lab approach. Consequently, we classified our findings based on (Hero et al., 2017) literature review on human innovation capability components, which we adapted to our results. To do so, we compared their occurrences in terms of competence categories per publication and per occurrence in all studies. Figure 6 shows these differences. Then we carefully reread all selected publications to better understand the meaning and contexts of these results. Some noticeable distinctions emerged from our analysis.

First of all, one main difference with (Hero et al., 2017) broader classification of human innovation competences when applied to the living lab context is the weight of "personal characteristics". In (Hero et al., 2017), this appears as the first category of competences since it is the most frequently cited in the innovation literature. In the case of living labs, social competences followed by management competences came out the most frequently, as shown in Fig. 6.

Moreover, motivation and engagement, as well as achievement orientation, were found in only three of the collected documents, even though empowerment is one of the main principles of living labs. One possible explanation is the focus on facilitators' competences, when elements such as motivation and initiatives should come from users, who are voluntary participants. Indeed, (Veeckman et al., 2015;

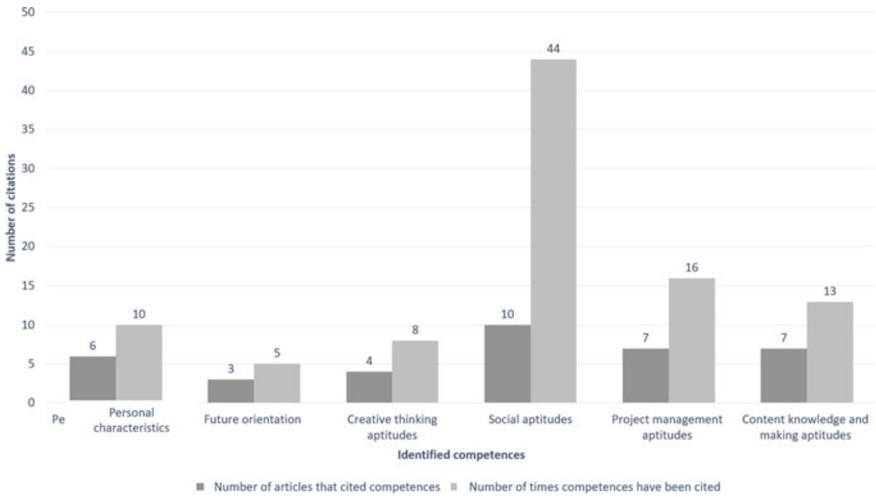

Fig. 6 Comparison of living labs' individual innovation capabilities categories in terms of occurrences per article and competences. *Source* Our research

van Geenhuizen, 2019; Juujärvi et al., 2013) present motivation as one key element of user involvement. Nevertheless, (Gago & Rubalcaba, 2020) cite motivation as an important component of facilitators' capabilities, especially to develop their soft skills. Furthermore, "self-esteem", self-management" and "achievement orientation", which appear as subcategories of the "personal characteristic" category in (Hero et al., 2017) classification, are absent from ours.

Next, surprisingly, creative thinking and future orientation are less present as individual components of living lab success: they appeared only 8 and 5 times in 4 and 3 articles, respectively, whereas (Hero et al., 2017) identified these competences as key components in most innovation studies, especially those related to idea generation. One plausible explanation could be that idea generation, and therefore creativity, could be components of users' innovation capability rather than that of facilitators, as users are active actors in the idea generation process of living labs. By way of illustration, creativity appears in (Hakkarainen & Hyysalo, 2013) as a required competence for intermediaries to adapt to unexpected situations and not, for instance, for the process of idea generation.

Other relevant components of individual innovation capability in living labs are project management as well as content knowledge and making competences, with respectively 16 and 13 citations found in 7 articles out of 12. These categories are concerned with living lab methods and tools such as research, design or evaluation competences (Juujärvi et al., 2013; García-Guzmán et al., 2013; Äyväri et al., 2019). An explanation for this result could be the predominant emphasis on managers' and facilitators' roles in the studies.

6.2.2 The Weight of Social Competences

As mentioned in the first general remark, social competences came out as the most essential competence category. They were indeed cited in almost all studies (10/12), and 44 times by all publications. This component of individual innovation capability appears to be crucial to the success of living labs. By way of illustration, (Hakkarainen & Hyysalo, 2013, p. 21) wrote: "most researchers see collaborative learning among stakeholders in real-life environments as the core rationale for setting up living labs". The importance of social competences is also made clear by Äyväri et al. (2019) who focus on the required skills of living lab orchestrators, which they classify into three categories: (1) skills in building relationships, networks and ecosystems; (2) skills in maintaining relationships, networks and ecosystems; and (3) skills in executing living lab projects. A similar point is emphasised by Gago and Rubalcaba (2020) who mainly concentrate on soft skills as required competences for living lab end-employees, who they define as facilitators. The authors argue, however, that both hard and soft skills ought to be considered and adapted to users. In this respect, they give an example of conflict management-related skills that could be used with mentally impaired individuals.

In fact, tensions between stakeholders and the need to manage conflicts appear to be key points in some studies analysed (Hakkarainen & Hyysalo, 2013; Edwards-Schachter & Tams, 2013). This could explain the omnipresence of social competences as compared to (Hero et al., 2017) more general classification. It is the very openness of the process (collaboration between actors from various horizons), so characteristic of open innovation approaches, that can lead to tensions (Hakkarainen & Hyysalo, 2013). As an answer to conflicts and power struggles, authors identified facilitators' capability to enhance collaboration as a crucial component. For instance, (Hakkarainen & Hyysalo, 2013) suggest hiring an intermediary person that is familiar with participants' context and needs, which appears in our findings as the capability to consider and acknowledge participants' differences in terms of needs and competences. Juujärvi et al. (2013) support this last argument when reporting tensions between various actors in a living lab project, although they do not focus on facilitators' role but merely point out the need to be able to identify users' real needs. Moreover, (van Geenhuizen, 2019) also identifies conflict as one of living labs' main challenges and encourages the use of intermediation when trust within user groups is difficult to attain. More broadly, several authors have underlined the need to balance power between stakeholders in a living lab (van Geenhuizen, 2019; Edwards-Schachter & Tams, 2013).

6.2.3 Reassessing the Individual Innovation Competence Classification in Living Labs

Last but not least, flexibility appears 10 times in 6 publications. This competence has mainly been reported as an essential component for facilitators, especially their capability to change roles when needed, for example when switching from a role of "knowledge broker" to that of "configurator" or "facilitator" (Hakkarainen & Hyysalo, 2016; Stahlbröst & Holst, 2017). Hence, adaptability appears to be an essential element for the success of living labs. Stahlbröst and Holst (2017) go even further in that sense by identifying managers' reflexive capability as crucial for adaptability development. Another example is provided by Veeckman and van der Graaf (2015) who defined ability as the capability to create a common language between participants and, in doing so, stress the need to use tools and adapt them to the situation. This last point confirms the idea that adaptability is a required competence to develop other competences.

All these findings allowed us to adapt (Hero et al., 2017) classification to our objective of defining individual innovation capability in a living lab approach. We chose to create a hierarchy within the authors' classification by changing the category of personal characteristics into meta competences, and adding reflexivity as a capability that would enable other capabilities to develop. Indeed, (Gago & Rubalcaba, 2020) also mention adaptability as one of the meta competences identified by the OECD. In addition, (Juujärvi et al., 2013) present motivation as a required competence to develop new methods to facilitate co-creation. Therefore, we decided to include self-motivation in the meta-competence category. The findings are shown in Table 2

Table 2 Classification of individual innovation competency factors in living labs

Meta competences	Adaptability	• Capability to reflect on action (5) • Adapt to change (4; 11) • Flexibility in project management (4) • Adapt co-creation methods to stakeholders (5; 7; 9) • Adapt roles to situations (5)
	Motivation and engagement	• Self-motivation (11; 10; 9)
Future orientation	Future thinking	• Tolerate uncertainty (2; 7)
	Alertness to new opportunities	• Create opportunities (1)
Creative thinking competences	Cognitive competences	• Open mindedness (1; 11) • Critical and analytical thinking (2; 11) • Practical thinking (4)
	Creativity thinking	• Creativity (4; 2)
Social competences	Collaborative competences	• Consider and acknowledge participants' differences (in terms of needs and competences) (1; 5; 10) • Recognise and involve participants (1; 8; 9) • Manage conflicts (3; 4; 7; 11) • Build trust and create embeddedness between different stakeholders (1; 4; 7; 8; 9; 11) • Listening competences (e.g. with users' feedbacks) (4; 5; 10; 11) • Organise and facilitate collaboration (1; 4; 8) • Respect participants' social values (e.g. cross-cultural) (7; 9; 11) • Create common language and objectives (7; 10)
	Networking competences	• Networking (find new contacts) (1)
	Communication competences	• Communicate participants' needs and feedbacks (1; 2; 4; 5) • Negotiate (change perspectives when needed) (1; 3; 4; 6) • Guarantee transparency (communicate project evolutions and plans) (4; 9; 11)

(continued)

Table 2 (continued)

Project management competences	Process management competences	• Research competences (1; 2; 3; 8) • Commercialisation and upscaling capacity (1; 9) • Manage time (4) • Evaluation capability (for tools and ideas) (1) • Knowledge transfer and management (1; 8) • Determine innovation strategy (8; 9)
	Management competences	• Strategic leadership (2)
Content knowledge and making skills	Content knowledge	• Knowledge about stakeholders' environment (4) • Knowledge about co-creation methods and tools (5)
	Making skills	• Design skills (1) • Use tools and methods to generate ideas (8; 10)
	Technical skills	• Interest in and use of technologies (4; 5) • Develop and configure technologies (6)

Adapted from Hero et al. (2017)

7 Discussion

The present study offers a systematic review of definitions of individual innovation capability in a living lab from a European perspective. The results have different implications: they improve our understanding of living labs, co-creation and open innovation, and offer new research perspectives and food for thought on the implications for European innovation capacity.

Few studies emerge from this literature review, but we hope that more research will focus on our target issue in the future. In this respect, the reproducibility of a systematic literature review makes it a great tool to provide updated answers to research questions, and we encourage researchers to use our framework for this purpose. Regardless of the number of publications considered, we managed to create a new classification of individual innovation capabilities in a living lab, mainly emphasising the importance of social skills and facilitator roles. Nevertheless, while soft skills are always needed regardless of the living lab project, the balance between soft and hard skills may differ from one project to another (Gago & Rubalcaba, 2020). As regards this issue, the types of projects could be considered in future research, for example whether or not they fit into triple, quadruple or quintuple helix typologies of living labs identified in this study, or to make a comparison between American and European living labs, as the few results from this literature review did not enable us to do so. More empirical research could provide us with this information.

Next, this study also raises the question of the required competences of users versus facilitators, as this difference does not clearly appear in the studies analysed in this review. Indeed, living labs are user-centric, open-innovation approaches which aim at involving users as innovation co-creators and which go beyond the trial and error process of service and product development (Eriksson et al., 2005). Consequently, taking part in a living lab process could be seen as a way to improve individual innovation capability. Hence, it seems relevant (1) to consider users' points of view in terms of competences needed and (2) to research the impacts of living labs on the development of these competences. In this vein, (Gago & Rubalcaba, 2020) underlined the importance of learning by doing in the development of living lab facilitators' soft skills. Another example is communication competences, identified as key competences in a living lab approach, which could be acquired through collaboration with different actors from various institutions (Leydesdorff & Etkowitz, 1996).

Consequently, one further question could be: what impacts does a living lab approach have on individual innovation capability? What do users and other stakeholders learn from taking part in a living labs approach? Our study offers a detailed reference model for living lab assessment that could serve for both practical use (for living lab process management) and for further research on the topic. This could indeed be seen as a first step towards answering the need for living lab impact evaluation, which remains challenging according to the scholarly literature (Ballon et al., 2018). Moreover, it would be relevant to go further in this direction by focusing on the impact of living labs on individual and organisational capability. How do living labs' impacts on participants resonate at an organisational level? Or simply put: how do living lab participants progress from single to double loop learning? This relates to the principle of empowerment, one major characteristic of living labs, which is also targeted by Edwards-Schachter and Tams (2013) study. Consequently, there is a need to focus not only on results but also on what is learned, how it is learned and what competences will be used in other contexts. These questions are aligned with (Dekkers et al., 2019) more general argument about the need to show the impact of open innovation approaches in order for stakeholders to adopt the process to a greater extent and more easily. A good way to consider this question would be to take on board (Stahlbröst & Holst, 2017) suggestion of making users reflect on action, as the development of this competence could help them develop their adaptability, among other things. This finding coincides with the need to explain and share individuals' mental models in order to learn and enable organisational learning (Kim, 1993; Stata, 1989).

8 Perspectives

Finally, differences in terms of individual innovation capabilities are notable among European countries. These differences mainly concern inequalities in terms of countries' official training and education institutions. In this respect, living labs could be seen as a way to deal with these disparities. Considering living labs' involvement in individual innovation capability, and their focus on co-creation, living labs could be considered as a first step towards a European innovation learning culture. As (Lundvall, 2007) underlines, it is high time we looked outside of formal institutions. Therefore, a living lab approach could act as informal training to enhance participants' innovation capability. Finally, living labs are seen as potential sources of creativity, productivity and innovation in Europe (Eriksson et al., 2005). It is therefore highly relevant to continue exploring and understanding how living labs do indeed impact upon European innovation capacity, as their user-centric character could be key to "renewing the European Innovation System" (Salmelin, 2016, p. 275).

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Multilateral Collaborations Between University and Industry: A Mixed-Methods Approach Yielding 10 Characteristics for Successful Innovations in the Era of Digitization

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Abstract Due to the increasing innovation pressure of industry, joint research between industry and science has become enormously important in recent years. Increasing complexity of the industry offer, the digital transformation and the upcoming of new forms of work, collaboration increasingly switches from classic bilateral collaborations between one company and one scientific partner towards multilateral research cooperation. A wide range of collaborative research formats are existing, facilitating bilateral collaboration between industry and research to aim a defined goal and facilitating mutual benefit. Accompanying research on collaboration performance exists for bilateral collaborative initiatives. However, still little research on formats for multilateral research cooperation exists. In the following study we want to identify existing forms of multilateral cooperation between industry and science and analyse them according to their collaboration performance in the age of digitalisation. Therefore, in a first step, desktop research was conducted to identify real, existing collaborations between industry and science. Within those, relevant key characteristics which affects the performance of multilateral collaboration were derived (such as "number of partners", "partnership structure", "funding model", "contractual arrangements"). In the second step, seven representatives of real multilateral collaborations were interviewed to characterise their research cooperations. The survey captures different perspectives of research collaboration management, the business partners, and the partners from academia. The third step involved an analysis of the interview results, which finally were merged with the findings from literature and formed the foundation for defining the ten relevant characteristics of successful research collaborations.

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1 Introduction

Innovation is the key driver of economic growth and competitive advantage in today's rapidly evolving global economy. As a result, organisations across all industries are investing heavily in research and development (R&D) to stay ahead of the curve. However, innovation is a complex process that requires a diverse set of skills, resources, and knowledge.

To increase the innovativeness, industry ever since has collaborated with science. Many research studies define "research collaboration" as a means of interaction with the aim of reaching a common research goal (Ynalvez and Shrum, 2011; Sonnenwald, 2007). Industry-research cooperation therefore involves collaboration between organisations in the private sector and academic institutions to conduct research, develop new technologies, and bring innovative products and services to market. However, differences arise in the definition of a collaborator. In this study, collaboration is defined as an interaction between two or more individuals, whether locally or remotely, within or across institutions or organisations, working closely together in a research project, to achieve (a) common goal(s).

Vial et al., defines digital transformation as "a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies" (Vial, 2019). Therefore, digital transformation addresses adjustments to current collaboration structures because of introducing new information technologies. It must be considered that the integration of technologies into existing collaboration processes should have the impact to improve collaboration and coordination among collaboration partners (Camarinha-Matos et al., 2019).

Another aspect is the integration of digital components in product-service systems. Integrating digital technologies into product-service systems, more functions can be provided to the customer (or other stakeholders along the value chain). However, digitalisation leads to much complex product-service systems, with more interfaces between the single product-service system subsystems. For example, a conventional shock absorber in a vehicle becomes a smart product through the integration of sensors, actuators, and software (see Fig. 1). By integrating digital technologies, the product not only absorbs shocks—the actual function of the product—but the product-service system can now also record data from the current road condition and process it in such a way that the damping can be adjusted accordingly (customer benefit: increase of comfort and security gain). In addition, the condition of the shock absorber can be monitored in real time, and a replacement can be suggested at a "noncritical" stage. However, there are also other parties along the value chain that are interested in these data, such as road maintenance authorities and automobile manufacturers.

Such complex and technically diverse product-service system leads to the fact that increasingly fewer competences are available within the company itself and that these competences need to be acquired externally. In the context of innovation,

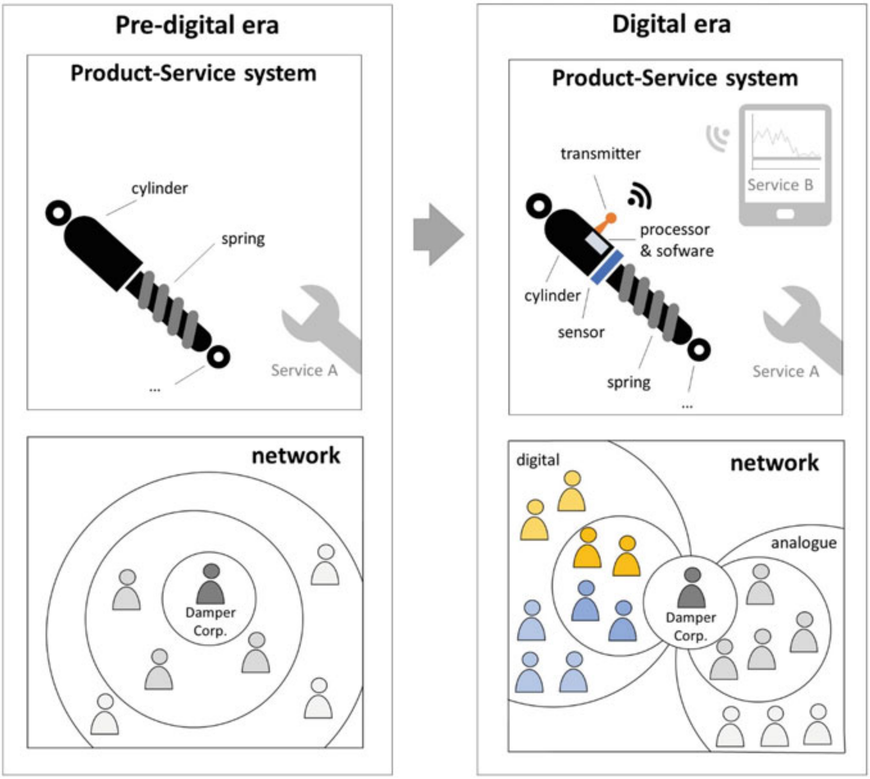


Fig. 1 The impact of digitalisation on product-service systems and research networks (example: damper)

Chesbrough subsumed this fact in early 2000 under the topic of "open innovation" (Chesbrough, 2003) and researched its mechanisms.

By leveraging the resources and expertise of both parties, industry-research cooperation enables companies to overcome technical and financial barriers that may impede innovation. Industry-research cooperation offers several benefits that are crucial for the innovativeness of companies. Some of these benefits include:

- Access to Expertise: Academic institutions have access to a diverse set of expertise, including subject matter experts, researchers, and scientists. Through collaboration, companies can tap into this expertise to gain insights into emerging trends, technologies, and best practices.
- Access to Resources: Universities and research institutes have access to state-of-the-art research facilities and equipment. Industry partners can leverage these resources to conduct experiments and develop prototypes.

- Reduced Risk: Collaboration with academic institutions reduces the risk associated with R&D activities. By sharing the cost of research and development, industry partners can reduce the financial burden of innovation.
- Increased Speed to Market: Industry-research cooperation enables companies to bring new products and services faster to market. By leveraging the expertise and resources of academic institutions, companies can accelerate the development process and reduce time-to-market.
- Increased Innovation: Collaboration with academic institutions can stimulate innovation by bringing together diverse perspectives, knowledge, and expertise. This can lead to the development of new technologies, products, and services that would not have been possible without collaboration.

In the last decades, however, the industry-science collaboration got increasingly complex, mainly due to digitalisation. On the one hand, digitalisation has revolutionised innovation by enabling the creation of new products and services that were previously impossible or impractical to develop. But digitalisation has also democratised the innovation process by providing greater access to resources, knowledge, and expertise, allowing a wider range of individuals and organisations to participate in the innovation ecosystem. Both, science and industry are in the midst of digital transformation which influences the collaboration.

As a legacy of Chesbrough's theory, the following relevant theses for innovation networks can be derived from digitalisation (Chesbrough, 2003):

Thesis I: Network growth and volatility

More partners need to be identified, integrated and managed

Innovation networks are becoming larger, as analogue competencies are complemented by digital competencies as well as by competencies for interface management between analogue and digital subsystems.

As more stakeholders are involved in the network, the risk that partners leak out rises (e.g. due to insolvency or other reasons), and concepts of resiliency need to be developed.

Thesis II: Partner diversity

Diverse partner network needs a 'common language' in research & communication

Innovation partners within network are becoming more diverse for several reasons: as more technology disciplines converge into the product-service system, the "clash" of the analogue and digital world needs to be managed.

Furthermore, relevant partners are increasingly found only on a global scale. This will turn into a "global run for partners" on the one hand and lead to cultural and infrastructural challenges in research collaborations on the other hand.

Thesis III: Technology development rate

More new technologies are available in less time

Digital tools have a positive impact on the technology development rate. This means, on the one hand, that an increasing number of new technologies will be available in the future and, on the other hand, that the half-life period of existing technologies will decrease (companies will have less time to generate return on investment). Therefore, "future compatibility" as an assessment criterion for the selection of technologies will be increasingly important. Another fact is relevant in terms of collaboration: Due to digitalisation, companies are progressively competing with research institutions as places where knowledge is generated, blurring the boundaries between the previous subsystems of business and science (Becker, 2003; Luhmann, 1992).

Based on these theses, this paper will discuss the critical role of industry-science cooperation in driving innovation and present 10 characteristics for successful innovation.

As a result of the above-mentioned theses, the establishment, maintenance, and management of research collaborations is becoming increasingly complex. This in turn raises the question of whether such networks can be formed, get to work, and be managed through the established research collaboration formats or if other formats need to be developed. For many years, innovative approaches in research cooperation have been successfully found in bilateral contract projects between industry and research institutions. However, considering the above-mentioned facts, this format of cooperative research seems to be reaching its limits.

In our survey of representatives of multilateral research collaborations, 85% of the participants stated that due to current trends, such as digitalisation and increasing complexity, new forms of cooperative research will be necessary to remain competitive. In many collaboration networks, it is no longer a question of individual bilateral research collaborations but rather of binding collaboration networks between science and industry to improve the use of knowledge (Becker, 2003).

The technological potential of digitalisation and the associated organisational changes and requirements pose major challenges for many companies. Therefore, in this area of tension, a considerable need for research and support services by research institutions, such as the Fraunhofer-Gesellschaft, is assumed. Our study is dedicated to cooperative research formats with several partners from science and industry—so-called multilateral research collaborations.

2 The Importance of Research Collaborations

Joint research between science and industry has gained enormously in importance in recent years. Companies are very interested in research collaborations and consider them a key driver of innovation for the future. In particular, they see the increasing complexity of technologies in conjunction with service-oriented performance, digitalisation and the associated new forms of work as trends that can no longer be approached on their own. These trends and developments offer far-reaching potential for new research and collaboration formats.

These new forms of cooperative research have been subject to little research to date, and further efforts need to be initiated. It is no longer just a matter of classic bilateral collaborations between a company and a scientific partner—the number of collaboration partners is multiplying. Collaborations with several partners from science and industry can be referred to as multilateral research collaborations. We focus our research interest on the present study to this format of cooperative research. On the one hand, we want to give a research impulse; on the other hand, we want to point out future challenges: What are the collaborative forms of multilateral research? What are the advantages of multilateral research formats? Which format is best suited for one's innovation goal?

Our study focuses on multilateral research collaborations between industry and science. It looks at national and global research collaborations that stand out for their inter- and transdisciplinary approach. Crossing organisational boundaries at the cultural, work-organisational, and technological levels also play an essential role. The identification and development of the corresponding levers plays an essential role in making research collaborations successful.

For defining a collaboration, numerous suggestions can be found in the literature. In any case, the minimum requirement is a collaboration between organisations and not within organisations (Becker, 2003), whereby collaboration is understood as the process of joint planning, management, implementation, and control of collaboration activities (Rotering, 1993). The basis for the emergence of collaboration is the increasing functional differentiation and complexity of modern societies into subsystems organised and specialised based on the division of labour (e.g. business and science) (Luhmann, 1992). The historical development of the definition of the concept of collaboration is striking. Initially, the focus was on the contractual or legal situation, whereas today joint access to resources plays a more central role (Bidlingmaier, 1967; Weber & Heidenreich, 2018).

In addition to the increasing importance and number of collaborations, the demand for interdisciplinary and transdisciplinary research has also been growing for some time. Many university-related centres and institutes have been established. On the one hand, this is evidence of the relevance of this topic, but on the other hand, it also shows the limits within universities. The science system is often too rigid to meet the need for cross-disciplinary research. In the case of complex problems that require a holistic approach to solving them, research collaborations usually offer the only solution. A team from different disciplines could join forces thematically and organisationally. This thinking outside the box creates innovation with new approaches to solutions—a core concern of interdisciplinarity (Hanebuth et al., 2015a, 2015b).

The wide range of ways in which research collaboration can be structured is shown by the different approaches to promoting collaboration between industry and science, such as clusters, competence centres, public–private partnerships, industry research campuses or innovation, and technology platforms (Koschatzky, 2013a).

If we take a closer look at the design of research collaborations, we find that certain structures recur and that almost all research collaborations can be classified on the basis of these structures. For example, research collaborations can be classified according to their strategic importance (Hanebuth et al., 2015a, 2015b)—from personal to global. Furthermore, a distinction can also be made, for example, based on the degree of formalisation (Belkhodja & Landry, 2007; D'Este & Patel, 2007; Perkmann & Walsh, 2009): From formalised, specified agreements to formalised, unspecified agreements of often long-term strategic nature to the establishment of new structures and organisations (Bonaccorsi & Piccaluga, 1994; Koschatzky, 2013b). Research collaborations can also be differentiated regarding the exploitation of results, such as spin-offs, publications, licensing or patents (Franco & Haase, 2015). Further distinguishing features can be the duration of the collaboration (D'Este & Patel, 2007), the degree of interaction during the collaboration (Perkmann & Walsh, 2007; Santoro & Saparito, 2003), the resource contribution to the collaboration (D'Este & Patel, 2007), the direction of the knowledge transfer (Arza & López, 2011), the utilisation potential of the research results (Perkmann et al., 2009), the spatial extent, the orientation within the value chain and the binding nature of the agreements (Killich, 2011).

In our study, the number of research partners is used as a central classification characteristic for research collaborations. If a distinction is made according to the number of partners from industry and the number of partners from science, a distinction can be made between four types (Fig. 2).

The classic bilateral research cooperation involves two partners—one from industry and one from science (1:1). The participation of one science partner and

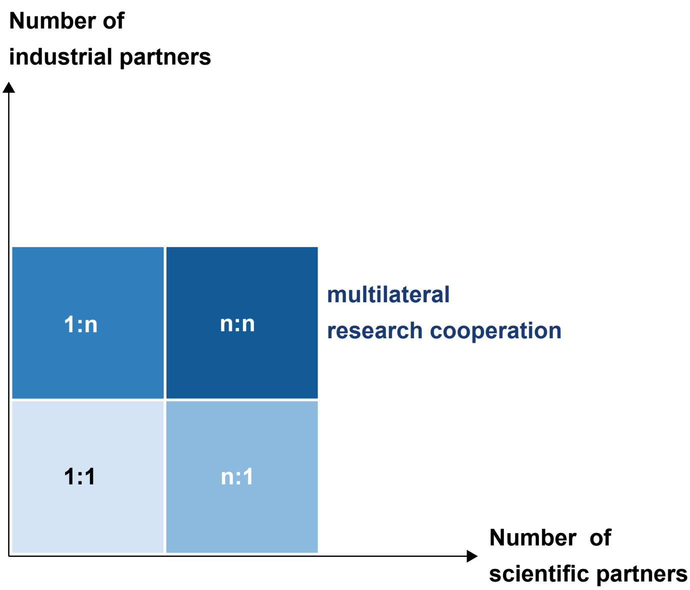


Fig. 2 Research formats of research collaborations

several business partners is shown in 1:n. Cooperation of several partners from science with a single partner from industry results in n:1. These are, for example, private-sector sponsored research formats.

A cooperation of several partners from academia and several partners from industry forms the basis for multilateral research collaborations (n:n).

Often, however, multilateral research collaborations are formed by more than just partners from industry and academia. Since governments are also interested in promoting economic and social development, governments also interact in modern collaboration networks (Leydesdorff, 2010). This framework was first thematised as the "Triple Helix" in the 1990s (Etzkowitz & Leydesdorff, 1995). Since economic growth is generated by constant innovation (Afonso et al., 2012) and the Triple Helix is not sufficient for long-term innovative growth (Kimatu, 2016), first the "Quadruple Helix" and then the "Qunituple Helix" emerged (Carayannis et al., 2012). Here, the needs of a wide range of stakeholders are taken into account. In addition to science, business, politics, and society, it also includes (social) ventures, "makers" and activists to illustrate the active role of citizenship (Calzada & Cowie, 2017).

3 Research Design

The study examines multilateral research collaborations. As the scope of this field is rather unclear, an explorative study was conducted. Explorative research can be seen as initial research that explores the subject further and helps obtain an overview by identifying patterns. The research design is divided into several steps. In the first step, a broad online search was conducted to collect and catalogue research collaborations between industry and academia. In total, 61 research collaborations were identified worldwide. Since the focus of the study is on multilateral research collaborations, collaborations with only one partner from industry and/or academia were excluded. Furthermore, pure management organisations or associations without research background were also excluded. In the end, 22 use cases could be included in the analysis. Parallel to the search for research collaborations, a comprehensive literature review was conducted regarding various aspects of research collaborations. The literature review included 174 publications, of which 157 were considered relevant. Most of these were published between 2000 and 2018, and a few were published in the following years until 2020 and during the twentieth century. The literature was examined with regard to the characteristics of research collaborations. As the various publications use different terms to describe the characteristics, a taxonomy was applied. For example, the term duration also includes terms such as period, length of agreement, long-standing, project length, and time span. The German translation as well as the word family of the root word were also included. In the second step, a questionnaire was designed based on the analysis of the use cases and the results of the literature research. Nevertheless, the approach was rather explorative, as more insights were needed. With the goal of being able to characterise research collaborations, this questionnaire addressed the key characteristics of research collaborations that emerged from the literature and their design in real research collaborations. With the help of the questionnaire, persons from seven research collaborations were interviewed in writing and orally. During the survey, the different perspectives of the coordination or management of the research cooperation, the business partners and the partners from science were recorded.

In the third step, an analysis of the interviews was conducted. As there were only seven interviews, no specific coding system was used. The scope of the interviews and the interviewees cannot be seen as representative bearing conclusive results, which, however, was not the goal of the study. These results were merged and compared with those of the use cases and validated by literature research. In this way, the ten characteristics of research collaborations could be defined.

4 Results of the Literature Review: The 10 Characteristics of Research Collaborations

The literature review revealed a system of ten characteristics of research collaborations that were mentioned extraordinarily often. An accurate number of counts/mentions can be found in Fig. 3.

Another category worth mentioning is outputs/outcomes, which was mentioned five times. However, this is far below the count of the other characteristics and therefore will not be discussed further.

The core of a research collaboration is the goal of the collaboration, i.e. the reason why the research collaboration is entered into in the first place. Grouped around the goal are six structural characteristics that describe the organisational characteristics of

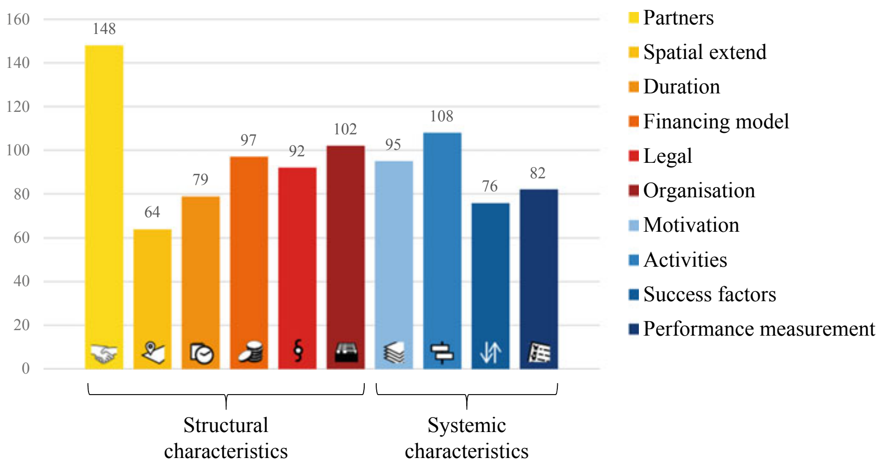


Fig. 3 The 10 characteristics of research collaborations

the research collaboration: the partners involved in the collaboration, spatial aspects (such as location and spatial extent), duration of the collaboration, funding, legal aspects (such as the legal form and contractual arrangements), and the organisation (for example, the collaboration type and domain) of the collaboration.

In addition to the six structural characteristics, there are another four characteristics that affect the entire research collaboration system: systemic characteristics. These four are the motives (i.e. factors that influence the motivation to enter a research collaboration), the activities (for example, joint projects, personnel exchange, sale or purchase of patents or publications), the influencing factors (i.e. factors that have a promoting or inhibiting effect on the success of the research collaboration), and the evaluation (such as goal definition and fulfilment or evaluation criteria) of the research collaboration.

In the following, the goal as well as the structural and systemic characteristics of research collaborations are described in more detail. First, the respective field of design is explained based on the literature. Then, the results of the empirical survey on the respective characteristic are presented to show its design in the interviewed use cases, which were introduced beforehand. For example, the literature analysis revealed motivation as a characteristic. The survey was used to clarify motives to be found in actual collaborations.

4.1 Goal

The first step at the beginning of a research collaboration is to define the purpose and goal of the research collaboration because ultimately success is measured by the achievement of this very goal. A distinction can be made between whether the collaboration partners are pursuing the same goal and aim to achieve a common goal by pooling resources or whether the partners are pursuing different goals and aiming to achieve their own goals with the help of the exchange of services (Junker, 2016; Killich, 2011).

In both cases, however, an exchange of knowledge or technology transfer takes place through which, for example, innovation, economic competitiveness or organisational capacities can be improved (Ankrah & AL-Tabbaa, 2015). Spin-offs can then be created, for example, or licences for patents can be acquired (Guimon, 2013; Owen-Smith et al., 2002).

5 The Structural Characteristics

The structural characteristics describe the organisational features of research collaborations. These are structures and parameters that can be recorded and compared.

5.1 Partners

This field of design describes the number and role of the partners involved. Here, partner selection and partner integration are also considered. After the goal has been defined, the partners for the research collaboration must be determined. Therefore, an evaluation of potential partners should be carried out. This can yield significant benefits by ensuring, among other things, that the collaboration is specific to the particular research collaboration (Ankrah & AL-Tabbaa, 2015). Existing relationships between partners can have an equally positive impact on the outcomes of the research collaboration. These are important because trust is built incrementally between organisations as they interact repeatedly and adapt to each other's expectations, developments, and requirements of previous collaborations (Gulati & Gargiulo, 1999). Another criterion in partner selection is resource endowment.

This can be tangible or intangible and includes, for example, financial assets, unique opportunities, skills or competencies, or management capabilities or technologies (Junker, 2016). Furthermore, location or company size can also influence partner selection (Ostertag, 2012).

5.2 Spatial Extent

In this field of design, information on the location and spatial extent of the respective research collaboration is presented. Geographical proximity can have a decisive influence on the performance of a research collaboration. Local and global designs of research collaboration have both advantages and disadvantages. Local partnerships promote the exchange of tacit knowledge and help reduce transaction costs due to physical, cultural, and institutional proximity. In this regard, physical proximity and regional partners can favour knowledge ties. In particular, collaboration among international partners can promote access to remote codified knowledge as well as flexible working models, provided that the partners involved gain access to different external knowledge pools, new culture, and new markets. Such relationships can lead to an increase in transaction costs as well as greater management control to avoid knowledge leakage that benefits external companies and competitors (Parrilli & Alcalde Heras, 2016).

5.3 Duration

This point concerns the planned duration of the research collaboration and the possibility of extending it. There are two types of partnerships: short-term and medium-to long-term. Short-term collaborations are useful, common and easy to facilitate (Perkmann & Salter, 2012), as they usually deal with experimental development or the development of business models (Stifterverband für die Deutsche Wissenschaft e. V., n.d.) or consist of “on-demand problem solutions” where the results are predefined and can be achieved quickly through contract research, consulting or licensing (Guimon, 2013). Medium- to long-term collaborations, on the other hand, are fundamental requirements for basic research (Stifterverband für die Deutsche Wissenschaft e.V., n.d.); Koschatzky, 2013a). These are more strategic and open and provide multiple platforms through which stronger innovation capabilities can develop over the long term (Guimon, 2013).

5.4 *Financing Model*

Another structural field of design is the type of financing or the financing model of the research collaboration. This includes the aspects of risk sharing and costs, especially access to government-funded research funds (Lang, 2013). For science in particular, collaboration with industry has become an indispensable part of funding (Rybnicek & Königsgruber, 2019), as industry often provides part of the funding for projects. In many cases, federal, state, and local authorities or universities are also involved as sponsors (Lee, 2000). There are various funding models involved, such as grant programmes, membership programmes, or core funding. These in turn influence governance structures, as the management and oversight levels must be staffed with the right representatives depending on the funding model (Hanebuth et al., 2015a, 2015b).

5.5 *Legal*

This field describes the legal form and contractual arrangements of the research collaboration. When choosing the legal form, it is important to bear in mind that this has a direct impact on important factors such as financing, decision-making, strategy development and collaboration partners (Hanebuth et al., 2015a, 2015b). Contracts must be concluded that also refer to and protect “intellectual property rights” (IPRs) in particular. Through such agreements, task and role allocations can be precisely defined, risks of later disputes minimised, and confidentiality or nondisclosure agreements made. At the same time, the achievement of objectives is verified, and confidence that each partner is fulfilling its responsibilities can be increased (Rybnicek & Königsgruber, 2019).

5.6 Organisation

The organisational structure plays an important role since the process of knowledge transfer is a complex task. A distinction can be made between whether the project is more centralised or decentralised and whether it is organised more formally or informally, which can have an impact on governance and organisational structures, among other things (Lang, 2013; Hanebuth et al., 2015a, 2015b). To ensure successful collaboration and the associated achievement of the set goals, project management is assigned a central role at the operational level. This is supported by the conscious introduction of repetitive processes and consistent standards. This enables routines in the innovation process and a planned approach, on the one hand to relieve the scientists and on the other hand to accelerate the joint progress in the collaboration. However, the moderate application and establishment of standards must not stand in the way of creativity (Hanebuth et al., 2015a, 2015b).

6 The Systemic Characteristics

The following systemic characteristics concern the overall system of research collaboration.

6.1 Motivation

Regarding how research collaborations come about, the motives—mostly empirically recorded—from collaboration research are of essential importance (Rotering, 1990; Lang, 2013). "The Merging of different approaches, objectives, and driving forces should constitute a fertile source for new ideas and innovations" (Autio et al., 1996). When industry and research institutions meet for collaborative projects or initiatives, one of the essential questions is how the different motives of a collaboration can be brought together profitably for both sides (Bayona et al., 2001; Rotering, 1990). Bringing together and continuously renewing and aligning the motives of the individual partners is an essential activity in initiating collaboration as well as for long-term sustainability. At the same time, however, it is also one of the most frequent reasons for the failure of collaborations (Specht et al., 2002). For research collaborations, it is difficult to perceive or even measure nonmonetary successes or not directly monetary successes. In particular, the epistemic benefits of research-industry collaborations are obvious and undisputed to everyone (Autio et al., 1996). However, are these advantages also used by the collaboration to achieve an economic or macroeconomic profit from it? How important are these motives for multilateral research formats?

For collaborations between research institutions and industry, it is assumed that conscious decisions are made to build the collaboration for an explicitly formulated goal (Ankrah & AL-Tabbaa, 2015). In a time of rapid development and high international competition, monetary success is mostly targeted as the main motivational goal (Rotering, 1990). Epistemic success is therefore not sufficient as a justification for an often costly or resource-intensive collaboration (Autio et al., 1996; Sydow, 2013).

6.2 Activities

After the establishment of a research collaboration, the relationship enters an operational phase (Ankrah & AL-Tabbaa, 2015) that can be described in terms of three elements: actors, activities, and resources (Andersson, 1998). These elements influence each other: actors carry out activities and control resources. Activities transform resources and are used by actors to achieve goals. Resources give actors power and enable activities (Ritter & Gemünden, 2003).

This chapter highlights various activities that can be used alone or in combination to achieve goals in research collaborations. These range from basic research to applied research and development. If possible, they culminate in concrete product or process innovations as part of the innovation process (Becker, 2003). The focus is on knowledge and technology transfer instruments, which represent activities between organisations that can be used to transfer technologies and knowledge (Meißner, 2001). Specifically, these can take the following forms (Tampe-Mai et al., 2011):

- Use of intellectual achievements (property rights, patents, know-how) between the participating organisations in the form of licences.
- Exchange of resources (tangible, intangible) via contractually regulated collaboration between the organisations. Databases or open innovation platforms may be used for this purpose.
- Personnel transfer for the temporary transfer of persons or knowledge carriers between the organisations.
- Scientific communication via presentations at events, such as trade fairs and congresses, or publishing in scientific journals.
- Training and continuing education through the awarding of internships or final theses.
- Project-based instruments such as contract research, in which one party provides the capital and the other the necessary expertise.

The intensity as well as the number of activities that occur in a research collaboration depends on the formality and complexity of the relationship (Ankrah & AL-Tabbaa, 2015). Regarding the categorisation of different activities, there are numerous proposals in the literature (Corsten, 1989), which can be applied depending on the purpose of the investigation. Often, subdivisions are made according to the form of collaboration between technology providers and technology takers (Walter, 2003). The activities can be grouped into five categories (Ankrah & AL-Tabbaa, 2015): Meeting and Networking, Communication, Training, Staff Mobility, and Gainful Employment. The concrete form of these activities is shown in Table 1.

Table 1 Activities in research collaborations

	Science	Industry	Coordination / Management
Access to the latest research	strong	strong	strong
Access to complementary resources	weak	strong	strong
Access to financial resources	strong	strong	strong
Access to complementary expertise	weak	strong	strong
Solving technical problems	strong	strong	strong
Recruitment of personnel	weak	weak	weak
Employment opportunities for university graduates / industry internship for students	weak	weak	weak
Sharing of development costs and risk reduction	weak	weak	weak
Possibility of applied research / application of theory	strong	strong	strong
Commercialization of inventions / licenses / patents	weak	strong	weak

■ strong ■ weak

Annotation Based on Ankrah & AL-Tabbaa (2015)

6.3 Success Factors

The success of a collaboration between partners from industry and science can be determined by a wide variety of influences. The success factors for classical science-business collaborations have already been investigated in many studies (Bruneel et al., 2010). Informal and cultural factors often play a more important role than formal rules (Koschatzky & Stahlecker, 2015). However, due to the differences in the organisational culture and structure (Ankrah & AL-Tabbaa, 2015) of the cooperating organisations, the collaboration requires considerable management effort to be successful (Barnes et al., 2002).

6.4 Performance Measurement

To achieve a comprehensive understanding of multilateral research collaborations and to be able to classify them adequately, the aspect of evaluation is crucial in addition to the consideration of motives, activities, and success factors. Although the topic of research collaboration between universities, industry, and nonuniversity institutions has increasingly come into focus as an area of study in recent years, there is a lack of tools to assess the outcomes and processes of such collaborations.

Since each research project is unique to the situation, performance measurement cannot rely on reference values (Perkmann et al., 2011; Lang, 2013; Bonaccorsi & Piccaluga, 1994). Consequently, the construction of evaluation models proves to be a complex task. On the one hand, it is necessary to measure both quantitative and qualitative criteria. On the other hand, this information should be collected from the perspective of all stakeholders at different organisational levels and at different points in time (Bonaccorsi & Piccaluga, 1994). The problem of measuring the performance of research collaborations is that their complexity and intangible nature make them difficult to grasp, and the results are usually not directly observable. This can be seen, for example, in the time lag of research activity and the resulting financial returns. Furthermore, it is often unclear where the results obtained will ultimately be used and which findings from previous projects have been incorporated. This makes it difficult to determine quantitative indicators and to make precise statements about the input and output of a research collaboration. Qualitative indicators, such as peer reviews, interviews, or surveys, are used for specific assessments but are very subjective. The evaluation criteria can be divided into four major groups: innovation-based metrics (e.g. patents filed, new products/processes), economic metrics (e.g. sales, number of employees), success (e.g. meeting expectations, project continuation), and barriers (e.g. problems with intellectual property rights regulation, different incentives). Last, it should be noted that the use of performance measurement can have a negative impact on the motivation and creativity of the actors involved in the research collaboration (Lang, 2013).

The following chapter presents the 22 use cases identified from whom seven were interviewed.

7 The Use Cases

See Fig. 4.

7.1 Practical Configuration of the 10 Characteristics of Research Collaborations

After introducing the ten theoretically based characteristics of research collaborations, the following chapter presents the results of the seven interviews with persons of the featured use cases. The results validate the ten characteristics and highlight their practical design.

7.1.1 Goal

All respondents stated that the goals of the research collaboration were defined at the beginning of the cooperation. Half of the respondents named concrete goals. However, these were defined in very general terms, such as strengthening the research location, guaranteeing sustainability, or enabling innovation.

7.1.2 Partners

The size of the research collaborations surveyed varies widely. They range from six to 101 partners. On average, the research collaborations surveyed have 38 partners. Among them are partly active and partly passive partners from science and industry. The partner structures are shown in Fig. 5.

More than half of the research collaborations surveyed were initiated by one of the partners from academia. The selection of partners was mostly done by the initiators at the time of foundation. Subsequently, in most cases, management/coordination takes over partner selection. The criteria for partner selection vary. For example, expertise, reputation and sustainable contribution to the success of the research collaboration are mentioned. However, the expansion of partners to fill gaps in the network (missing competencies, geographical gaps, missing areas) also plays a role. To broaden or deepen research content, new partners are integrated on an ongoing basis in 70% of the research collaborations surveyed.

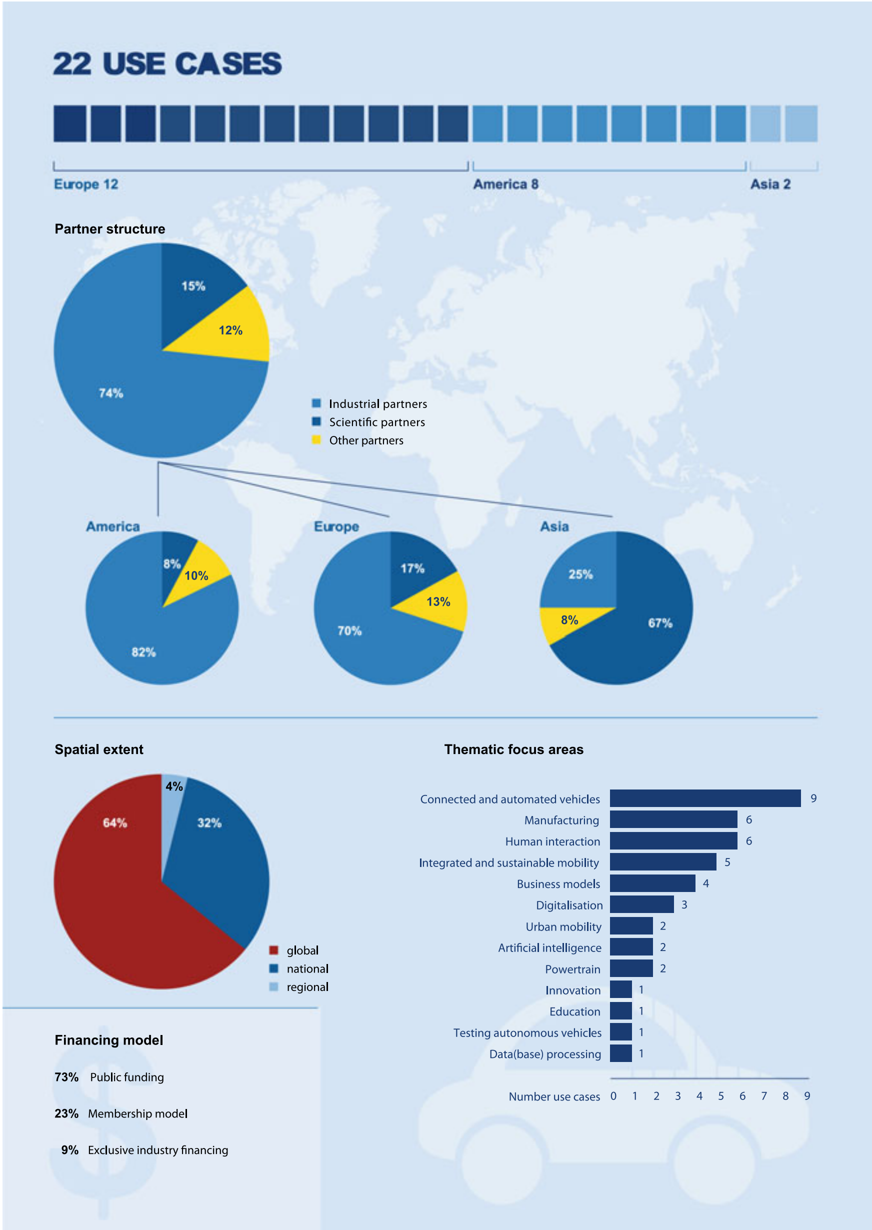
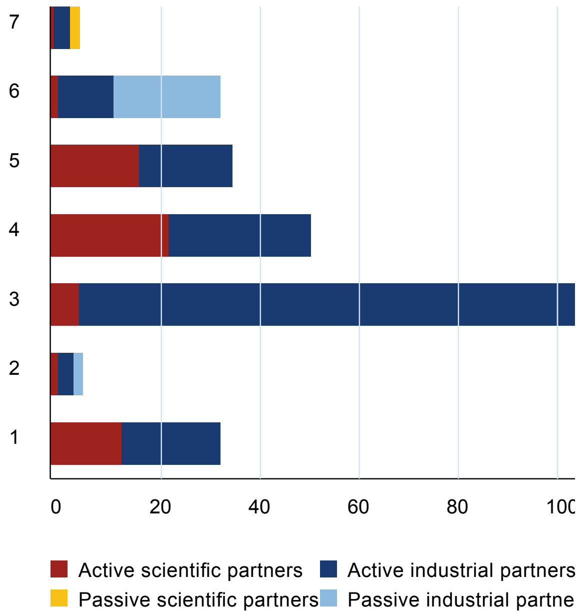


Fig. 4 Use cases

Fig. 5 Number of active and passive partners



7.1.3 Spatial Extent

None of the research collaborations surveyed have only one location. One research collaboration classifies itself as regional, two as national, and four research collaborations as global (Fig. 6).

7.1.4 Duration

The duration of the research collaborations surveyed varied from 1.5 to 15 years. The average collaboration duration is eight years. All but one research collaboration indicates that an extension is possible.

7.1.5 Financing Model

The funding models of the research collaboratives surveyed vary widely. Two of the research collaborations are financed exclusively by third-party funds—these are national funds or funds from the European Union. The third research collaboration finances its management through membership fees. The projects of this research collaboration are either publicly funded or industry funded. The fourth research collaboration is funded half by the government and half by private donors. In the fifth research collaboration, funding is made up of third-party funds as well as contributions from the project partners. The sixth research collaboration has multiple

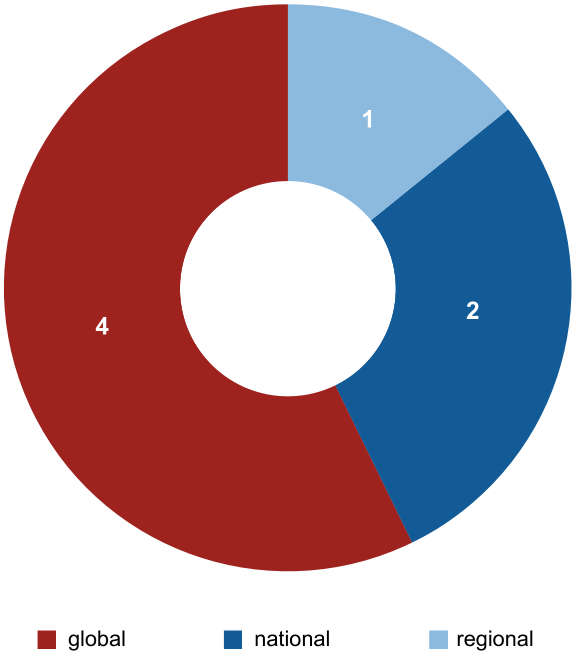


Fig. 6 Spatial extent of research collaborations

sources of funding—two from government funds, partner contributions, in-kind contributions, and revenue from facility operations. The seventh research collaboration follows Fraunhofer-Gesellschaft's funding model—approximately 30% base funding and approximately 70% through contracts from industry and publicly funded research projects.

EXCURSUS: Promotion and financing of research collaborations
Since the mid-1980s, a rapid increase in research collaborations between universities and industry can be observed (Bayona et al., 2001; Bonaccorsi & Piccaluga, 1994; Carayol, 2003; Faria et al., 2010). The establishment of such partnerships is equally in the interest of the players, as they offer great innovation potential (Koschatzky & Stahlecker, 2015), and in industries, the input of expertise can lead to greater innovative capacity and thus also increase competitiveness (Chi Kei Lam et al., 2012). Thus, various research institutions, forms and models of collaboration, and funding programmes have developed worldwide (Koschatzky & Stahlecker, 2015).

The Industry/University Cooperative Research Centres (I/UCRC) programme in the **U.S.** has existed since 1973 (National Science Foundation (Ed.), n.d.) and is one of the world's first and most enduring funding programmes aimed at developing long-term partnerships between academia, industry, and government. Except for the Office for Science and Technology, which does not have its own funds, the U.S. does not have its own departments for national research and development. The highly decentralised nature of the U.S. system means that funding programmes rely on a variety of funding sources, including government, membership dues, and small grants from foundations such as the National Science Foundation (NSF) (Koschatzky et al., 2015; Owen-Smith et al., 2002).

In **Latin America**, the picture is the opposite. There are very few collaborations between business and academia; in the last decade, the average percentage of collaborations in Latin American countries was less than one percent (Confraria & Vargas, 2019). A number of research centres were opened in Latin America between 1950 and 1980, but they tend to focus on key industries, such as coffee in Costa Rica, aviation and oil in Brazil, oil in Mexico, and agriculture in most countries (Confraria & Vargas, 2019; Dutrénit & Arza, 2010). **Brazil** is considered one of the biggest drivers of collaborations. In 1985, Brazil's government founded, among other programmes, the Ministry of Science and Technology (MCT), which, in collaboration and with the co-financing of the World Bank, established the Support Programme for Scientific and Technological Development (PADCT) (Machado Rezende, 2010) with a total budget of $360 million (World Bank Group, 2005). In the third phase (PADCT III), which was implemented between 1998 and 2002, 142 projects were supported (Passos et al., 2004).

In the **EU**, several funding programmes for national research collaborations have also been created. Funding tends to be centralised, and funds are managed at the national level (Owen-Smith et al., 2002). A distinction must be made between primary funders of a research collaboration, such as the European Commission, credit and development banks, foundations, international organisations, and secondary funders, which consist mainly of scientific organisations. Primary funders provide funding to secondary funders to support projects and collaborations of their choice (Hanebuth et al., 2015a, 2015b). One EU funding programme is the Horizon 2020 framework programme, which aims to build "a knowledge- and innovation-based society and a competitive economy across the EU" (Bundesministerium für Bildung & Forschung, 2019). The European Institute of Innovation and Technology (EIT), the Competitiveness and Innovation Framework Programme (CIP), and the continuation of the EU's Seventh Research Framework Programme (FP7) to further expand the European Research Area (ERA) are also related to this. The aim is to cover the entire innovation chain, from basic research to "fully developed products, services, and processes for the market and society" (Bundesministerium für Bildung & Forschung, 2019). Furthermore, this will create jobs and ensure sustainable development. For projects under Horizon 2020, the principle of co-financing applies, in which the European Commission bears part of the costs, while the project participants bear the other part of the costs (Bundesministerium für Bildung & Forschung, 2019).

In 2012, **Germany** established the funding initiative "Research Campus—Public—Private Partnership for Innovation" from the Federal Ministry of Education and Research (BMBF), which supports long-term collaboration between players from science and industry. The nine research campuses are each funded with two million euros per year, while the partners from science and industry make their own contributions, which are not necessarily monetary but can also take the form of the provision of personnel or infrastructure (BMBF, 2018). The research campuses are each designed to run for nine to 15 years. The aim is to bring together different players through spatial proximity, "research under one roof" (BMBF, 2017), bring together different actors and to draw skills, opportunities, and benefits from the collaboration (Koschatzky et al., 2015). In **Austria**, the "Competence Centres for Excellent Technologies" (COMET) programme is considered a showcase model of the Austrian innovation funding architecture in the "Cooperation between Science and Industry" field of action. It promotes the establishment of competence centres that focus on long-term high-quality research programmes. The models for this are the "Cooperative Research Centres" (CRC) in Australia, the "Competence Centres" in Sweden or the "Network Centres of Excellence" (NCE) in Canada. COMET is designed as a programme at the national level. The programme is owned by the Federal Ministry of Transport, Innovation and Technology (BMVIT) and the Federal Ministry of Education, Science and Research (BMWFW), while administration is handled by the Austrian Research Promotion Agency. The annual budget is 50 million euros, with additional funding from the federal states (Koschatzky et al., 2015). In **Sweden**, competence centres have been opened since the early 1990s. This involves bundling competencies or research activities in one place, preferably on university campuses or in research institutions. A total of 18 centres are supported by a binding public–private partnership and financed in four stages for a maximum of ten years. Funding will come equally from business and industry, while the government will provide an additional seven million euros percentre over a period of 20 years (Koschatzky et al., 2015).

"Catapult Centres" in the **UK** are another example of the ever-increasing popularity of research collaborations. Catapult Centres are networks comparable to research campuses in Germany but are not funded by the government, instead providing one-third funding supported by company-funded R&D contracts, collaboratively applied R&D projects funded by the public and private sectors, and public funding for long-term investment in infrastructure, expertise, and skills development. The Catapult Centres are considered separate legal entities, and each has its own board of directors and management (Catapult Network, 2021).

The Cooperative Research Centre (CRC) in **Australia** has been in existence since 1990 and focuses on increasing research collaboration by concentrating research activities in one location or through effective methods of networking, promoting research training, and the economic and social benefits of research. Role models include the Catapult Centres in the UK, the NCE in Canada or the Fraunhofer-Gesellschaft. However, the CRCs do not focus on collaboration between science and industry but rather on private organisations or public institutions that are able to apply the transfer of research results. The Ministry of Industry and Science is responsible for administration, as there is no project management agency. In principle, CRCs are designed for a long-term period of five to ten years with the possibility of triple extension, similar to research campuses. However, partners do not have to commit to participation or financial support for the entire funding period (Koschatzky et al., 2015).

After **China's** trade policy changed in the late 1970s, topics such as technology and innovation also came into focus. In the process, national strategic goals were set, and collaboration between companies and academia in the area of research and development became indispensable. By sharing the costs, companies were able to generate benefits (Fiaz, 2013). In 1992, the policy-oriented “University-Industry Alliances on Collaborative Development Engineering” was established by the former State National Economic and Trade Committee, the Ministry of Education of China (MOE) and the China Academy of Science (CAS) (Chen et al., 2012). In the mid-1990s to mid-2000s, major institutional reforms were undertaken in **Japan** to promote collaborations between academia and industry, which did not take hold until 2010 due to the growing popularity of “open innovation”. In the process, a new form of U-I collaboration developed, in which collaborations were set to be larger and more long-term than before (Kuwashima, 2018).

Due to the increasing importance of research collaboration, it will become increasingly important in the future to allow exchanges to take place transnationally. European governments have been supporting **transnational research collaboration** between companies, universities, and other research institutions since 1984 with the help of the “European Framework Programmes” (FWPs) (Caloghirou et al., 2001). The German Federal Ministry of Education and Research (BMBF), for example, promotes joint research projects and networks, particularly in the Asia–Pacific region, since this is one of the largest and most important research areas alongside Europe and North America. The BMBF (2017a) provided 6.25 million euros for the two-year start-up phase until 2019. The European Research Area network (ERA), for example, offers good conditions for implementing transnational collaborations in the European region and is also funded by the BMBF (n.d.)

7.1.6 Legal

The research collaborations interviewed illustrate the importance of contractual arrangements in collaborations. All seven research collaborations interviewed state that they have established contractual regulations that include, for example, confidentiality declarations or IP regulations. Three of the research collaborations surveyed choose an association structure as their legal form, one is a separate company, one collaboration states that it is a programme of a research institute, and two do not specify the legal form of their research collaboration.

7.1.7 Organisation

The survey of research collaborations also confirmed the relevance of project coordination. Six out of seven respondents stated that their research collaboration had its own management, and only one research collaboration did not have its own management.

7.1.8 Motivation

Within the scope of our study, the respondents evaluated different motives. Accordingly, the factors with the greatest influence on an organisation's motivation to enter a multilateral research collaboration are as follows:

- Access to the latest research results
- Access to financial resources
- Solution of technical problems
- Possibility of applied research/application of theory.

The factors with the smallest influence on an organisation's motivation to enter a research collaboration are as follows:

- Recruitment of personnel
- Employment opportunities for alumni/industry internship for students
- Sharing of development costs and risk.

The factors influencing an organisation's motivation to enter a research collaboration are shown in Table 2. A distinction is made between science, industry, and coordination/management.

Table 2 Influence on the motivation of multilateral research collaborations

Meetings and Networking	Meetings
	Conferences / Workshops / Seminars
	Exhibitions / Fairs
	Networking activities
Communication	Communications by voice / post / mail / conference calls (formal or informal)
	Publications or co-publications of research papers, reports, newsletters, brochures
Training	Tailored educational programs for industrial personnel
	Internships in companies for students
	Students' involvement in industrial projects
	Joint supervision of master's theses and dissertations by academic and industrial personnel
	Industrial fellowships for students and faculty
	Industry involvement in curriculum development
Personnel mobility	Exchange of personnel to work at another's research facilities
	Lectures by industry members at universities and vice versa
Employment	Employment of university researchers in industry
	Employment of graduates
	Representation on industry committees or university committees

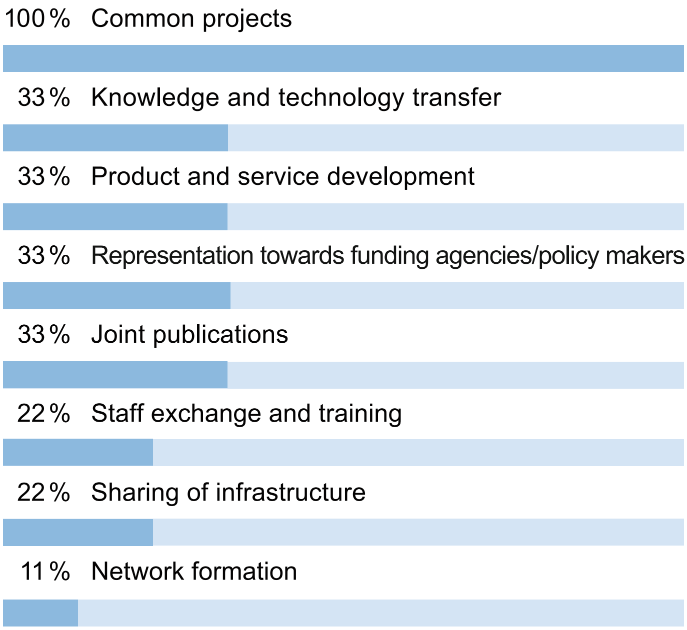


Fig. 7 The main activities of multilateral research collaborations

7.1.9 Activities

Our study asked about the three main activities of multilateral research collaborations.[1] The frequency with which the main activities were mentioned is shown in Fig. 7.

All respondents mention "common projects" as one of the main activities of their research collaboration. The mentions range from the implementation of joint projects to the development of standards and the generation of new research projects. While there was a high degree of unanimity in regard to naming "joint projects", the other main activities are clearly differentiated. Since all respondents name joint projects as one of the main activities of their research collaboration, it can be assumed that multilateral research collaborations are always formed with the goal of joint projects.

7.1.10 Success Factors

In this regard, it is to be validated whether the described success factors also apply to multilateral research collaborations. Looking at the research collaborations surveyed,

[1] The survey was conducted as an open-ended question without a set answer and without prioritisation.

it is striking that almost all collaborations have their own management. The considerable management effort was thus recognised. The number of people working in management varies greatly and ranges from 1.5 to ten full-time equivalents.

As part of our study, respondents rated the influence of various factors on the success of their research collaboration. The evaluation of the success factors is shown in Table 3.

The only factor that was rated as inhibiting by all respondents is “Opposing interests”. Some of the queried influencing factors were rated differently, i.e. these were rated as promoting by some and as inhibiting by others. In some cases, it was also stated that these factors had no influence. The factor “right to publish of the academic partner” stands out in particular. The respondents from academia rate this factor as conducive. The respondents from business, on the other hand, rate it as

Table 3 Success factors

	Science	Industry	Coordination / Management
Experience with collaborations	conducive	conducive	conducive
Suitability of partners (topics, people, motives, goals)	conducive	conducive	conducive
Trustful interaction	conducive	conducive	conducive
Technical competence	conducive	conducive	conducive
Different level of knowledge of the partners	conducive	no influence	inhibiting
Opposing interests	inhibiting	inhibiting	inhibiting
Existence of financial resources / personnel of the partners for the collaboration	conducive	no influence	conducive
Regulation of Intellectual Property Rights	conducive	no influence	no influence
Differences in organisational culture	conducive	no influence	no influence
Differences in organisational structure	inhibiting	conducive	no influence
Clear problem definition	conducive	conducive	conducive
Realistic goals	conducive	conducive	conducive
Acceptance of collaboration in the respective organisation	conducive	conducive	no influence
Continuity of personnel	conducive	no influence	no influence
Geographical proximity	conducive	conducive	no influence
Effective communication	conducive	conducive	no influence
Experienced project management	conducive	conducive	no influence
Right to publish of the academic partner	conducive	inhibiting	no influence
Independence through partner diversity	conducive	no influence	conducive
Evaluation	conducive	conducive	no influence
Political funding programmes	conducive	no influence	conducive

no influence conducive inhibiting

inhibiting. Respondents from management/coordination indicate that this factor has no influence.

Overall, many factors were rated as conducive by respondents from all three views. The following factors were rated as particularly conducive to the success of a multilateral research collaboration:

- Experience with collaborations
- Suitability of partners (topics, people, motives, goals)
- Trustful interaction
- Technical competence
- Clear problem definition
- Realistic goals.

In addition, the survey asked about the factors that contribute most to the success of the research collaboration. The following factors were mentioned in this regard: common project goals, communication, openness, trust, commitment of partners, motivation, common vision, heterogeneous partnerships (e.g. from different countries, preferably one actor each from the knowledge triangle: science, business, politics), good mix of competent partners, understanding of the customer's wishes, a common building with a management located there, and financial clearances.

In addition, the participants were asked about the factors and framework conditions that are missing to make their own research collaboration (even) more successful. Named were clearly defined and transparent communication of interests, coordinated focus on selected topics within the budget, marketing, longer duration of the collaboration, greater budget freedom (enabling "moonshot" activities), greater diversity of partners, management structure in the scientific area, clarification of IP rights, uniform financing models, thematic focus/sharpening of one's own profile, and improvement of project management skills (especially on the scientific side).

7.1.11 Performance Measurement

As part of our study, we examined whether the research collaborations surveyed used performance measurements. In addition, if so, on what basis and according to what criteria is this evaluation carried out?

A review of the collaboration's achievement of objectives is conducted at regular intervals for all respondents. In this context, the review is carried out through the following measures:

- Regular meetings
- Continuous documentation, e.g. regular progress reports
- Continuous development of the joint project plan
- Evaluation by external parties and industry partners.

All respondents stated that the review of target achievement is associated with consequences. The following consequences were mentioned in the case of nonachievement:

- Course correction/refocusing
- Cancellation/discontinuation of funding
- (possible) end of the project.

Regarding the evaluation of the success of the research collaboration, the respondents named various criteria. Publications were named the basis in most cases, followed by the amount of project funds raised, the personnel effort, the visibility of the project, and the commitment to the community.

8 Conclusion and Outlook

Due to the high level of technical complexity and the resulting high degree of interdisciplinarity and transdisciplinarity, increasingly high demands are being placed on collaborations between science and industry. The resulting high complexity of these collaborations is synonymous with a high management effort, which can be provided by collaborative structures. In the present study, therefore, a framework was developed in which multilateral collaborations between science and industry can be mapped in ten defined characteristics. The ten characteristics are intended to provide indications of which levers exist for successful research collaboration and how these can be designed. The ten characteristics were analysed and researched in an initial brief study.

The characteristics are divided into six structural and four systemic characteristics. In the case of the structural characteristics, there are major differences between the research collaborations studied.

The number and structure of **partners** varies. In terms of **spatial classification** and **duration** of research collaboration, the research collaborations studied vary widely. The same applies to the **financing model** and the **legal form**. However, there is agreement on the importance of **contractual regulations** for collaboration and the necessity of a project coordinator or collaboration management. In the systemic field of design of collaboration **motives**, factors were found that have a major influence on the motivation to enter a research collaboration, both for the science partners and for the business partners. In the field of design of **activities**, it was found that joint projects are the main activity of multilateral research collaborations. It can be assumed that these serve as the main goal of initiating a collaboration. At the same time, the statements on other activities differ significantly. In the field of design of **success factors**, some factors were identified that are conducive to the success of research collaborations from both a scientific and a business perspective. However, some factors are rated as beneficial by one side and as inhibiting by the other. In the **evaluation** field, it became clear that defined goals should always serve as the basis for collaboration.

The review of the achievement of objectives and the corresponding consequences are also very different and leave further questions open. **Limitations** exists regarding to performance measurement, as no holistic approach is apparent. Instead, individual criteria are used as a basis for evaluation, such as joint publications.

Basically, it should be noted, that initial indications for the design of the individual characteristics of the developed framework could be identified. However, no concrete statements can yet be made about the interpretation of the results, interdependencies between the characteristics, their levers and partner constellations, or the effects of the characteristics of individual factors within the characteristics. Likewise, some answers indicate that many levers within the characteristics are not yet known. Those control levers that are contrary to the literature in our study need to be analysed in more depth.

In view of the diversity of research partners and the complexity of technical innovation goals, these questions also need to be explored on a case-specific basis. Whether innovation- and partner-specific patterns can be identified needs to be examined. These statements, which have been missing thus far, would be essential to measure and scientifically evaluate the innovative power of research collaborations and to be able to promote them accordingly in a partner- and innovation-specific manner.

The **implication for practise** of applying the characteristics on science-industry collaborations are manyfold. Considering the identified characteristics for collaboration can enhance the efficiency and effectiveness of the innovation process. It can facilitate the creation of new products, processes, services, and business models that meet the needs of the market and generate economic and societal impact.

Thus, it can help to bridge the gap between fundamental research and practical application and foster a culture of innovation and continuous improvement, where both parties are committed to exploring new ideas, solving complex problems, and generating value.

For **research policy** the benefits of implementing our characteristics in the collaboration between industry and science are also meaningful. Good collaboration practise can be used by research policy for highlighting key drivers and barriers of effective collaboration, and thus providing guidance on how to design and implement policies that support successful collaborations.

The identification and implementation of characteristics in setting-up collaboration between industry and science can contribute to the development of research policies that promote knowledge transfer, open innovation, and collaborative research, leading to increased research impact and societal relevance of scientific research.

Furthermore, using the characteristics for collaboration setting facilitates the transfer of knowledge and technology between academia and industry, leading to the creation of new research opportunities and even collaborations.

In conclusion, it can be said that initial findings have been obtained from the present study. However, there is still a need for further research on the clarity of research collaborations to answer the above-mentioned open questions through further research activities. The present study contributes to approaching the subject of multilateral research collaborations and can be considered the basis for further, more conclusive research that aims to reach data saturation on that topic.

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Universities and Regional Innovation in the Central- and Eastern European Context—A Hungarian Case

Katalin Erdős and Zsolt Bedő

Abstract Universities became inevitable actors in regional innovation in the past almost half a century. On the one hand, they are an important source of knowledge that led to success stories both in technological and geographic sense. On the other hand, significant differences have been observed in the capacities and capabilities of universities to transfer their knowledge into wealth generating products and services, and to enhance the advancement of their region. One of the relatively recent policy concepts that strongly relies on universities' contribution is the regional innovation strategy for smart specialization (RIS3) that aims to spur the development of regions from the highly lagging to the most advanced ones. One of the central elements of the concept is the entrepreneurial discovery process that immanently necessitates the presence of an entrepreneurial mindset and culture in the region. Consequently, in our view one of the most important of the many contributions of universities to the design and implementation of RIS3 is the creation of an entrepreneurial ecosystem that supports entrepreneurial thinking and acting within the region. In this chapter, we applied the university centered entrepreneurial ecosystem approach for a large, comprehensive university in a lagging region to analyze the role that the university can play in smart specialization by developing an entrepreneurial mindset and ecosystem. We found that the elements of the puzzle are on the table, but owing to the insufficient connection of the elements there is a suboptimal outcome of the ecosystem. Areas for improvement are also addressed.

Keywords University centered entrepreneurial ecosystem · Universities and regional innovation · Smart specialization · Entrepreneurial university

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1 Introduction

Smart specialization rapidly became a central element of the European Union's cohesion policy. Universities are seen to be key actors in the development and implementation of smart specialization strategies. They are important sources of knowledge and technology, providers of consultancy and contributors to regional governance, and not least they can be seedbeds of entrepreneurial thinking and acting. The smart specialization related communication suggests that the conceptual framework of the contribution of universities to regional development through smart specialization can be described by the quadruple helix model that is an enhancement of the triple helix's academia-business-government helices with the civil society (Foray et al., 2012). This underpins the importance of developing an entrepreneurial mindset within and outside the walls of the university. Though universities are especially important actors in the smart transformation of lagging regions where in general the resources are limited, the level of internationalization is low, and entrepreneurial skills are insufficient, the application of the quadruple helix is not self-evident.

In some of these regions of the Central and Eastern European countries, there is a lack of good cooperation practices of the three helices, thus the involvement of the civil society in a manner suggested by the quadruple helix is even less pronounced. The causes of this are rooted in the historical development of the scientific organizational and economic systems of these countries that severely limited the unfolding of the entrepreneurial potential. Our case, the University of Pécs is located in South Transdanubia that is one of the least developed regions of the European Union. The economy of the region still did not fully recover from the shock caused by the collapse of mining, agriculture, and many industrial sectors after the political system change in 1989/90.

Though the University of Pécs is the oldest and one of the largest universities in Hungary, the transfer of knowledge and technology generated still does not support sufficiently the economic development of the region. It can be owed to many factors that range from the low level of entrepreneurial skills and negative entrepreneurial attitude both within and outside of the university to the lack of related legal, economic, and infrastructural elements. This chapter focuses on the role of universities in enhancing entrepreneurial thinking and activity that are important triggers of the knowledge spillover from the university to the actors of the region, which is the fundamental building block of successful smart specialization. To tackle this highly contextual nature of the entrepreneurial university in lagging regions, we applied an entrepreneurial ecosystem approach that in our view is an appropriate concept to operationalize the factors that are required to investigate the entrepreneurial university in a holistic way. We argue, in line with Qian (2018) that for the regional development that is the result of smart specialization to emerge the knowledge spillover mechanism must function efficiently. The functioning of such mechanism is the consequence of the knowledge spillover entrepreneurship (Acs & Armington, 2006; Acs & Plummer, 2005; Acs et al., 2009; Audretsch & Keilbach, 2008; Audretsch & Lehmann, 2005; Audretsch et al., 2006; Qian et al., 2013). Knowledge spillover entrepreneurship can only emerge if the local context is supportive of such activity, which makes the local entrepreneurship ecosystem a crucial component to be studied and to be understood. In a university town, where the knowledge is generated within the university, the role of the university is critical to be taken into consideration when assessing the local entrepreneurial ecosystem.

The chapter is structured as follows. The second part provides an overview of the smart specialization and the entrepreneurial university, respectively their relationship. The third part introduces the conceptual framework that can be applied to analyze the entrepreneurial university through an entrepreneurial ecosystem approach that encompasses framework and systemic conditions. Part four analyses the development of entrepreneurial spirit within the university-based entrepreneurial ecosystem approach. Conclusion closes the chapter.

2 Smart Specialization and the Entrepreneurial University

Smart specialization is a regional policy framework that aims to enhance innovation-driven growth (OECD, 2012) by supporting prioritization of innovation policy aims (McCann & Ortega-Argilés, 2013). It became a central element of the cohesion policy in the EU (McCann & Ortega-Argilés, 2015) "[…]despite a frail theoretical background and implementation difficulties" that are even more striking in case of less developed regions (Krammer, 2017, p. 95). Smart specialization is not entirely new in the sense that many of its approaches have already been present in the policy domain. However, it has some important distinguishing features, like the suggestion that lagging regions should focus on the development of co-applications of Key Enabling Technologies and General Purpose Technologies, rather than trying to target leadership directly in these areas (OECD, 2012). However, the most important novelty is maybe related to the role of entrepreneurship (McCann & Ortega-Argilés, 2015) in form of the so-called entrepreneurial process of discovery. The entrepreneurial process of discovery targets the identification of promising research and innovation domains where the regions have a chance to excel (Foray et al., 2009).

The entrepreneurial discovery process requires thorough knowledge of the local context, thus the participation of various local and regional stakeholders can provide the best outcome. Even if there can be many obstacles to be overcome, universities can be especially important actors in case of lagging regions where the private sector has a limited research and development potential (Foray et al., 2012; Goddard & Kempton, 2011).

The contribution of universities to smart specialization can take multiple forms. Goddard and Kempton (2011) highlight four key areas where universities can contribute to regional development: research and innovation, enterprise and business development, human capital development and enhancing social equality. They also emphasize that to generate the highest impact universities should be involved in activities that are rather transformational than transactional in their nature. Goddard and Kempton (2011) argue that to achieve the highest possible outcome, innovation should be broadly interpreted to acknowledge the role that, e.g., social sciences can play in the field of regional entrepreneurship. They also highlight the importance of establishing diverse partnerships between the stakeholders of the region that are sustainable on the long-run. This requires specific organizational structures on the side of universities that might be well described by the entrepreneurial university model. Though there is not a generally accepted definition of the entrepreneurial university, the different approaches have some common features. Most of the concepts mention that knowledge generated at institutions becomes increasingly commodified, thus typical forms of technology transfer include patenting, licensing, and spin-off activity through the support of intermediary organizations like, e.g., technology transfer offices (Clark, 1998; Gulbrandsen & Slipersæter, 2007; Rothaermel et al., 2007; Yusof & Jain, 2010). It is also important that the institution is full of entrepreneurial spirit (Clark, 1998; Yusof & Jain, 2010). Goldstein, (2010) argues that "[…] although many versions of the idea of the entrepreneurial university have been put forth, the triple helix model is perhaps the most well-articulated and best historically grounded in the evolution of the university and the requirements of the knowledge-based economy" (p. 88).

The triple helix can be best understood by the developmental mechanisms and evolving structures in the university (Etzkowitz et al., 2000). "The entrepreneurial university rests of four pillars:

1. academic leadership able to formulate and implement a strategic vision;
2. legal control over academic recourses, including physical property such as university buildings and intellectual property emanating from research;
3. organizational capacity to transfer technology through patenting, licensing, and incubation; and
4. an entrepreneurial ethos among administrators, faculty and students". (Etzkowitz, 2008, p. 28).

Etzkowitz summarizes the norms that can support the entrepreneurial turn of universities; capitalization, interdependence, independence, hybridization, and reflexivity (Etzkowitz, 2008). Following his argumentation, an entrepreneurial university creates knowledge that has a double role by serving scientific advancement and entailing practical use simultaneously. It is an institution that maintains a balance between being an independent actor that closely cooperates with the government and the business spheres through hybrid organizations and continuously revises its relationship with them and implements internal structural changes if needed.

Though the triple helix is a well-elaborated model for the entrepreneurial university, there some argue that to unfold full potential for smart specialization the quadruple helix concept is more appropriate (Foray et al., 2012). It is the extension of the already introduced triple helix with a fourth sphere, the civil society that can be interpreted as media- and culture-based public (Carayannis & Campbell, 2012). Despite the existing differences in the interpretation of the fourth sphere, "most of the QH approaches focus innovation generated by citizens" (Cavallini et al., 2016, p. 15). Appropriate mechanisms, like, e.g., crowdfunding can support the unfolding

Table 1 Transition zones between triple helix, quadruple helix, and living lab concepts

	Quadruple helix university	Living lab
Triple helix university	Knowledge and research commercialization	
Quadruple helix university		Co-creation Open innovation Sustainability

of the full potential of users who are at the center of the innovation process as drivers and owners of it (Carayannis & Grigoroudis, 2016).

Once considering the quadruple helix and the contribution of citizens to innovation one inevitably needs to discuss the concept of living labs that are described by the website of the European Network of Living Labs as "real-life test and experimentation environments that foster co-creation and open innovation among the main actors of the Quadruple Helix Model".[1] Skiba et al. (2012, p. 2) argue that "Even if literature is full of Living Lab definitions […] we can note that basically a Living Lab approach is defined by three main characteristics:

- Uses analysis and integration in the design process: to make the concepts more relevant;
- Collaborative work: to maximize points of view, share knowledge, generate new ideas;
- Experimentation in real-life context: to reduce the difference between anticipated uses and real uses".

Based on an extensive literature review, Hossain et al., (2019, p. 981) found that the key characteristical elements of living labs are real-life environments, stakeholders, activities, business models and networks, challenges, outcomes, and sustainability. They conclude that diverse stakeholders and users contribute to the societal development of urban areas through their co-creation activities.

Bergvall-Kareborn and Stahlbrost (2009) argue that the general framework of the living lab ensures stability, while the hosted projects enable spontaneity and make the lab living. They also highlight based on empirical analysis of technology related project, that one of the biggest challenges for success is related to one of the composition of partnerships. It was found to be difficult to create partnerships that are stable and flexible and also achieving real engagement of actors, like municipalities can be challenging.

The above described approaches can all contribute to the understanding of the role of universities in regional development through smart specialization. The identification of transition zones (Table 1) can support the better conceptualization of the research as it was demonstrated, e.g., by Dekkers et al. (2020) for supply chain and finance integration.

[1] https://enoll.org/about-us/ (Accessed: 31.05.2023).

3 Conceptual Framework

The entrepreneurial nature of a university in our view cannot be evaluated by looking at isolated, standalone institutional elements, activities within the institution rather the institution should be assessed in a holistic, complex manner and in interactions with its environment. This argumentation is well supported by Lockett et al. (2014) who document the evolution of academic entrepreneurship starting from the establishment of the first tech transfer offices (TTOs) at universities. Furthermore Fetters et al. (2010) collect multiple case studies on activities at different universities, which are designed and operated to enhance the entrepreneurial capacity of multiple stakeholders of the university, along with researchers, who were the sole subject of such activity in the '80s and '90s. These cases show that curriculum, co-curriculum and extra-curricular activities, to name a few, are all parts of the capacity building process and that these programs and activities complement the traditional function of the TTOs.

Siegel and Wright (2015) raise the issue of rethinking academic entrepreneurship while reviewing the literature and pieces of evidence that point to the direction of a more holistic, more comprehensive approach in evaluating universities in this respect. They argue that in the area of the traditional perspective, the issue was narrowly scaled down to the activities of faculty members of the university, their outputs and the institutional units, elements that supported their efforts. In the emerging perspective researchers and lecturers were joined by students and other citizens of the university along with outside stakeholders of the higher education institution (HEI). Outcomes of the activity were broadened from the "potentially lucrative 'block-buster' patent licensing deals" (Siegel & Wright, 2015, p. 582) to student and alumni initiated startups. The role of the HEI in the local environment was rethought as well from solely generating a financial return for the institution to social value creation for the members of the regional socio-economic environment. This new direction in the role of the universities in a particular location requires a better understanding of entrepreneurship as a mechanism for transmitting knowledge spillovers to boost knowledge-based regional economic development (Qian, 2018).

The characteristic of the entrepreneurial activity to facilitate knowledge spillover in a particular geographical location is dependent on multiple factors that can be aggregated under the category of entrepreneurial environment. To explain and to evaluate this entrepreneurial environment we base our conceptual framework on the currently popular concept of entrepreneurial ecosystem (EE) and follow the lead set by Fetters et al. (2010) by positioning the university in the center of the ecosystem, consequently naming our conceptual approach university centered entrepreneurial ecosystem (UCEE).

The notion of entrepreneurial ecosystem emerged from the work of Isenberg (2010) and has been adopted by scholars to explain the contribution of the entrepreneurial activity in a particular location to regional growth (Acs et al., 2014; Feld, 2012; Foster et al., 2013; Spigel, 2017; Stam, 2015). Supranational forums and organizations have also been using the concept to orientate policymakers toward the creation and the support of entrepreneurship friendly environments. Appreciating the work of all contributors of the theoretical construct we base our UCEE on the work and definition of Spigel and Stam. Spigel (2017) distinguishes between cultural, social, and material attributes that include different dimensions that shape the ecosystem and determine its sustainability. He argues that the EE is constructed of three layers of attributes that interact with each other making the structure and the specificity of the EE continuously evolving. He defined EE as "…the union of localized cultural outlooks, social networks, investment capital, universities and active economic policies that creates environments of supportive of innovation-based ventures". (Spigel, 2017, p. 49).

Stam's definition is more general but adds to that of Spigel by introducing the term "productive entrepreneurship": "…the entrepreneurial ecosystem as a set of interdependent actors and factors coordinated in such a way that they enable productive entrepreneurship". (Stam, 2015). This feature of Stam's definition is important because it highlights the significance of the individual with value creation capabilities within the ecosystem, who creates value for herself and the community as well by "creating the ecosystem and keeping it healthy" (Stam, 2015, p. 1.) This reciprocity is also explicit in the original definition of productive entrepreneurship proposed by Baumol (1990): "…any entrepreneurial activity that contributes directly or indirectly to net output of the economy or to the capacity to produce additional output" (Baumol, 1990 p. 30). Both Stam's definition of the EE and Baumol's definition of productive entrepreneurship stresses the significance of value creation of the entrepreneurial activity, which must not be narrowed down to the generation of financial return solely. The outcome of a vibrant entrepreneurial activity is a socio-economic environment that is capable of creating jobs, generating economic growth through mobilizing local resources via creating unique, innovative solutions that enhance living standards in that particular location and also competitive in the global market. This argumentation is in line with the view of Spigel as well: "…successful ecosystems are not defined by high rates of entrepreneurship but rather how the interaction between these attributes creates a supportive regional environment that increases the competitiveness of new ventures". (Spigel, 2017, p. 50).

To evaluate the "vibrancy" of the EE we apply the metrics suggested by Bell-Masterson and Stangler, (2015). The quality of the entrepreneurial activity within an EE according to the authors is the function of the entrepreneurial vibrancy measured by the density, fluidity, connectivity and diversity of the ecosystem (Bell-Masterson & Stangler, 2015). In Stam's framework, entrepreneurial activity is the direct outcome of the functioning of the EE (see Fig. 1). The performance metrics of the EE is as follows:

- Density: density of new and young firms, share of employment in new and young firms, and high-tech (or your preferred sector) density.
- Fluidity: population flux, labor market reallocation, and number of high-growth firms. "One of the principal resources that entrepreneurs need is people, and population flux should provide a mixing and remixing of people, strengthening entrepreneurial bricolage". (Bell-Masterson & Stangler, 2015, p. 4).

- Connectivity: program connectivity, spin-off rates, and dealmaker networks.
- Diversity: economic diversification (multiple economic specializations), immigration, and income mobility.

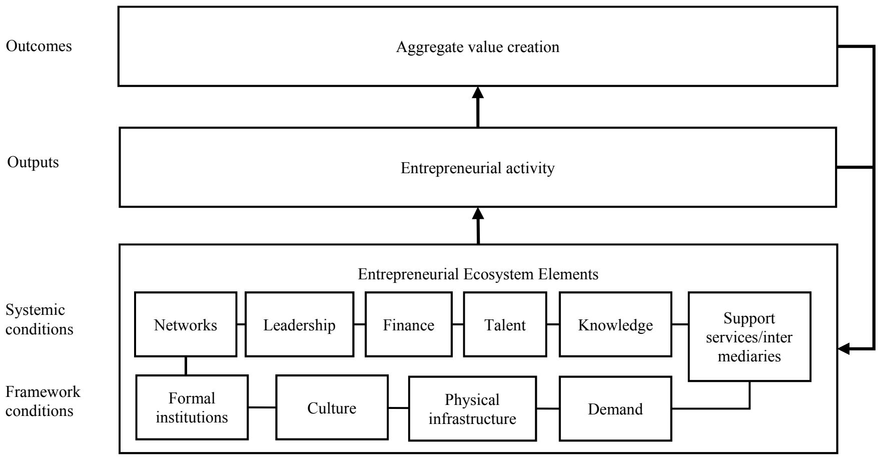

Fig. 1 Key elements, outputs and outcomes of the entrepreneurial ecosystem (Stam, 2015). *Source* Stam (2015, p. 1765)

Stam's (2015) concept consists of three layers that feed into each other in both an upward and a downward direction. Framework and systemic conditions enable entrepreneurship activity to emerge, which will transform socio-economic conditions, settings by creating value. Both the value creation outcome of the functioning of the ecosystem and the outputs of the entrepreneurial activity will feed back into and will trigger certain transformations in the elements of the framework and systemic conditions, which might stimulate higher entrepreneurial activity for further value creation.

According to Stam (2015) one of the most important outputs of the well-functioning ecosystem is the innovative entrepreneur behind the productive entity that can be considered as a contributor to productive entrepreneurship. Besides job creation in the domain of the productive entrepreneur emergence of innovative ventures can also be an intermediary output of the system. The enhanced entrepreneurial and innovative capacity of the individuals within the ecosystem will strongly contribute to value creation on the level of society that is difficult to quantify but an important feedback loop into the entrepreneurial culture among the framework conditions.

Among the framework conditions we find formal and informal institutions, entrepreneurial culture, physical infrastructure that facilitates entrepreneurs and the demand for the product and services of the new entrepreneurial initiatives. The demand element is important not only for the realization of the actual transaction between producer and buyer, service provider and client, but actors on the demand side can support the entrepreneur in the development process with valuable validation feedback about the new product or service.

Elements of the systemic conditions are called the "heart of the ecosystem". In line with his argumentation, we stress that these elements determine vibrancy in the ecosystem that is one of the sources of co-learning and co-creation. Networks trigger the informal flow of resources within the ecosystem among which we find labor and capital, two of the most important resources of the entrepreneurial evolutionary process. Leadership provides direction to the members of the ecosystem and also gives inspiration to those who are at the beginning of this journey. Leaders are not formal, appointed leaders but successful entrepreneurs who serve as role model for others. Finance is the source of funding of all level, FFF, angel investors, private equity, and VCs. Crowdfunding can also be mentioned here, keeping in mind that it also serves other purposes in the development process. Knowledge and experience in a particular segment of the market generate a competence focus or specialization within the ecosystem. Support services and intermediaries are the enablers of entrepreneurial individuals to go through the development process as time efficiently as possible.

While the EE concept outlined by Stam (2015) is a useful and applicable framework to understand the drivers of entrepreneurial activity in a geographical location to generate knowledge spillover and as a result economic growth it needs to be transformed to mimic the characteristics of a university. The need to transform the general EE to a more specific UCEE is supported by Carlsson et al. (2009) who argued that there are organizational and institutional barriers to the realization of the market value of new knowledge, which applies particularly to the knowledge created in universities (Qian & Yao, 2017).

Figure 2 illustrates the UCEE based on the concept of Stam (2015) that we will discuss in the following section.

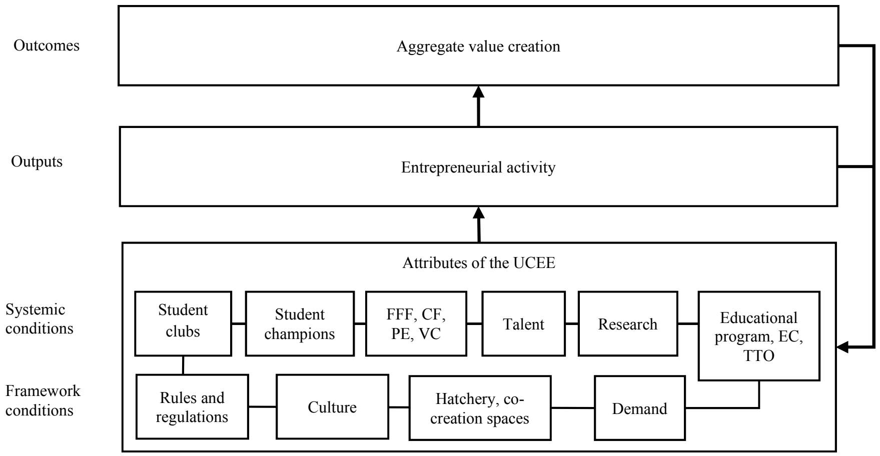

Fig. 2 Key elements, outputs and outcomes of the UCEE. *Source* Based on Stam (2015)

3.1 Rules and Regulations

In the UCEE concept among the framework conditions the first attribute is the "Rules and regulations" attribute. This includes institutional strategy and structure that have an effect on "key criteria including: educational impact, financial sustainability, academic credibility, human capital, structural embeddedness, context and infrastructure, alignment with institutional strategy and policy, community engagement, and alignment with policy context and funding" (Pittaway & Hannon, 2008, p. 202). Among the many criteria, one that we will be discussing in the empirical section of this work is the structural embeddedness of the entrepreneurship center within the university, which is responsible for stimulating entrepreneurial initiatives, actions and interaction among the citizens of the university, and cooperation among the different units of the university.

According to Pittaway and Hannon (2008), the entrepreneurship center (EC) can be embedded into the university's organizational structure differently according to the stage of development of the entrepreneurial initiative of the institution.

3.2 Culture

In terms of culture, we rely on the definition of Hofstede (2001), who views culture as a "collective programming of the mind" (p. 1). In terms of entrepreneurial culture this implies among others values and norms such as proactiveness, risk-taking, accepting failure, openness to new ideas, individualism, independence, and achievement. Such a mindset trigger a "herding" effect, which means that entrants will attract more and more entrants into the entrepreneurial activity as observers consider the entry of others as the sign of exploitable opportunities (Sørensen & Sorenson, 2003). Such a tendency further intensifies the legitimation of entrepreneurship as individuals seeing others engaged in entrepreneurship legitimate the practice (Etzioni, 1987; Stuart & Ding, 2006) and also the social cost of becoming an entrepreneur decreases as the number of individuals entering the entrepreneurial space increases (Etzioni, 1987).

3.3 Physical Spaces—Hatchery, Co-creation Spaces, FabLabs

Physical spaces like incubator houses, hatcheries, co-creation spaces, and FabLabs play the role of bringing entrepreneurs together to co-learn and to co-create. While the majority of interaction is conducted through the virtual space in recent times the role of the physical space is still important (Pittaway et al., 2018). While the presence of such facilities can stimulate entrepreneurial interaction and knowledge spillover there are cases when space could not serve this purpose and remained an empty building.

In a university context, such spaces offer the opportunity for instructors to hold courses embedded in the curriculum, while having extra-curricular activities there at the same time making the curricular activity open for outsiders and also enabling students to engage in discussion with the outside world more easily. These spaces by being positioned in a frequently attended and transparent place can contribute to awareness raising and the development of the entrepreneurial culture on campus.

3.4 Demand

During the entrepreneurial journey it is crucial to conduct continuous validation of the concept and in a later stage the product or service (Ries, 2011) to maximize the likelihood of success. This ongoing validation process requires easy access to potential demand that can provide feedback about the product or service. This—in another words—enables the entrepreneur to engage in multiple cycles of product or service experimentation and as a result learning activity. The validation and in a later stage of the product or service development process the purchase of the product or the service is a "pull mechanism" between the demand and the entrepreneurial initiatives. Potential future consumers or users of the products or services also can serve as a valuable source of socio-economic challenges to be solved by the university. This "push mechanism" can orientate the knowledge generation process at the university toward a more meaningful, applicable one.

3.5 Educational Programs

The role and effectiveness of entrepreneurship education, within the systemic conditions of the UCEE, in entrepreneurial capacity building has been extensively researched and debated. Results are mixed in terms of its effect on students' capacity development (Rideout & Gray, 2013). Universities conduct such activities in the form of standalone courses, certificate programs, degree programs specifically for students and in the form of extra-curricular activities and training programs for researchers. Forrest and Peterson (2006), and Neck and Greene (2011) argue that andragogy and experiential learning via games, simulations, or even actual venture creation, may improve learning outcomes. Besides the teaching methodology its disciplinary nature is also important. For UCEE to efficiently emerge and to be sustainable entrepreneurship education must be present in the curriculum across campus implying that students from all disciplines can enroll into curricular, co-curricular, or extra-curricular programs.

3.6 Research

The role of research activities in universities is at a crossroad in terms of its required socio-economic impact, and focus. Siegel and Wright (2015) argue that activities at universities need to function "To provide a wider social and economic benefit to the university ecosystem" (p. 585). While the knowledge generated at these institutions are required to make a difference in the local socio-economic environment not all type of research has the characteristics to fulfill this requirement. According to Asheim and colleagues (Asheim & Hansen, 2009; Asheim et al., 2007, 2011), there are three types of knowledge bases: synthetic, symbolic, and analytical. Qian's (2017) empirical study showed a positive causal relationship between innovative activities in cities and engineering knowledge as synthetic and arts knowledge as symbolic knowledge base, while there is no effect of biomedical knowledge (analytical).

3.7 Talent

The ecosystem must rely on knowledge and on people with high-quality capabilities in entrepreneurship. Students have to be considered as an asset for the ecosystem and not simply as "customers", who enroll into programs and then leave the institution upon graduation. This perspective in the form of efficiently functioning alumni organizations is not unknown for Anglo-American universities but outside of this socio-cultural environment such type of community formations rarely function in a meaningful manner. Talent must be filtered out and promoted in all stages of the entrepreneurial capability developing process and either need to be put in roles that enable knowledge spillover to their peers (e.g., student mentors) or need to be promoted as role models. Competitions organized at the university across disciplines to select the best students are a sufficient tool to achieve this objective.

3.8 Finance—FFF, Angel and Venture Capital, Crowdfunding

Funding must take into consideration the early-stage nature of the initiatives of the student projects and also that of the discoveries put forward by researchers. Angel and informal funding networks can contribute to a great extent to the early-stage validation of the innovative projects and besides their role as funders their professional networks can serve the acceleration of the projects even more than the funding itself. Pre-seed funding by venture capitalists can serve the purpose of funding minimum viable products (Ries, 2011) to enable entrepreneurs to conduct the first market-based experiments of the product/service concepts. This learning phase is invaluable for these early-stage startup initiatives. Crowdfunding with its community building and experimentation features can even further expand the validation opportunities and space for students and for researchers as well (Kuti & Bedő, 2016, 2018).

3.9 Student Champions and Dealmakers

Individuals with a successful track record in entrepreneurship who are able to create a bridge between others to facilitate knowledge spillover and to stimulate the "resource integration" process of entrepreneurs are as important to the ecosystem as networks of professionals and/or investors. This powerful mechanism has been discovered by Feldman and Zoller (2012): "The empirical results suggest that the local presence of dealmakers is more important for successful entrepreneurship than aggregate measures of regional entrepreneurial and investors' network". (p. 23). This implies that the coordinating body of the ecosystem, let it be any organizational unite of the university must convert talents into champions who have the capabilities to function as dealmakers in the ecosystem to expand the opportunity space for others.

3.10 Student Clubs

Student empowerment contributes greatly to entrepreneurial capacity development, which can take the form of creation and the leadership of student-created and led organizations. Pittaway et al. (2015) discovered that the establishment and the management of student clubs on the part of the student members enhance student learning benefits that simulate important aspects of entrepreneurial learning, such as learning by doing, learning through mistakes and learning from entrepreneurs. Apart from entrepreneurial skills students develop invaluable leadership skills also vital for creating and running entrepreneurial ventures.

4 Analysis—The University of Pécs as a Seedbed of Entrepreneurship for Innovation

We would like to demonstrate the role of the University of Pécs (UP) in the smart specialization of the South Transdanubian region by using the theoretical concept introduced in the previous section. Though universities clearly should directly play an important role in the development of smart specialization strategies, this is not the focus of our investigation. This chapter aims to introduce the potential contributions of the University of Pécs to smart specialization through the enhancement of the entrepreneurial spirit at the institution and in its surrounding through various activities. This case can be a good representative of the difficulties and the possibilities faced by other universities that are located in lagging regions with weak potential for developing high-tech cluster and wish to contribute to the smart specialization of their surroundings.

Through the detailed analysis of the University of Pécs, this chapter can contribute to the better understanding of universities' role in regional innovation through entrepreneurship. Since this can led to identification of policy implications, it is important to make a comment on the quality of the qualitative evaluation based on Spencer et al. (2003) who highlight that a qualitative research must be contributory, defensible in design, rigorous in conduct, and credible in claim. They argue that the most extensively used methods in government-based evaluations are interviews, focus groups, observation, and documentary analysis.

Interviews were extensively used for our research. Open ended interviews were conducted with key actors of the University's entrepreneurial ecosystem. To better understand the top-down approach of the institution with respect to its entrepreneurial strategy the Rector, Vice Rector for Innovation was included in the sample. To assess the strategy implementation, the processes within the institution mid-level personnel way involved in the data collection process from the Technology Transfer Office. Members of the Faculties were important from the data collection perspective to understand the perception of the units that were directly effected by the rules and regulations on how they see the functioning of the ecosystem. During the hour, hour and a half long open-ended interviews we used the university centered entrepreneurial ecosystem framework as a guideline of our discussion to assess if all elements are present in the system of the University of Pecs.

In order to expand the data collection to the bottom-up initiations within the organization further interviews were conducted among faculty members, mentors and facilitators who are involved in the activities of the Simony BEDC Entrepreneurship Center. The information obtained from these stakeholders can help us better understand the individual level perception of efficiency of the system.

To understand the case, we must start with a brief introduction of the national and the local contexts. South Transdanubia encompasses three counties: Somogy, Tolna, and Baranya. "[…]is an underdeveloped, modest innovator region, characterized by relatively low share of manufacturing and foreign direct investment (FDI), few innovative companies and low support absorption capacity. South Transdanubia (ST) had a population of 886,840 inhabitants in 2018 (Eurostat, 2019) and an area of 14,169 km^2. Despite intensifying gross fixed capital formation and substantial investment in R&D infrastructure and in new technology, ST is among the least developed European regions."[2]

[2] https://ec.europa.eu/growth/tools-databases/regional-innovation-monitor/base-profile/south-transdanubia (03.09.2020).

Since in lagging regions universities are key actors in smart specialization, it is clear that the University of Pécs[3] that is the oldest and one of the largest universities in Hungary should play a crucial role too. With its 10 faculties,[4] 7200[5] employees, among them 2000 researchers,[6] more than 20,000 students, among them more than 4000 international ones,[7] it should play a central role in the entrepreneurial transformation of the region. However, the entrepreneurial attitudes and skills in universities are generally very low, respectively the institutional mechanisms for establishing boundary-crossing partnerships for collective action are underdeveloped owing to the historical development of the organization of science in Hungary. In the statist triple helix or triple helix I that was present in many socialist countries owing to the Soviet impact (Gaponenko, 1995; Inzelt, 2015) the state was the dominant actor encompassing the academic and the business spheres and guiding interactions between them (Etzkowitz, 2008; Etzkowitz & Leydesdorff, 2000). Despite the reforms carried out in the 1970s and 1980s, the fundamentals of the system remained unaffected until the 1990s (Radosevic, 1996). After the system change in Hungary, the first legislative efforts were made by the government to facilitate research at universities and enhance university-industry cooperation (Inzelt, 2002, 2004). Though since then this was followed by further strategic and legal actions (Inzelt, 2008), the entrepreneurial turn of universities is still in a very early phase and based on the report of the OECD institutional structures do not support activities of the third mission that is very narrowly comprehended by many stakeholders (OECD & European Union, 2017).

4.1 Institutional Strategy and Structure (Rules and Regulations)

The organizational structure of the UP (Fig. 3), codified in the rules and regulations of the institution is created in a way that there are three organizational units that contribute to the generation of entrepreneurial capacity and to the commercialization of the knowledge generated at the ten faculties of the university in different formats. Within the Chancellor's Office the Department of Innovation and Grant Management includes the Technology Transfer Office (TTO) that works with researchers mainly in the field of IP protection and also responsible for the management of

[3] Also another university, University of Kaposvár is located in the region, but we restrict our analysis to the University of Pécs, because that is the home of the Simonyi Business and Economic Development Centre (BEDC).

[4] Faculty of Law, Medical School, Faculty of Humanities, Faculty of Health Sciences, Faculty of Pharmacy, Faculty of Cultural Sciences, Education and Regional Development, Faculty of Business and Economics, Faculty of Music and Visual Arts, Faculty of Engineering and Information Technology, Faculty of Sciences (https://pte.hu/english/faculties, accessed: 17.05.2018).

[5] UP employment data.

[6] https://innovacio.pte.hu/en/content/research_and_innovation_university_pecs (03.09.2020).

[7] UP facts and statistics https://adminisztracio.pte.hu/sites/adminisztracio.pte.hu/files/files/Egyetemunk/Tenyek_adatok/Statisztikak/pte-osapkivonat-2018-oktober.pdf (Accessed: 10.05.2021).

the IP portfolio of the UP. Furthermore, the TTO in cooperation with the Simonyi BEDC Entrepreneurship Center (Simonyi BEDC) organizes workshops and training to develop the entrepreneurial skillset of researchers on all levels (PhD, post-doc) at all faculties of the UP. Event organizing is also part of the responsibilities of the TTO, which are either conducted in cooperation with Simonyi BEDC and the Institute of Transdisciplinary Discoveries (ITD) or by itself. Another main role of the TTO is to actively conduct commercialization activities of the research results that have been included in the IP portfolio of the UP. This implies frequent communication and interaction with the private sector that includes strategic buyers and venture capital companies. Project managers at the TTO manage the IP portfolio and from a business and a legal perspective as well.

The Simonyi BEDC Entrepreneurship Center is embedded in the Faculty of Business and Economics as a "center of excellence". It interacts with the 10 faculties of the UP informally without any formal jurisdiction over them, unlike the TTO that has a formal jurisdiction. This informality is also true for ITD, that's main aim is to boost interaction between the different disciplines across the 10 faculties. Simonyi BEDC's primary target audience is the student body across all faculties, but it also interacts with faculty. It initiates, organizes and coordinates curricular, co-curricular and extra-curricular activities in the area of entrepreneurship education.

ITD is part of the Szentagothai Research Center (SzRC) as an independent institute. Its main mission is to facilitate scientific discoveries in the multidisciplinary space by involving the non-university sphere as well. Relationships of all three units with non-university actors are informally communicated across the three units to

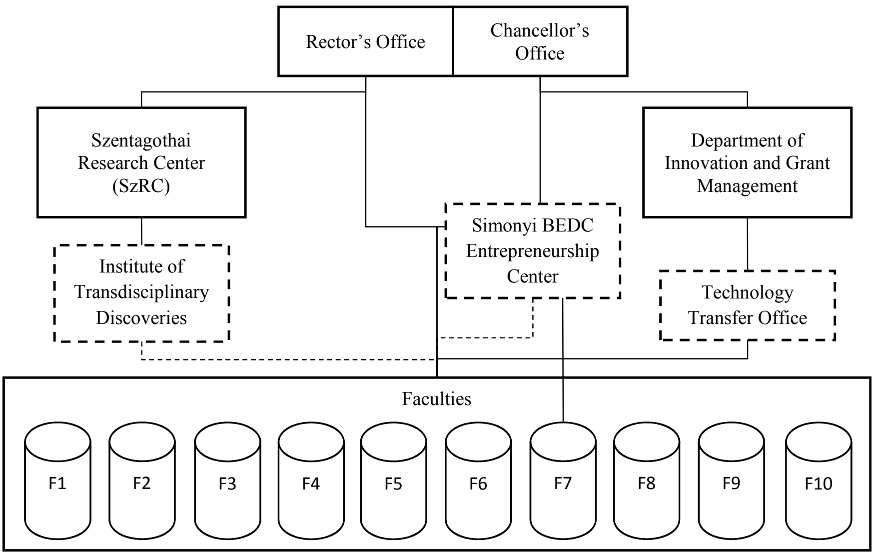

Fig. 3 The organization structure of the UP concerning the units responsible for entrepreneurship capacity building and knowledge commercialization

share opportunities, but this coordination is not structured. In the rules and regulations of the UP relationship between the three units are not explicitly defined, which in many cases the source of internal conflicts and miscommunications.

4.2 Culture

While culture within an ecosystem is a crucial element it is hard to detect and measure it. The literature has made numerous attempts to create a metrics system, while the measures and indicators are not always present in a particular location making it impossible to apply these measures. In the case of the UP there are no indicators or statistics that can be appropriately applied to quantify the entrepreneurial culture, nevertheless, we rely on anecdotal evidence and the level of publicity as an indicator of the public discourse on the theme of entrepreneurship.

The term entrepreneurship is a somewhat controversial term in Hungary and the Pécs region as well as "entrepreneurs" after the fall of the socialist regime (1990) were those people, who used semi-legal tools and solutions to run their business activities. These semi-legal or fully illegal activities downgraded the term entrepreneurship to be used for the gray segment of the economy. This adverse tendency currently with the startup boom and with some very successful Hungarian startups, like Prezi, USTREAM, LogMeIn is recovering but still persists to some extent.

The presence of large, multinational companies mainly in the central part of Hungary graduates of the university mostly consider being employed at some of these companies as a career path instead of starting an own initiative. Being a creative, entrepreneurial employee or a corporate entrepreneur (intrapreneur) within a company is a highly rare career objective due to its unknown nature among graduates. Anecdotal pieces of evidence show that there are more and more graduates who start their career as an employee at a large company and then found their own after some years when sufficient routine and experience is generated in that particular industry. To understand better the post-graduation patterns a well registered and managed Alumni database is under construction.

There is a limited number of publications at the university and on the regional level as well that discuss entrepreneurialism explicitly and systematically raising conscious awareness of the issue. Articles about success stories and initiatives, innovative actions are present in a non-systematic way. Hornyák, (2016) assessed the causal relationship between economic performance on a local level and "news sentiment" and found that the Pécs region is highly negative, which is connected to a lagging economic performance relative to other regions of Hungary. This finding more specifically implied that news publications are more negative in nature, in other words are more pessimistic, also stories in these publications are more past-oriented instead of future-oriented. To come to this conclusion, Hornyák used data mining and text analysis methods to construct a sentiment indicator that later was related to the local economic performance. This finding to some extent reflects on the poor entrepreneurial culture in the region of Pécs, which has emerged after the closure of the coal mines in the mid- ‘90s.

4.3 Physical Spaces

UP on the university level has not created a common space for student and or faculty entrepreneurs to interact with each other with the explicitly communicated purpose of entrepreneurial opportunity sharing and enhancement. Such space only exists in the building of the Faculty of Business and Economics coordinated by the Simonyi BEDC named Simonyi BEDC Hatchery. The Hatchery gives a home for curricular, co-curricular, and extra-curricular activities for all students at the UP, but being on the edge of the campus its visibility is limited. In the Hatchery students involved in any programs organized by the Simonyi BEDC can share office spaces, can use the co-creation space with videoconferencing opportunities. ITD is located in the building of the SzRC within office spaces and also access to seminar rooms.

While scientific evidence is limited in terms of the role of the physical space in entrepreneurial skill creation, anecdotal evidence supports the importance of these spaces to enable the interaction of individuals pursuing entrepreneurial activities. Such interaction is a crucial element of the entrepreneurial ecosystem because its peer-to-peer, co-learning, co-creation aspects, enhancing access to entrepreneurial opportunities.

4.4 Demand

The South Transdanubian region where UP is located is a depressed region of Hungary as its main economic activity was coal mining that in the mid- ‘90s was terminated due to inefficient production. The consequence of this shock is still observable in the region that can be detected in the number of companies and also in the rate of high-growth companies in the region. This conclusion is further supported by the Regional Entrepreneurship Development Index (REDI) (Szerb et al., 2013). The REDI index is a complex measure of the development of the regional entrepreneurial ecosystem that takes into consideration individual and institutional level variables. The variables aggregate into pillars that compose the index. Within these variables, product, and process innovation is factored in.

Figure 4 shows that except for the central region of Hungary, which includes the capital city of the country, Budapest the rest of the country was in the lowest REDI score domain in 2017. The low level of entrepreneurial development (REDI score) implies that innovative ideas coming from student entrepreneurs of from researchers

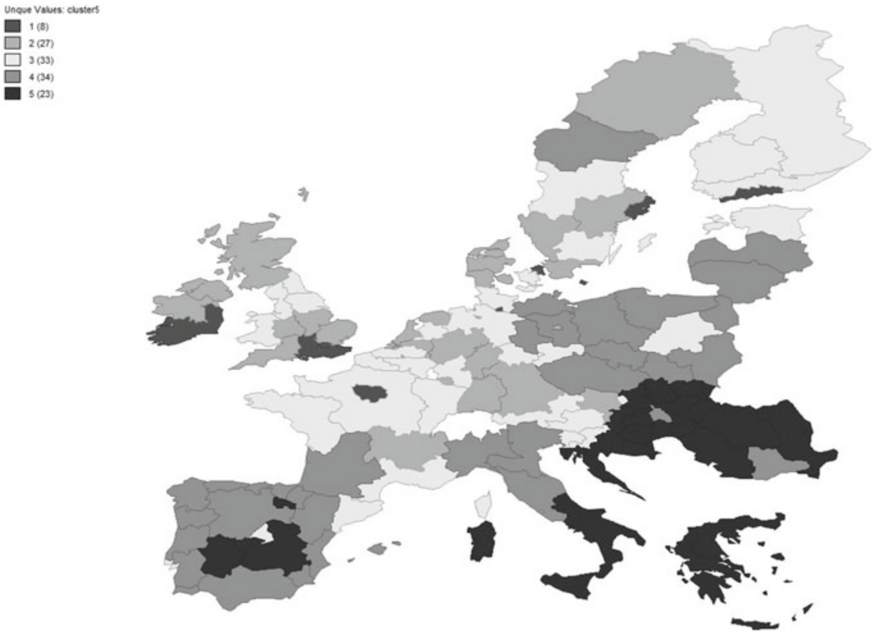

Fig. 4 The map of REDI 2017 scores in five cluster categories in 125 European Union regions. *Source* Szerb et al., (2017, p. 34)

face a low level of probability of meeting with companies that (1) can participate in the validation process; (2) can serve as strategic partners in the development process; (3) have the capability of functioning as strategic buyers in a later stage of the product or service development process.

This disadvantageous position of the UP arising from the poor company base in the region that should support entrepreneurial and innovation activities at the institution is further amplified by the fragmented and uncoordinated company relations mechanism within the institution. After conducting multiple interviews with personnel responsible for company relations it became clear that this responsibility is scattered over the organization, which causes parallel initiatives, uncoordinated activities and at the end frustration on the part of the organization units and the company partner. Interviews made with researchers verified this frustration on the project owner level as well, which, according to the responses of the project owners greatly damages the motivation and the internal drive of individuals to carry out entrepreneurial activities through the administrative processes of the institution. In many cases the outside stakeholder interacts with the researcher via private channels leaving the UP out of the interaction, preventing the organization to learn from the interaction and also receiving a share from the financial reward of the interaction, transaction.

4.5 Intermediaries (Educational Programs/EC/TTO)

At the UP multiple organizational units focus on entrepreneurship, the third mission of the university or the execution of the quadruple helix mission of the university. The Technology Transfer Office (TTO) under the leadership of the Chancellor's office manages the IP portfolio of the university and brings researchers, research results together with industry participants. The TTO is also responsible for the protection of the IP. It organizes interactions and training programs for researchers to equip research staff with the necessary knowledge on market forces and mechanisms and also to develop entrepreneurial skills. The objective is not to develop entrepreneurs who are capable of running their own businesses but to create a basic understanding of market forces.

The Simonyi BEDC Entrepreneurship Center, which is embedded in the Faculty of Business and Economics but reaches out to other faculties of the UP is responsible for entrepreneurial capacity building and development through its programs (see Table 2). The programs are designed to take in students or researchers in their capacity development stage, let it be early or more advanced. The programs are using experiential learning, project-based educational technics, where the mentor has a significant role in following the path of the entrepreneur. The programs also intend to bring together individuals with complementary capacities to establish teams that can execute the ideas or business concepts. The relatively isolated allocation of the UP is intended to be resolved by the Internet-based platforms that enable entrepreneurs to show their projects' value proposition to seek validation from people at other institutions and also involve team members from other cultures who can increase the chance of penetrating foreign markets in the framework of a scale-up strategy.

The TTO and the Simonyi BEDC is closely connected to the ten faculties of the UP but the codification of this relationship is still not solved in the organizational chart of the UP. While all organizational units are open to work with the TTO and the Simonyi BEDC the "institutional" motivation is still lacking.

4.6 Research/Knowledge

Using Asheim and colleagues' (Asheim & Hansen, 2009; Asheim et al., 2007, 2011) knowledge base identification UP has analytical (science-based), synthetic (engineering-based), and symbolic (art-based) knowledge base emerging from its ten faculties and the central research center. In the IP portfolio of the UP 70% of the portfolio element are related to science-based type of knowledge, more specifically they are in the area of medical research; 20% is in the field of engineering and the remaining 10% is originating from the art-based knowledge.

Transdisciplinary research is conducted, in an institutionalized form at the Institute of Transdisciplinary Discoveries (ITD) that is embedded into the Faculty of Medicine, located physically at the Szentagothai Research Center. The main mission

Table 2 Educational interventions at the UP focusing on entrepreneurial capacity building and development

Name of the intervention	Role of the intervention in the process	Description of the intervention
Inspiration.pte.hu	Awareness raising	Internet-based platform enabling students to display their study outputs in the form of videos, pictures, posters, and a short one-pager. The objective is to motivate students to communicate the value proposition of their competencies in the form of showing their work
Certificate in entrepreneurship certificate in data science entrepreneurship certificate in bioentrepreneurship	Idea generation and business concept development with special disciplinary focus	These short term programs, with an academic year time span serves the purpose of awareness raising and the introduction of business concept development and validation with a special focus on current scientific trends
Elective courses	Idea generation, business modeling, functional areas of the business development process	Basic introductory courses are offered across campus for those who already understand the concept of entrepreneurship and would like to engage in the process of opportunity seeking and recognition followed by business model generation and validation
Idea competition	Ideation	This tice a year competition draws attention to opportunity seeking and recognition and intends to involve people, who have the desire to execute their ideas but are lacking any support
Incubation program	Business concept development	The idea competition is followed by this incubation program that is designed to create a team around the idea owner and walk the team through a 15 week process which helps the team to validate the idea and to create a viable business concept around the idea
International video pitch competition	MVP creation and validation	Projects that have an MVP let them be developed in any program can participate in this international competition which enables the business concepts to seek further validation; to interact with international entrepreneurs; to develop skills in MVP development in general and in video creation in particular

(continued)

Table 2 (continued)

Name of the intervention	Role of the intervention in the process	Description of the intervention
NetMIB, global incubation program/ platform	Business concept development in an international context	Project owners who intend to develop their ideas, projects in an international environment can enroll into the NetMIB program, which follows the same design as the 15 week incubation program but it is organized on an online platform where student entrepreneurs of international universities also develop their project. Via this platform more frequent validation, interaction, co-learning can be achieved while receiving multidisciplinary and multicultural exposer
Summer social entrepreneurship program	Ideation, business concept development with the focus of social entrepreneurship	This program specifically focuses on challenges in the local area that is dealt with by student teams with diverse international background. This three week experiential learning, project-based program intend to deliver hand on solutions to social projects in the Pecs region

of the ITD is to facilitate, beside multidisciplinary research initiatives enable science to spill over to the local society in the form of "citizen science". This in another word implies the conversion of science into an understandable form that enables citizens to actively participate in research projects by providing impulse to the projects and also continuous validation. Such a relationship and mechanism would pressure research projects to orientate toward local socio-economic problems. Research that is conducted and organized between disciplines in a multi- or cross-disciplinary form is unknown at this point, which does not necessarily mean they do not exist at the UP, they are just not registered officially at the Innovation and Research Administration System.

4.7 Talent

The function of talent management, which has the role of helping students in realizing their competence strengths and orientating them toward the areas that suit their strengths the best, is positioned in a central unit within the UP. This central unit is the Career Center (CC). Programs, activities and initiatives related to the CC are available to all university students at the UP. We conducted interviews with the leadership of the CC to discover if they have activities specifically focusing on the area of entrepreneurship. They confirmed that there are tests and screening processes that are aiming at discovering the entrepreneurial skills of the students who are eager to understand their competence profile. Due to the optional nature of these tests and assessments, only about 10% of the students on an annual base go through such a process. Participating students are advised according to their profile implying that the ones with strong entrepreneurial orientation are introduced to the opportunities offered by the Simonyi BEDC entrepreneurship center.

According to the expert interviews at the CC and different faculties of the UP career service and talent management activity is only conducted at the Faculty of Business and Economics (FBE) in a systematic and coordinated manner. The CC of the FBE, called TalentSpot, coordinates closely with the central CC in terms of screening and evaluation but runs discipline-specific training and interactions.

4.8 Finance

According to the Hungarian Private Equity and Venture Capital Association in 2017 the most popular investment stage in terms of amount invested was seed capital (21.7 million EUR), followed by buyout (14.4 million EUR) and startup (2 million EUR). 92 out of the 95 transactions were seed investments with an average deal size of 263 thousand EUR. Companies from seven sectors received funding in 2017 out of which transportation accounted for 40% of the total transaction value. The most popular sector based on the number of transactions was the business product and services and ICT (17% and 16%, respectively).

In the venture capital market, as the result of the decision of the Hungarian government, a state-owned company started its operation in the year of 2016. Hiventures offers pre-seed investment (EUR 50–200 k), seed investment (EUR 200–650 k), and growth-investment program (EUR 650 k–2.5 M).[8] Hiventures has a close relationship with UP's entrepreneurship ecosystem by accrediting the incubation program of the Simonyi BEDC Entrepreneurship Center. This accreditation implies that any early-stage investment (Incubation phase) that has received Hiventures funding can decide to join the Simonyi Incubation Program for the 12 months investment terms. During this period the project must develop an MVP and must show that there is sufficient market demand for the product or service. At half time of the investment period, Hiventures assesses if the project has further growth potential and if the next round of investment becomes available in the form of the "Seed" investment product. The UP by having Simonyi Incubation Program accredited by Hiventures can receive a maximum 3% ownership stake in the companies it incubates in the early stage. The decision if the project is incubated by Simonyi BEDC or mentored by an accredited mentor of the Hiventures is made by the project owner. The ownership stake allocated for this support service is negotiated by the parties involved and after an agreement a trilateral agreement is signed by Hiventures—project owner—mentor/accredited incubator.

[8] https://startup.hiventures.hu/en (Accessed: 28.06.2023).

UP, also resulting from a government-initiated decision that was funded by the EU, has a connection with a private accelerator, which should fund and support "Incubation" phase, pre-seed stage, and seed-stage companies emerging out of the ecosystem of the university. This accelerator was formed in 2017 as the result of a government grant of 2 million EUR to create an acceleration process that is integrated with the incubation process of the UP. In the framework of this grant, the accelerator is required to make investments, mainly in the seed phase by the end of 2020 and also to develop the entrepreneurial ecosystem of the UP. By 2021 there were 4 startups mentored in the frame of the cooperation.

Besides the state-initiated and operated pre-seed and seed-stage investment vehicles ideas and companies emerging from the UP ecosystem have the same access to venture capital (VC) and private equity (PE) as anyone else in Hungary or Europe. Accessing private equity in Hungary although is not as easy as in countries with a developed PE network as the activity of the informal PE networks is rather limited. Banks' involvement and activity in this sphere of investing are negligible in Hungary and the Pecs region as well.

4.9 Champions

While recognizing that successful student or researcher entrepreneurs are crucial to developing an entrepreneurial culture in an ecosystem, such promotional activity is ad hoc and fragmented in the UP ecosystem. Success stories appear in the quarterly newsletter of the Simonyi BEDC that mainly focus on student entrepreneurs, while neither researchers are promoted for their entrepreneurial achievements nor faculty members for their entrepreneurial teaching activities. There are two awards that are to recognize entrepreneurialism out of which one is explicitly and the other is implicitly for entrepreneurship. The award provided at the end of the International Video Pitch Competition (IVP) organized by the Simonyi BEDC requires contestants to upload their 2 min pitch videos of their projects and a one-pager to an Internet-based platform. This competition is organized at 15 universities around the world with 50 projects in 2019 competing against each other. Projects successfully passing the first round (local round) of judging will compete in the international round. In each round, the first two are selected and named based on the evaluation of non-university professionals from each participating universities. IVP is designed to fit the curriculum of university education offering a unique tool for lecturers to boost motivation in class and also to promote entrepreneurialism at the same time. While the objective is clear this integration opportunity has been utilized by only a few universities in the consortium, according to our interviews.

The TTO of the UP organizes "Innovation Award" every year for post-doc and student researchers as well. This award is intended to promote research and activities associated with it irrespective of the field, theme of the research. While the award aims at bringing new initiatives to public attention its main message is research excellence instead of entrepreneurship.

4.9.1 Student Clubs/Networks

Network formation and student organization activities at the UP mainly center around the official Student Union (SU) of the university. The SU is the official student organization of all students with subunits at every faculty serving the representation of the student body. The SU has seats in the Senate of the UP, which is the highest level decision making body of the university. This organization being more of an official entity does not promote entrepreneurialism either explicitly or implicitly.

Other student organizations are focusing on academic activity and academic excellence. The majority of these organizations are discipline focused some with an interdisciplinary approach. The main objective of these organizations/clubs is to serve as an inspirational community for talented students wanting to pursue academic life or a high level of proficiency in a particular area. While entrepreneurship is not explicitly promoted, implicitly entrepreneurial orientation and innovation is motivated within some subgroups of the organizations.

5 Conclusion

In this chapter we argued that the sufficiency of smart specialization is the function of the entrepreneurial activity in a particular location, which enables knowledge spillover to emerge and to persist generating economic prosperity in the local economy. Knowledge spillover as the result of the vibrant entrepreneurial activity is highly dependent on the context it emerges in. This context is the entrepreneurial ecosystem, which consists of individuals with complementary competencies, factors and institutions supporting proactive, self-dependent, risk-taking activities of individuals in that location. In a small town like Pécs with a university that is the biggest employer of the region expectation of knowledge being the main driver of economic activity is self-evident. One would expect that knowledge generated at the UP would quickly spill over to the regional socio-economic environment and would trigger unique and innovative initiatives that would revitalize the economy. This ideal scenario is only achievable if the knowledge base, which is UP in this instance consist of individuals (students and faculty members) with an entrepreneurial mindset and orientation to trigger and implement entrepreneurial projects for and with local stakeholders. While entrepreneurial mindset is vital, the entrepreneurial ecosystem within and around the UP is also needed for this optimal case to occur.

In our case study, we broke down the building blocks of the university centered entrepreneurial ecosystem of UP and assessed these elements using hard data and anecdotal evidence as well. We found the existence of almost all building blocks, while discovered that the systematic integration of these is missing. In other words, the elements of the puzzle are on the table but they are either not connected to each other or are connected in a wrong way. The most crucial component to be adjusted or improved is the culture of entrepreneurship which is misunderstood for historical and for social reasons. Students and faculty members must understand that entrepreneurialism is not identical to venturing exclusively and does not imply semi-legal or illegal activities. Graduates have to experience entrepreneurial activities within organizations let it be a course or a student organization making them aware of intrapreneurship to reinforce that entrepreneurship does not imply company formation on their own.

Besides the entrepreneurial culture, formal institutions must be adjusted to motivate stakeholders to engage in entrepreneurial activities and to connect with each other. Research needs to be focusing on problems and challenges that emerge in the local socio-economic setting that have the scale-up potential to solve global problems as well. Teaching activities will have to be transformed to apply skill development instead of knowledge-generating pedagogies in the form of project-based, experiential learning methods. Students have to view learning as an opportunity to express themselves as opposed to a formal "tick the box" activity. In order to achieve this on the part of students their motivational system and performance metrics, just like in the case of faculty members must be redesigned.

Our research contributes to the field in multiple ways. Although there are many approaches to universities' regional developmental role, their operationalization in terms of an analytical framework is often missing or limited. Our work demonstrates a case for the application of the entrepreneurial ecosystem framework to support the analysis and understanding of universities' contribution to regional development in specific context. The Central- and Eastern European location represents an important setting due to the inheritance of these countries in terms of organization of science and entrepreneurial attitude. The university centered entrepreneurial ecosystem framework enables to go beyond the rigid numerical assessment of entrepreneurialism at universities that inevitably results in a limited understanding of the phenomenon and supports the identification of potential bottlenecks on the soft side as well that might be highly contextual in nature.

Of course, our research has many limitations. Our case is a large, comprehensive university with ten faculties. Smaller, specialized institutions might face different challenges and opportunities in terms of creating a university centered entrepreneurial ecosystem. Furthermore, despite the common roots, many differences emerged between the countries of the former Soviet block during the past three decades since the system change. These mean that the transferability or generalization of the results of this single case study must be done with caution even in the Central- and Eastern European context.

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A Holistic Model for Measuring Sustainable Performance Generated by Innovative Projects: The ESCO Energy Transition Case

Jean-Pierre Segers, Dirk V. H. K. Franco, Didier Van Caillie, Elina Gaile-Sarkane, and Janaina Macke

Abstract In recent years, our society has witnessed a number of paradigm shifts and transitions with potentially severe consequences for the economy and the world of work. Wicked problems and black swan events such as the COVID-19 pandemic, the climate, energy and Ukrainian crisis, the supply chain disruptions triggered a growing attention for grand societal challenges. The latter requires novel holistic and systemic approaches, new models of innovation and adapted business models. In the quadruple—public and private—helix of government, higher education, business, and society, there is a growing attention for a multilevel perspective on sustainability transitions, anchored in the United Nations' Sustainable Development Goals. Universities—through their core activities of education, research, regional stewardship, and community engagement—are well positioned to contribute to sustainability issues, as they seek solutions for grand societal challenges, such as (re)imagining the energy transition. Based on the above, a holistic approach for measuring sustainable performance generated by innovative projects in a (higher) education setting is outlined. In particular, this chapter presents an interpretive case study for the model of Energy Service Companies—the "ESCO energy transition case".

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1 Introduction

The chapter is structured as follows: In the conceptual framework (Sect. 2), the multilevel perspective (Geels & Schot, 2007; Loorbach et al., 2020b) is introduced as a holistic and systemic approach to innovation. Additionally, the evolution toward new and sustainable energy business models is outlined. Section 3 is dedicated to the ESCO energy transition case. Sections 4 and 5 provide a discussion of the findings, conclusions, and suggestions for future research.

Interaction, interdependence, and collaboration are vital elements to collectively cocreate and codevelop solutions for global challenges and wicked problems (Rittel & Webber, 1973), such as the massive use of fossil fuels, greenhouse gases (GHG), and especially, CO_2 in the Earth's atmosphere (Vince, 2019; WMO, 2017). We are witnessing a paradigm shift to meet societal needs beyond conventional economic needs (Hepex, 2020). The necessary transition toward a zero-carbon economy (IPCC, 2021) reshapes our way of living and managing businesses and projects. Demographic growth and natural resource exploitation at increasing rates are environmental problems—a combination of heatwaves, droughts, wildfires, hurricanes, arctic vortex, and snowmageddon—that worsen social issues such as health problems, extreme poverty, and social inequality (Pérez & Frank, 2019; Trouet, 2020). Societal resilience and adaptation are needed to remain competitive and to avoid significant consequences for the climate (Vince, 2019). With the introduction of the Sustainable Development Goals (UN, 2020), environmental objectives and social and ethical aspects intertwine with the definition of sustainable development in the Brundtland Report (Brundtland, 1987; UN, 2020). Organizations and companies increasingly integrate corporate, societal, and environmental resilience into their strategy. Innovation is the engine that powers the global energy transition, as it is both systemic and interwoven. Engaging organizations and companies to generate and adopt energy-efficient innovation is crucial for balancing energy needs for sustainable development (Šūmakaris et al., 2021). It provides momentum for new and formerly unexplored solutions for societal, economic, technological, and environmental challenges. This has led to sharing common values and benefits for various stakeholders and ensuring a more holistic perspective, leading to a new paradigm of innovation: holistic innovation. The latter is total and collaborative innovation driven by a strategic vision in an era of strategic innovation, which aims for a sustainable and competitive advantage (Chen et al., 2018). According to Manceau and Morand (2014), a holistic view of innovation combines research and development and creativity and includes recent design thinking, open innovation, digitalization, sustainable development, and resource-limited innovation. The holistic approach is driven by (1) the multilevel perspective and (2) new business models, as outlined in the following section.

2 Conceptual Framework

The multilevel perspective—MLP—is a prominent transition framework (Avelino, 2017; Geels & Schot, 2007; Loorbach et al., 2020b) to outline the interplay between the various players necessary for a paradigm shift to take place. The MLP posits that transitions come about through interaction processes within and among three analytical levels: niches, sociotechnical regimes, and a sociotechnical landscape:

1. The *macrolevel* forms the "external structure or context for interactions of actors"; oil prices, economic growth, wars, immigration, broad political coalitions, cultural norms, environmental problems, and paradigms are possible factors determining this.
2. The *meso (regime) level* can be seen as the "rule-set or grammar" of processes, technologies, skills, corporate cultures, and artifacts embedded in institutions and infrastructures. The regime tries to maintain itself and ignore the pressure from above, the macrolevel (Stewart, 2012).
3. There is much pressure on this regime from below due to the *microlevel*. This is where radical innovation will happen. This level acts as incubation rooms and allows for research and learning through experience. This area provides the space and time essential for networks to be established.

The framework is shown in Fig. 1.

Collaboration and coherence between the different niche levels are essential. Paradigm shifts of the regime can be seen as the result of a cascade of changes over time. According to Loorbach et al. (2020a), as transition dynamics increase and internal tensions push incumbent actors to reflect upon longer-term futures, transformative innovations will emerge and become more attractive and viable. The vision of a transforming world or business context usually arises with a group of people who are intensely aware of it; from this group, it is necessary to evolve from a transition team via change projects to a change network (Van Yperen et al., 2017). In such paradigm shifts, attention must also be paid to internal and external resistance. At the heart of transition theory lies a paradox: an innovation to have transformative impact needs some degree of diffusion, mainstreaming or institutionalization, but—by definition—this decreases its original, innovative power. Logically, this gradual but rapid paradigm shift that encourages the organization, private or public, to respond to societal needs beyond traditional conventional economic needs (Hepex, 2020) has also had an impact on the dominant vision of organizational excellence, as reflected in the main holistic performance models, notably the one of the European Foundation for Quality Management (EFQM). The very first version of the Business Excellence EFQM Model, already revolutionary at the time of its publication, encouraged us to base this excellence:

- On the capacity of the organization to focus on the continuous meeting of the needs and expectations of its "customer-users".
- Through a permanent search for optimization of its global internal processes.

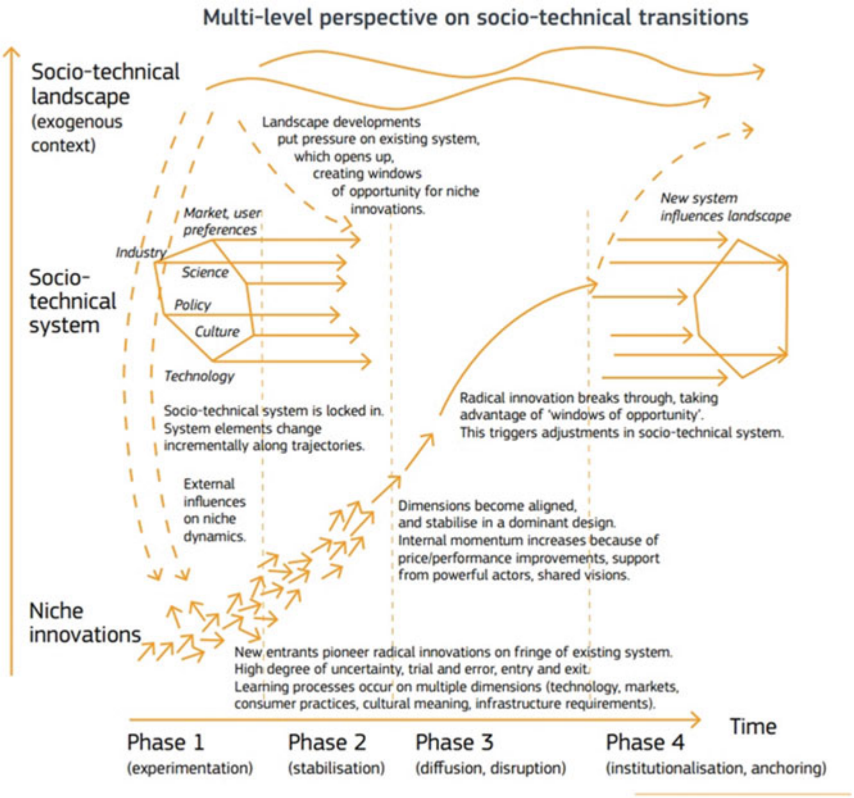

Fig. 1 Multilevel perspective (Geels & Schot, 2007)

- Based on its key resources, committed strategic partners, strong leadership, and a strategy inspired by creativity and innovation.

Its most recent version (EFQM, 2020) places at the heart of this excellence the sustainable performance of the organization, in a holistic vision of an organization evolving in constant interaction with an increasingly important Volatile, Uncertain, Complex, and Ambiguous (VUCA) environment, and as a result, in constant search of organizational innovation capable of making it more reactive and flexible to the real needs of its beneficiaries and society at large, both in terms of its processes and the services it provides. Consequently, achieving organizational excellence implies simultaneously meeting the expectations of its main stakeholders (including society as a whole) by combining a search for continuous optimization of internal processes with effective change management driven by innovation, creativity, and knowledge management. Responding in an agile and efficient way to emerging internal and external threats, transforming them in a progressive but continuous perspective into opportunities by developing a culture based on cocreation with its ecosystem members becomes the fundamental managerial paradigm. By integrating the eight fundamental concepts of excellence supporting the framework of the EFQM model (2020) with the strategic paradoxes highlighted by De Wit and Meyer (2010), we can consider a sustainable organization (and, by extension, the projects it carries out):

- Has a primary vision of creating a sustainable future for itself and society as a whole.
- Develops an activity and a network strategy based on three clear strategic choices: to add value for its customers or beneficiaries, to contribute to the development of its internal capabilities and to harness creativity and innovation to develop its intangible capital.
- Follows three organizational priorities: to lead the organization (or its projects) with vision, inspiration, and integrity, to manage with agility, and to succeed through the talent of the people involved.
- And finally has as a mission to maintain sustainable and resilient results over time (see Table 1).

Therefore, in this VUCA context, organizational performance is, both at the overall level of the organization and the level of each of its projects,

- Necessarily sustainable.
- Holistic and transversal.
- Constantly seeking alignment, through innovation and creativity, with the external expectations and requirements of its environment and stakeholders and its employees' internal aspirations.

Conceptually, this vision of sustainable organizational performance emerges from a holistic and combined use of four theories now dominant in management science, translated into four paradigms:

Table 1 Strategic look at the EFQM 2020 core principles in a VUCA context

Strategic level	Principles of a strategy to support sustainable organizational excellence
Vision	P1. To create a sustainable future for the stakeholders involved in the organizational project (beneficiaries, intermediaries, employees, shareholders, civil society)
Strategy	P2. Consistently delivering real-added value to clients, intermediaries, and beneficiaries P3. Continuous development of organizational capabilities P4. Continuous exploitation of creativity and innovation in a cocreative perspective with key stakeholders to continuously adjust to changes in a VUCA environment
Operational activities	P5. Leading with vision, inspiration, and integrity, which translates into a flexible strategy and transparent and rigorous governance P6. Manage with agility and responsiveness P7. Succeeding through the talent of people
Mission	P8. To continuously maintain sustainable and resilient results

- The elemental resource-based view (Barney, 1991; Barney et al., 2011; Priem & Butler, 2001; Wernerfelt, 1984) means that any organization or project is considered supported by a portfolio of scarce resources (tangible, intangible, human, and financial) coordinated and balanced via the leadership function.
- The global value chain theory (Gereffi et al., 2005), which means that:
  - Each organization or project develops its internal value chain (combining core design, production, and delivery activities with business and management support activities in the logic of Porter's (1980) value chain model).
  - Each organization is integrated into a global value chain bringing together, most often via complex relational mechanisms, all the actors involved in the design, production and/or provision of a product and/or service in an increasingly fragmented and globalized economic and societal VUCA context.
- The theory of strategic alignment (Henderson & Venkatraman, 1990) means that the organizational transformation induced by this evolution toward organizational excellence necessarily emerges from a continuous alignment between an organization or its project, the information and communication technologies available to it, and the opportunities and requirements of its environment.
- Stakeholder theory (Donaldson & Preston, 1995; Freeman, 1984), which means that ongoing attention to the interests and well-being of stakeholders that can enhance or constrain the achievement of organizational or project goals is the primary driver of organizational performance when managing for and with stakeholders.

New business models and new value propositions (Acs et al., 2017; Autio & Thomas, 2014; Pique et al., 2018; Stam & van de Ven, 2019; Yaghmaie & Vanhaverbeke, 2019) are shaped, disrupting industries—e.g., the energy industry—that are undergoing significant transitions. A business model (Chesbrough & Rosenbloom, 2002) is the sum of complementary elements that define how a company creates, delivers, and captures value (Wirtz et al., 2016). Developing new business models is challenging for organizations and companies. It requires rethinking the strategy and exploring how to incorporate social and environmental dimensions into business architecture (Gassmann et al., 2014; Teece, 2010), design (Boons & Lüdeke-Freund, 2013; Cavicchi & Vagnoni, 2020; Evans et al., 2017; Lüdeke-Freund et al., 2019), innovation and strategy (Magretta, 2002), interconnected and interdependent activity systems (Zott et al., 2011), value generation (Osterwalder & Pigneur, 2010; Osterwalder et al., 2005), open innovation (Podmetina et al., 2017; Vanhaverbeke & Chesbrough, 2014), and managerial and entrepreneurial analysis units (Schaltegger et al., 2016). According to Amit and Zott (2020), business models are opportunities for innovation and can be considered a relevant alternative for creating value for the organization capable of bringing benefits to its customers, suppliers, and other partners (Freudenreich et al., 2020; Matzembacher et al., 2020). Amit and Zott (2020) stress the fits between the business model, the classic strategy (strategic fit), the organization (internal fit), and the ecosystem (external fit). Business models emphasize a holistic approach, looking at the broader societal perspective. In an ecosystemic mindset (Health Proc Europe, 2021), silos are broken down to move toward a holistic mindset and circular thinking, thus replacing isolation by collaboration. The main idea is to simultaneously maintain or even increase economic prosperity by including the holistic concept of sustainability and in line with the multilevel perspective from above. In other words, a move from a business model focusing purely on profit, with low sustainable value, to a new business model with a high sustainable value (Matzembacher et al., 2020). Sustainable business models are viable avenues for companies to pursue corporate sustainability and shared value creation (Porter & Kramer, 2011) by improving the effectiveness and efficiency of their activities in the spheres of the natural environment, society, and the economy and still profiting from these activities (Lüdeke-Freund & Dembek, 2017; Schaltegger et al., 2016). "Shared value results from policies and practices that contribute to competitive advantage while strengthening the communities in which a company operates" (Porter & Kramer, 2011). According to Mourik et al. (2021), the business model related to energy efficiency is a product-based and technology-centered model and directed toward the commercialization of energy efficiency technologies (Hamwi, 2019), e.g., smart grid services, lighting as a service, heating as a service, and smart energy management as a service. The main focus of the current contribution is on the Energy Service Company model (ESCO) and Energy Performance Contracts (EPCs). Energy Service Companies provide energy services that reduce energy consumption using more efficient energy systems. Energy Service Companies employ a unique financial model and assume most financial and technical risks. They provide holistic energy services and create environmental and social benefits (Hamwi, 2019; Hamwi & Lizarralde, 2019).

3 The ESCO Energy Transition Case

To be successful in the transition into the Post-Fossil-Carbon Society and to reduce climate change, there is a need to reduce energy consumption, in addition to energy flexibility. In its 2030 outlook, Europe imposes 40% CO_2 savings (compared to 1990), a minimum 32.5% energy savings (compared to 2007) and at least 32% of the energy must be renewable. Different member states have set different targets; for Belgium, this is 35% CO_2 savings by 2030 (EU, 2020). Energy use in buildings (residential, educational, business, industrial, government) represents 6.5% of direct and 12% of indirect global CO_2 emissions (Ritchie & Roser, 2020). The energy aspects of buildings are not the core business of companies. The Energy Performance of Buildings Directive in Europe requires all new buildings to be nearly zero-energy by the end of 2020. Additional efforts must be made, especially for existing buildings, as only approximately 1% of the building stock is renovated yearly (EU, 2019; Magrini et al., 2020). Energy optimization in buildings through Energy Service Companies (ESCO)—as defined by directive 2006/32/EC of the European Parliament (2006)—is an interesting and increasingly used methodology. It is "a natural or legal person who provides energy services and/or other measures to improve the energy efficiency in a user's facilities or buildings for a longer period, usually 5–20 years, and accepts some degree of financial risk by doing so" (Bleyl, 2014; Bleyl et al., 2019). The ESCO and Energy Performance Contract are output-driven. The Energy Performance Contract is often combined with a maintenance contract; thus, the bonus–malus ratio can be negotiated (Belesco, 2020—Fig. 2). Interactions with all building stakeholders (Franco et al., 2017, 2018) are important to obtain a good bonus/malus ratio for the Maintenance Energy Performance Contract—(M)EPC. The stakeholders are building owners, building operators, facility managers, school boards, and users (professors, students).

On the other hand, the total cost of ownership shows that only 20% of the costs over the entire life are related to the construction costs and 80% to the maintenance afterward. This 80% can be largely attributed to energy (Kale et al., 2016). The interaction of several stakeholders during the process enhances the integrated business model (Bleyl, 2014). Figure 3 explains the integration across the supply chain.

Non-energy benefits (Freed & Felder, 2017) have recently increased in importance when using an EPC, partly due to initiatives such as the WELL Building Standard (Well Standard, 2020) and the BREEAM standard (Breeam, 2020; World Green Building Council, 2020). The Well Building Standard provides a model for developing and integrating functions that promote human health and comfort in a built environment. The World Green Building Council states that improved indoor air quality leads to an 8–11% increase in worker productivity. Moreover, a healthier

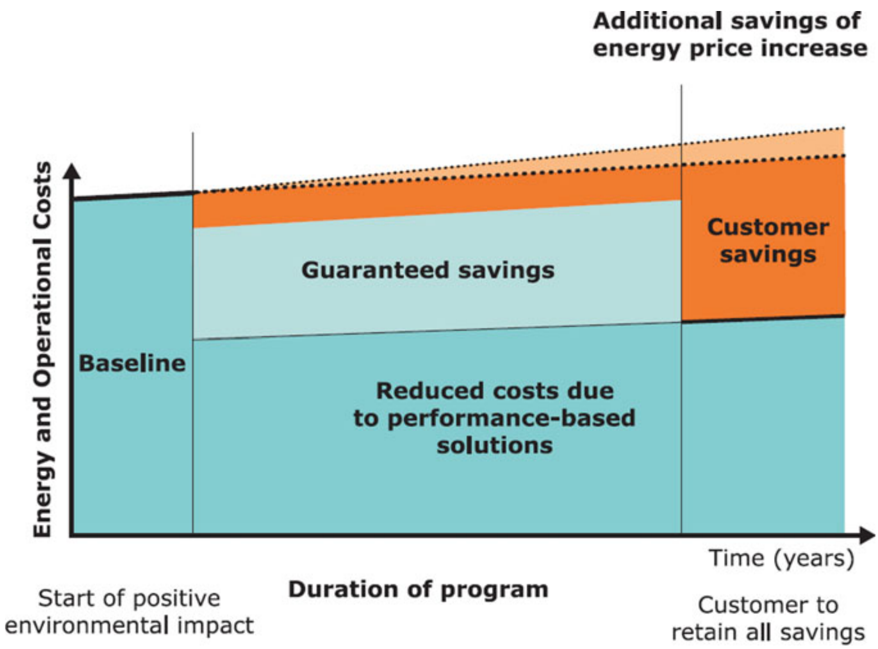

Fig. 2 Bonus–malus system for energy performance contracts (Belesco, 2020)

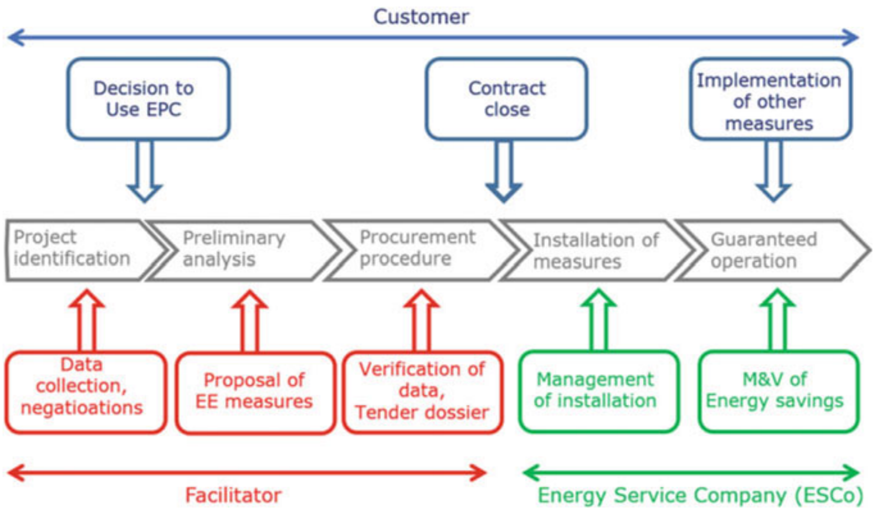

Fig. 3 Role of different stakeholders in energy performance contracts (adapted from Bleyl, 2014)

building has been shown to significantly decrease absenteeism and illness. A "profit" of 1% of the wage costs is often included in the business model (World Green Building Council, 2020). The combination of the MEPC with a more holistic vision linked to the Sustainable Development Goals of the United Nations (UN, 2015, 2020) is shown in Fig. 4.

Educational buildings have enormous potential for improvements in energy efficiency. They represent a large volume managed by a single owner. Moreover, they offer a forum to involve various stakeholders (facility managers, visitors, students, teaching, and research staff) with diverse backgrounds to create, support, and marshal evidence for energy conservation. Energy efficiency has a key role to play in the move toward using the educational campus as a living lab (Franco et al., 2017, 2018; Mazutti et al., 2020)—combining student learning with carbon reduction aspirations (Franco et al., 2022).

In what follows, an interpretive case study according to Walsham's (2006) classification is presented for an energy transition case. In line with Yin (2009) and the complexity of the research topic, a qualitative approach supplemented by expert interviews is suggested. Interpretive methods such as multiple case studies are the preferred method to study holistically complex phenomena within a real-life context such as energy transition and novel insights in energy business models. The proposed case study focuses on the energy efficiency of educational buildings in Belgium. Pooling (clustering) of campus buildings leads to optimization of payback periods and standardized contracts. We discuss the pooling of two building clusters:

- Cluster 1: Sint-Niklaas Association of schools (secondary education—private and public): several owners—one energy coach. The association of schools in Sint-Niklaas has 54 different locations in the city, united in four different school

Fig. 4 Holistic view of the maintenance energy performance contract approach

communities: GO! Education of the Flemish Community, Municipal Education Sint-Niklaas, the Sint-Niklaas primary, and the Sint-Niklaas secondary school community, both Catholic Education Flanders. Eleven different authorities manage these 54 school locations (23,000 students and 2700 employees). This is a unique project for Flanders, as there is only one energy coach for all buildings (Franco et al., 2017, 2018).

- Cluster 2: PXL University of Applied Sciences and Arts (higher education—public): several buildings—one single owner. PXL University of Applied Sciences and Arts has nine faculties and is organizedin a quadruple helix model (Carayannis et al., 2012), i.e., the interaction between government, knowledge institutions, (regional) business and industry, and the broader society. PXL is a public body and the sole owner of its buildings. It has 10,500 students and employs approximately 1200 employees.

Value propositions for stakeholders and the energy system are investigated, particularly with respect to the business model of Energy Service Companies—the "ESCO energy transition case". The ESCO case can be classified as a holistic innovation project with an overall impact on sustainable performance and competitive advantage.

4 Main Findings and Discussion

Clustering can offer many benefits, both technically and financially, although the complexity of the cluster must be considered. Shared and multiple value creation (Porter & Kramer, 2011) is of vital importance in the ESCO case. A tailor-made sustainable energy business model (Franco et al., 2020) emerges: the public–private partnership *model* employing a so-called "special purpose vehicle" governance structure. The selected business model relates well to transitions in government and higher education, where the public part of the sustainable energy business model is mostly about societal impact and the private part relates to return on investment for the value proposition. The potential for mutual gains has been verified by improving energy efficiency (public part) and investor financial returns (private part). This confirms the emergence of a holistic model for measuring sustainable performance generated by innovative projects.

Cluster 1—School Association Sint-Niklaas

Due to the complex structure of the 54 schools in Sint-Niklaas and the specific cultures within each school board, it is not possible to apply a copy–paste principle and roll out an identical process in each school. The Energy Performance Contract drawn up by the schools is a pilot project in 2018, which brings about additional uncertainties. However, it will act as a catalyst for other schools in the association of schools in Sint-Niklaas. After many workshops with all stakeholders, the energy coach performed the first audit for four different schools in the association. Two scenarios were developed: Scenario 1 limits the yearly investment budget for the ESCO to € 12,500 per school and per year that the contract is supposed to last. This budget corresponds to approximately 10% of the average annual energy consumption. Considering the average lifetime of 15 years, an investment cost of € 187,500 per school is allowed. Scenario 2 considers an additional investment budget for the schools of € 200,000 per school throughout the project, which increases the total investment cost allowed per school to € 387,500. The financial and CO_2 savings are reported in Table 2. If this money was transferred to the ESCO, the discounted payback time for the ESCO would be below 15 years, so a contract of 15 years becomes feasible (Berk & DeMarzo, 2015). By clustering the investment over the four schools, financial savings in three schools can subsidize the energy savings in one school. Unfortunately, the internal rate of return (IRR) is too low to get the ESCO on board. Even if the total financial savings are transferred to the ESCO, the internal rate of return equals 9.3%, whereas a typical ESCO often requires a minimum return on investment of at least 15%. As the NPV is positive, it is possible to transfer part of the savings to the ESCO.

Cluster 2—PXL University of Applied Sciences and Arts

At PXL University of Applied Sciences and Arts, the Energy Service Companies' (ESCOs) energy transition and the Maintenance Energy Performance Contract (MEPC) led to the setup of a transition team, as shown in Fig. 5. The transition group

Table 2 Scenario 1 **(Scenario 2)**—results cluster (4 schools)

	Electricity (kWh)	Gas (kWh)	Fuel (kWh)
Total annual consumption	1,182,194	3,822,663	2,863,236
Annual savings (%)	14 (**32**)	9 (**15**)	9 (**9**)
Total investment (€)		552,274 (**1,227,082**)	
Annual savings (€/year)		55,551 (**96,693**)	
Payback time (PBT) (year)		9 (**11**)	
(DPBT) (year)		11 (**14**)	
IRR (%)		9.3 (**5.7**)	
(NPV) (€)		248,948.71 (**167,524.64**)	
Reduction CO_2 (ton/year)		167.9 (**277.9**)	

The figures in bold = (Scenario 2)

is the pivotal point in the bottom-up and top-down realization of the new policy plan (2021–2026) in which (1) sustainability is included in the mission and vision and (2) further elaborated in the operational policies of education, research, personnel, and facility management. The transition group expanded to a "coalition of the willing" and later to a "coalition for change" in line with the multilevel perspective approach.

The Maintenance Energy Performance Contract (MEPC) introduction might only be valid for four schools in the Sint-Niklaas secondary school cluster. In contrast, it is a catalyst for all the building complexes in the PXL cluster. This is highlighted in the elements of strategic vision and long-term orientation. MEPC is used as the kick-off for a sustainability project within the United Nations Training affiliate (CIFAL-UNITAR Flanders), i.e., the Sustainable Development Goals Pioneer label. The PXL

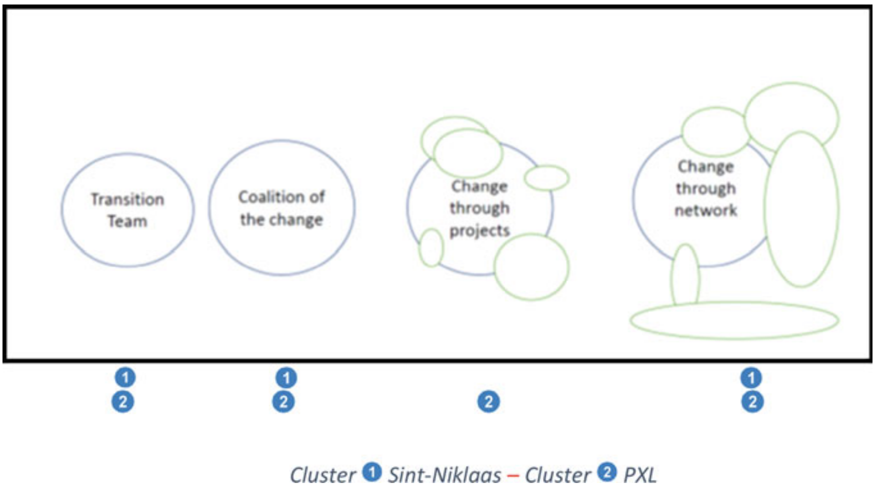

Fig. 5 Change through transition teams (Van Yperen et al., 2017—adapted)

cluster collaborates with local small businesses and industry partners such as the VOKA Chamber of Commerce in a cocreation process to incorporate energy reduction, waste, water, and circularity in the MEPC concept. Additionally, a pilot project on the PXL-Green and Tech (technology) campus was kicked off as a living lab for all building users. PXL will investigate an extended sustainability performance contract process, where not only will energy saving be an objective but equally important:

- Realization of other sustainability aspects, such as water savings, circular renovation, waste reduction.
- Intensive involvement of students and professors throughout the entire trajectory over several academic years.
- Development of key performance indicators, measurements, and analyses.
- Stakeholder management and searching for synergies at the campus level (e.g., one central heating network for the entire campus).

Based on the data collected in the investment matrix, we consider two investment scenarios (Table 3). The base case "heating/sanitary hot water (SWH) and lighting" has an investment volume of € 2,610,903, which generates annual savings of € 242,569 with a simple payback time of 11.5 years, and the enhanced case "heating/SHW and lighting" has an investment volume of € 4,145,854, which generates annual savings from € 296,581 with a simple payback time of 15.2 years.

Table 3 Base and enhanced case PXL buildings

Topic	Base case	Enhanced case
Consumption total (kWh/y)	9,891,356	9,891,356
Consumption total (kWh/m^2/y)	136.9	136.9
Consumption total (€/y)	778,044	778,044
Consumption total (€/m^2/y)	10.8	10.8
Total investment (€)	2,610,903	4,145,854
Total investment (€/m^2)	36.1	57.4
Savings (kWh/y)	3,329,616	4,156,002
Savings (kWh/m^2/y)	46.1	57.5
Savings (kWh/y)	3,065,465	3,869,488
Savings incl rel (kWh/m^2/y)	42.4	53.6
Savings (€/y)	242,569	296,581
Savings (€/m^2/y)	3.4	4.1
Savings (€/y)	226,720	271,940
Savings (€/m^2/y)	3.1	3.8
Savings total (%)	33.66	42.02
Savings total incl effect rel (%)	30.99	39.12
Payback time (y)	11.5	15.2
Reduction CO_2 (ton/y)	606	762

A focus group of experts was created for an in-depth understanding of possibilities to measure holistic innovation models. The experts agreed that the main parameters included in the analyzed elements are R&D, creativity, cultural design thinking, open innovation, digitalization, sustainable development, strategic vision, sustainable and competitive advantage, long-term orientation, and uncertainty avoidance. For the measurement of the results, a visualization method was applied. Experts evaluated each parameter from the ESCO case by applying symbols, as shown in Table 4.

One aspect that differs in the two cases is uncertainty avoidance (Hofstede, 1997). Belgium has a history marked by governments and nonconsensual rules. This fact generates a search for security in organizations, more deductive teachings and training, and more detailed rules (change policies are considered stressful). Regarding "uncertainty avoidance", despite the national Belgium culture trend (Hofstede, 2021), the PXL case shows an effort to overcome this national feature. This fact indicates that the members of the PXL case feel more comfortable with innovative or unknown situations and do not use beliefs and agreements that try to avoid them (which can be seen in the "open innovation" and R&D dimensions). Regarding creativity and design thinking, both cases are similar. Considering "long-term orientation" (Hofstede, 1997), the cases were also evaluated similarly, although the "strategic vision" is more present in the PXL case. The long-term view indicates a pragmatic orientation when people believe that the truth depends greatly on the situation, the context, and the time (Hofstede, 2021).

Table 4 Analysis of holistic elements of innovation projects within the ESCO case

Holistic approach elements	ESCO cluster 1 School Association Sint-Niklaas (secondary education—private/public sector)	ESCO cluster 2 PXL University of Applied Sciences and Arts (higher education—public sector)
R&D	○	◕
Creativity	◕	◕
Culture	●	●
Design thinking	◔	◔
Open innovation	◑	●
Digitalization	◕	◕
Sustainable development	◕	◕
Strategic vision	◑	●
Sustainable and competitive advantage	◔	◕
Long-term orientation	●	●
Uncertainty avoidance	●	◑

Symbols: ●—yes; ○—no; ◕, ◑, ◔—partly

Considering the ESCO case from a sustainable performance perspective, Tables 5 and 6 show that this holistic innovation project applies the eight fundamental principles of sustainable excellence and the four theories supporting this vision.

Table 5 ESCO energy transition case and the fundamental principles of sustainable performance

Strategic level	Principles supporting sustainable excellence
Vision	The project creates a sustainable future for the owners of the buildings, their users (students and teachers), and the Regional and Federal Authorities, allowing to meet requirements imposed by energy transition For PXL, the SDGs are integrated into the policy plan (2021–2026) (mission and vision)
Strategy	The project adds an accurate value for each key stakeholder – For the owners by increasing energy efficiency, reducing then the use and maintenance costs of their infrastructure, and freeing budgets for alternative projects (especially, for pedagogical projects directly connected to their main educational missions) – For users (students, researchers, and teachers) by benefiting from a healthier and environmentally efficient work environment – For Federal and Regional Authorities by reinforcing their capacity of meeting long-term environmental objectives imposed by the Energy Performance of Buildings Directive The project develops continuously organizational capabilities by its very long-term perspective, by its focus on energy efficiency in the use and maintenance of buildings, and by being supported by an adequate and specific long-term contract The project harnesses creativity and innovation in a cocreation perspective with key stakeholders using a Specific Purpose Vehicle built up in a long-term horizon for effectively meeting the expectations of each stakeholder and by its ability to design and implement new innovative intangible and tangible solutions for solving the evolving problems caused by the objective of maintaining energy efficiency results in a long-term perspective
Operational activities	The project is led with vision and engagement, inspiration and integrity, capitalizing on strict and transparent governance of the SPV put in place for controlling the project The project is managed with agility and responsiveness, evolving in its implementation with the opportunities offered by the development of technologies focused on energy efficiency The project is succeeding through the talent of the many motivated people involved all along with its design and implementation phases
Mission	In the two clusters considered, the project aims at sustaining outstanding and resilient energy efficiency results For PXL, the SDGs are integrated into the policy plan (2021–2026) (mission and vision)

Table 6 ESCO energy transition case considered from the four dominating theories supporting the EFQM 2020 model

Theory	Application to the ESCO energy transition case
Resource-based view	The project is based on a permanent combination of human, technical, and intangible resources, resulting in the production of new technological solutions and of a specific know-how in terms of energy efficiency practices, in financial returns for the Energy Service Company acting as a facilitator and in budgetary results for owners of the buildings
Global value chain theory	The project is completely developed in a global value chain vision, with the emergence (at a macro level) of a new economic actor acting as a facilitator in a support position between the multiple owners and beneficiaries and with meaningful evolutions in the internal value chain of each stakeholder (through the transfer of costly and unproductive activities to the facilitator)
Strategic alignment theory	The project is by nature strongly aligned with the constraints and opportunities emerging from the global environment, being justified and built up for meeting notably the objectives of the Energy Performance Buildings Directive
Stakeholder theory	And finally, this project appears as a typical application of the stakeholder theory as expressed by Freeman (1984) and Donaldson & Preston, 1995, solving the paradoxes induced by the diverse specificities and the multiple and often divergent expectations from many stakeholders

5 Conclusions, Limitations, and Future Research

There is a paradigm shift toward meeting societal needs and mission goals such as climate change and energy transition beyond conventional economic needs and reshaping business as usual toward a more holistic approach to business and innovation. The current research on innovation and its impacts on performance management still largely neglect this, while innovation provides momentum for new and formerly unexplored solutions for societal, economic, technological, and environmental challenges.

The Energy Service Companies' (ESCOs) energy transition case confirms the emergence of a holistic model. It is a good example of how a holistic model for measuring sustainable performance generated by innovative projects could be created. The proposed ESCO case is an excellent illustration of scaling up and compliance with the EPC standard for buildings. This research also contributes to the existing scientific literature with an analysis of a multilevel perspective by classifying business models, giving insight into lifelong learning, highlighting EFQM, anchored in four dominating theories in management science, which in line with the United Nations Sustainable Development Goals gives new insight into new measuring possibilities of sustainable performance. The findings support the unique role of the quadruple helix approach in holistic innovation projects and emphasize the role of higher educational institutions in all aspects of business development.

Further research should be devoted to analyzing a holistic approach to innovation projects from the perspective of higher educational institutions. Higher education is understood as a national development function that aims to prepare talent and create added value for the economy. However, the question remains how much added value higher education brings.

6 Closing Remark

A transition from one-sided driven economic models toward multisided ecosystem models and a transition from shock-sensitive to resilient systems is needed. We are lucky that pioneers have emerged, especially for the energy transition. A movement has been set in motion that must now go into top gear. The different interpretations and approaches to sustainable development make it clear that there are no simple solutions. Even if the analysis of the wicked problems is shared, a simple approach remains difficult. In addition, there are also contradictions within the sustainable development goals themselves, but this should not lead to avoiding the debate. In contrast, interpretation from different points of view is important to reach a more holistic view, involving as many stakeholders as possible (inter- and intradisciplinary). Ultimately, we are preparing the world we want to live in for the next generations, and it is the world of tomorrow that we will shape through our actions today.

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Comparative Studies

A Ray of Hope for Central and Eastern Europe: Has the ICT Service Sector Become a Cure for Lagging Behind the Rest of EU Countries in Global Value Chains?

Ewa Cieślik

Abstract The CEE economies (CEE) had relatively high positions in GVCs during the first years after EU accession. However, over time, CEE was reduced to factories assembling intermediate products. The advanced links of the value chain were dominated by Western European countries, as well as Asian countries (mainly China). However, an opportunity has arisen for CEE economies in rebuilding their position in GVCs in terms of a new sector services. In view of the adoption of Industry 4.0 by many economies, the article focuses on ICT services as a potential source for the renewed position of CEE economies in GVCs. The main objective of the study is to analyse the place held by CEE in GVCs in services, especially in ICT services. The study verifies the hypothesis that services, particularly ICT services, are becoming a new activity through which CEE countries can improve their relative position in global production linkages. The results of the study proved inconclusive. Only selected CEE economies (usually with smaller GDP) performed better in ICT service in GVCs. The largest economies generally worsened their positions in the services' GVCs.

Keywords Global value chains · ICT services · Industry 4.0 · Central and Eastern Europe

1 Introduction

In recent decades, changes have been observed in the paradigm of international trade. As a result of decreasing trade barriers and the reduction in trade costs, companies were able to divide their production into stages and locate it in different countries according to their competitive advantage. Eventually, the production process became more fragmented, both geographically and vertically. This means that intermediate

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products are shipped across the board many times, and every exporting economy provides some value added according to its competitive advantage. As a result, global value chains (GVCs) have become one of the most important features of international trade. Many studies have described this phenomenon. For example, according to Gereffi and Fernandez-Stark (2011), GVC describes the complete process by which firms and employees work to bring a product from conception to final production and beyond. It includes activities such as concept, design, production, marketing, promotion, distribution, and support to the final consumer. GVCs can be organized within a single company or divided among different companies. The activities that make up a value chain have generally been carried out in interfirm networks on a global scale in the context of globalization. Humphrey and Schmitz (2002) tried to describe the scope of local upgrading schemes for producers that operate in global value chains. Moreover, they discussed industrial clusters for the role of interfirm collaboration and local authorities in facilitating development. They argued that clusters are introduced into GVCs in different ways and that this has implications for enabling or disabling local-level upgrading efforts. In turn, Milberg and Winkler (2013) developed an institutional model of trade and development that began with the development of GVCs, or global production networks, that have restructured the global economy and its governance over the past decades. They find that offshoring contributes to greater economic instability in industrialized countries that lack adequate workforce facilities. Offshoring also helps businesses reduce domestic investment and instead concentrate on finance and short-run stock movements. Timmer et al. (2013) proposed an ex post accounting scheme of value added and employees that are directly and indirectly related to the production of final manufacturing products. The report of Kommerskollegium (2013) contributed to the state of the policy debate on GVCs and services, which is still in its infancy. Open trade and investment policies are critical to enable services to be facilitators of GVC development and operation, as seen from the outset. Service modal neutrality (implies that all modes of service delivery) and regulatory coherence are two more specific factors that contribute to this goal.

Central and Eastern European economies (CEEs) are a particularly interesting subject of GVC studies. The transition of the economic and political systems of the CEE states, initiated in the early 1990s, earned them EU membership in 2004. Accession to the European Union (EU) structures meant that these countries achieved the status of a free market economy and should be treated as full members of global business networks. Moreover, the decline in trade costs (transport and transaction), greater openness of their market, and the removal of trade barriers have all helped CEE states join GVCs.

Hence, CEE economies will be more heavily involved in global production linkages. Many empirical studies have presented the close and dynamic integration of these countries with the EU market (especially the EU-15) and in a more limited scope with the whole global economy as well (Amador et al., 2013; Behar & Freund, 2011).

Behar and Freund (2011) stated that the EU enlargement coincided with an increase in Factory Europe's complexity. They applied two measures of the complexity of intermediates products and showed that internal EU intermediates trading has become more sophisticated and uses more relationship-specific inputs over time and relative to external EU trade. The Factory Europe has become smarter, but not necessarily brawlier. They also proved an asymmetry—new members have become a more important source of intermediates for the EU-15, as well as a more important market. Basically, the structure of EU trade has changed: not only has the EU-15 given the new members a larger share of their duties, but it has also given them harder ones.

In turn, Amador et al. (2013) described the main features of GVCs between the euro zone as a whole and other major world trade players such as the USA, China, and Japan, which also function as monetary unions. Moreover, they proved that there is a strong correlation between regional production links in Europe, with Germany and Central and Eastern European countries playing a significant part. Generally, democratization, the strengthening of political and economic relations (particularly with the EU), and the modernization of many sectors (including the financial sector and more advanced industries) were common elements of the long-term development policies of the CEE countries. One of their priorities was the redirection of foreign trade towards the EU and joining the global production links.

The chapter analyses the place held by the CEE economies (11 countries: Czechia, Hungary Poland, Slovakia, Slovenia, Estonia, Latvia, Lithuania, Bulgaria, Croatia, and Romania; sometimes called EU-11) in GVCs in services, especially in ICT services, relying on trade in value-added data retrieved from the OECD's Inter-Country Input–Output Database, available during the period 2005–2018. The author assessed the role of these economies in international production links using value-added methodology.

In the author's opinion, there are common characteristics between CEE countries that justify studying them together. First, the level of economic sophistication of the CEE countries was quite low and similar. However, it should be noted that the structures of their economies were different. Second, their involvement in GVCs was low. Third, the countries' foreign trade was based on low- to medium-advanced products. Fourth, the countries had sizable labour resources. Fifth, the governments of these countries began to introduce various strategies to integrate them into Western European value chains. Moreover, there are under the transformation process of their economies (first from the postcommunist structures, then towards service-based economies). All analysed CEE countries differed from the Western European economies significantly, both in the advancement of their production structures and their role in global production links.

This study led to the verification of the hypothesis that services, particularly ICT services, are becoming a new activity through which CEE countries can improve their relative position in global production linkages.

The choice of services for analysis was motivated by the following observations.

First, between 2005 and 2018, ICT services in all CEE countries were characterized by the high growth of total gross exports, gross exports of final products, value added and gross exports of intermediate products. Second, after the 2008 crisis, the average productivity growth rate of ICT services in all countries not only outstripped other types of services in most CEE economies but also exceeded the average annual productivity growth in manufacturing. Furthermore, the gross value added per person employed in ICT services also surpassed other service activities after the financial crisis. Third, all CEE countries have introduced programmes promoting the development of Industry 4.0, including ICT services and innovative technologies.[1] Fourth, in all analysed countries, the market value of ICT services has grown significantly. Fifth, there is increasing expenditure on R&D reflected in the climbing export of high-tech goods, rising revenue from the sale of licences and patents abroad, and an increasing number of registered trademarks and designs (CEIC, 2021).

The study consists of five sections and introduction. First, it discusses the role of CEE economies in global production links in services in the light of the literature, followed by a brief description of the methodology applied in this study. The third and fourth sections analyse the CEE countries in terms of paths of participation in GVCs in general and in ICT services and verify the research question stated in the chapter. The last section consists of conclusions.

2 The Links of CEE Economies with the Global Economy in Terms of GVCs: Review of the Empirical Literature

Several studies have been conducted to analyse the GVC links of CEE economies in the context of an international economy. The author decided to present the studies conducted after the world financial and economic crisis started in 2008. This was the turning point in the development of the GVC relations of the CEE economies. According to the UNCTAD report (2015), after the crisis, technical and technological developments were the main motor of production fragmentation. Moreover, regional agreements have started to play an important role, and whole trade liberalization has not gone further at the world economy level. Suppliers from the CEE region became increasingly integrated into EU GVCs, as proven by Domański and Gwóźdź (2009) and Jürgens and Krzywdzinski (2009). There was also some literature proving that Germany in particular gradually weakened its trade ties with Southern Europe in favour of CEE states (Simonazzi et al., 2013). Similar conclusions led Coricelli and Wörgötter (2012) to argue that for Germany, the New Members of the EU were "an opportunity to outsource low-skilled processes abroad, import the necessary inputs from Central European cost-efficient economies, and keep mid-skilled processes on domestic soil". However, there were some signs of upgrading the role of CEE

[1] There are some examples of innovation strategies introduced by chosen CEE governments. In Poland, there are several national programmes focused on boosting innovation, e.g. Start in Poland, Polish Industry 4.0, Future Industry Platform, Smart Growth Programme or From Paper to Digital Poland. Czechia introduced the National Research, Development and Innovation Policy of the Czech Republic 2016–2020 or Innovation Strategy of the Czech Republic 2019–2030. Hungary operates inter alia Industry 4.0 Working Groups. Romania introduced National Strategy on Digital Agenda for Romania 2014–2020. Slovakia introduced programms the Smart Industry for Slovakia or Industry 4UM.

in GVCs before the crisis (Sass & Szalavetz, 2013). However, this trend did not continue.

An interesting observation made in Baldwin's (2014) writing: "The world economy is not global; it remains regionally segregated, such as Factory Asia, Factory Europe, and Factory North America. What matters is not value (added) but jobs, especially good jobs". This statement showed that the enlargement of the EU has played an important role. Citing Degain et al. (2017): "Eastern European countries have developed intensive bilateral trade links in industrial inputs with other European countries. The joining of the EU and the adoption of its regulations have been conducive to the development of these ties within European GVCs. Czechia, Hungary, and Poland, the largest players in intraregional trade in manufacturing inputs among European economies, accounted for more than 11% of intra-Europe exports in intermediate goods in 2015, a share that has more than quadrupled since 1995".

Many studies have emerged that examine the case of CEE states, but it is derived from the literature that the transportation industry played the predominant role (Pavlínek & Ženka, 2011; Sturgeon et al., 2008). Other sectors have only been examined more rarely and selectively, e.g. the apparel industry in Slovakia in Smith et al. (2014) or Plank and Staritz (2013) and electronics in Hungary in Sass and Szalavetz (2014). For a more comprehensive study on GVC upgrading in the CEE region, see Vlčková et al. (2015).

In CEE economies that excluded the traditional core regions of the transport equipment industry, such as Czechia or Slovakia, the crisis interrupted the steady 15-year increase in FDI (Szent-Iványi, 2017). On the other hand, Dischinger et al. (2014) argued that, being dependent on FDI inflows, CEE economies were prone to potential value transfer to economies that were the source of capital. According to Pavlínek and Ženka (2016), foreign-owned companies created and captured much more value than less developed domestic firms in the CEE region. One step further went to Nunn (2007), who identified "contract-intensive" industries in the CEE states that included transport equipment, computer equipment, and telecommunications equipment, which are among the most exported articles from this region. Similar conclusions were drawn by Sankot and Hnát (2015) and Ma et al. (2010). In turn, Sass and Hunya (2014) proved that CEE countries have recently been less involved in traditional industries with labour-intensive activities and more involved in electronics and transport industries. According to Sass and Szalavetz (2013), Hungarian transport and electronics were affected the most by the crisis; companies have had functional upgrading effects and reorganization. Stöllinger et al. (2018) argued that thanks to the New EU Members, the EU-28 as a whole suffered a moderate loss in GVCs.

According to some studies (Fortwengel, 2011; Jacoby, 2010; Cieślik, 2019, 2022), CEE economies are found in downstream markets in GVCs in the majority. Unfortunately, the expansion and competitiveness of CEE states' exports have been supported by acquired technology, capital, and know-how. The main concern of CEE economies is to climb to the upstream market of GVCs for more knowledge-intensive production. Similar results were obtained by Vrh (2015). These studies showed that the CEE countries experienced an approximately 5% lower domestic value added embodied in their trade partner gross exports compared to the EU-15. Unfortunately, the gap between EU-15 and New Members of the EU is visible in knowledge-intensive industries (8%) and the lowest in knowledge-intensive services (0.3%). Furthermore, it should be remembered that CEE economies need to face strong competition from Asia, especially China, which is determined to increase the manufacturing of the GVC.

One step further, Smith and Swain (2010) argued that CEE state integration with the EU was driven mainly by export-led development and GVCs, which was an important implication for the dissemination of the crisis. Kandilov and Grennes (2010) and Marin (2010) examined changes in employment and labour structure in CEE economies as a result of joining GVCs. Hillberry (2011) proved that improvements in transport connectivity have been significant for intensification of production fragmentation in CEE countries. Behar and Freund (2011) applied international trade statistics in intermediate products to examine fragmentation in Europe. They discussed how the process of EU integration could facilitate intra-EU trade in intermediate goods. In turn, Elekdag and Muir (2013) examined the relations between Germany and CEE. They stated that these countries underwent deep economic integration, which led to the development of GVCs within the EU. They suggested that final demand in Germany was not necessarily the main determinant of the exports of CEE economies to Germany. Moreover, the study proved that the side effect of the growth in openness of the countries analysed was a greater exposure of the CEE states to global shocks.

According to empirical studies by OECD (2017) and World Bank et al. (2017), the growth of CEE exports relied mainly on import inputs and relatively high proportions of intermediate goods in trade. It is believed that the regional production links of the CEE countries were greatly based on German and EU-15 production. CEE economies also play an important role in the development of multinational corporations (Rahman & Zhao, 2013).

Generally, CEE economies are perceived as more specialized in labour-intensive and resource-intensive industries by using their comparative advantages (Dobrinsky, 1995). This specialization seemed to be the effect of foreign direct investment (FDI) inflows and trade in the sector (especially intraindustry trade). However, this situation is changing. Apart from manufacturing, CEE economies have become more involved in global services linkages, which reflects the general tendency in international trade.

The latest edition of the World Trade Report of the WTO highlighted that the services sector has become the most dynamic component of international trade and that its role has grown in importance. The service sector accounts for approximately 50% of GDP worldwide, on average. For developed economies, these numbers are much higher—approximately 34% of their GDP is created by services. The share of services in GDP proportion is also growing rapidly in developing economies. According to the WTO, trade in services has increased on average 5.4% per year since 2005. In contrast, trade in goods has increased annually by 4.6% since 2005. Trade in ICT and R&D services has recorded the most rapid annual growth over the past decade. The organization predicts that by 2040, the share of trade in services in total trade could increase by 50%. This phenomenon is the result of decreasing trade costs, digitalization processes, and lifting restrictions (WTO, 2019).

More detailed studies focusing on selected branches of CEE can be found. Kaminski and Ng (2005) emphasized that the growth of specialization in selected sectors was an important driver of economic growth. They presented production links, among others, in sectors experiencing the "information revolution" in Hungary. According to Kaminski and Ng, these sectors underwent a significant transition: a shift from labour-intensive production to more advanced production connected to an expansion beyond the European markets.

In conclusion, there are very few studies that focus on the role of services in GVCs of CEE economies. Usually, this participation has been analysed with regard to manufacturing or as a background to the manufacturing, especially automotive or electronics industries. Many authors did not treat services as an important part of GVCs in CEE states before the crisis. Today, this perception has changed, while CEE economies are losing their positions in manufacturing GVCs, particularly in their flagship industries. Therefore, this article is a contribution to the literature on the subject. The evaluation of the participation and relative positions of CEE economies in GVCs, as well as the foreign value added embodied in their gross exports and the domestic value added embodied in their gross trade partners, has never been conducted, to the best of the author's knowledge.

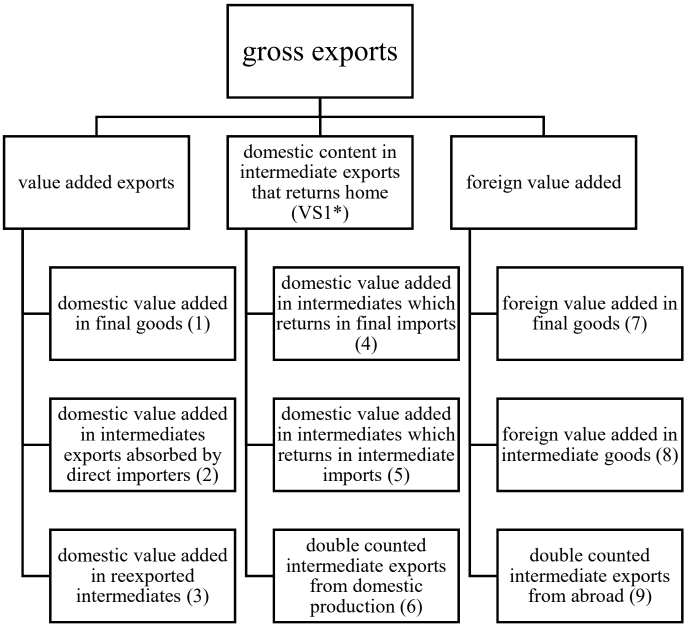
3 Methodology

To analyse the participation and position of the CEE economies in GVCs, the methodology of value-added flows was applied. A multiregional input–output model was employed, which also included value added in industries/sectors. This approach was a combination of methods adopted by several authors (Hummels et al., 2001; Johnson & Noguera, 2012; Koopman et al., 2014; Timmer et al., 2012). These authors have applied models to calculate the value added for the entire economy, not for individual sectors. In the applied approach, these models were expanded to sector/industry analyses, as far as statistical data allowed.

The applied method makes two main assumptions for the input–output measure: (a) first, all imported intermediate inputs must contain 100% foreign value added and no more than one country can export intermediates; (b) second, it is assumed that the intensity of import input use is the same whether goods are produced for export or for domestic final demand (Scheme 1).

Currently, there are S sectors and N countries. Each sector in one country produces a single differentiated product.

$$\begin{bmatrix} X_{11} & \cdots & X_{1N} \\ \vdots & \ddots & \vdots \\ X_{N1} & \cdots & X_{NN} \end{bmatrix} = \begin{bmatrix} B_{11} & \cdots & B_{1N} \\ \vdots & \ddots & \vdots \\ B_{N1} & \cdots & B_{NN} \end{bmatrix} \begin{bmatrix} Y_{11} & \cdots & Y_{1N} \\ \vdots & \ddots & \vdots \\ Y_{N1} & \cdots & Y_{NN} \end{bmatrix},$$



Scheme 1 Gross export decomposition method. The number of equations are in brackets. Based on Koopman et al. (2014)

where

- B total amount of gross output in producing state i needed to fulfil final demand in state j
- X gross output produced in state i and absorbed in state j
- Y gross output produced in state i and consumed in state j.

Then, a value-added production matrix $\hat{V}BY$ was created:

$$\begin{bmatrix} \hat{V}_1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \hat{V}_N \end{bmatrix} \begin{bmatrix} X_{11} & \cdots & X_{1N} \\ \vdots & \ddots & \vdots \\ X_{N1} & \cdots & X_{NN} \end{bmatrix} = \begin{bmatrix} \hat{V}_1 \sum_j^N B_{1j} Y_{j1} & \cdots & \hat{V}_1 \sum_j^N B_{1j} Y_{jN} \\ \vdots & \ddots & \vdots \\ \hat{V}_N \sum_j^N B_{Nj} Y_{j1} & \cdots & \hat{V}_N \sum_j^N B_{Nj} Y_{jN} \end{bmatrix}$$

Elements in the diagonal matrix mean value added absorbed at home. All elements of the off-diagonal matrix mean value added embodied in the partner's gross exports.

Because the study focused on the foreign value added embodied in gross exports, some equitation concerning domestic value added and domestic intermediate exports that returns home were omitted.

Foreign content embodied in a county's gross exports can be formulated as follows:

$$\mathrm{VS} = \sum_{j \neq i}^{N} V_j B_{ji} E_{i*} = \sum_{t \neq i}^{N} \sum_{j \neq i}^{N} V_t B_{ti} Y_{ij} + \sum_{t \neq i}^{N} \sum_{j \neq i}^{N} V_t B_{ti} A_{ij} \left(I - A_{jj}\right)^{-1} Y_{jj} + \sum_{j \neq i}^{N} V_t B_{ti} \left(I - A_{jj}\right)^{-1} E_{j*}$$

where $\sum_{t \neq i}^{N} \sum_{j \neq i}^{N} V_t B_{ti} Y_{ij}$ is the foreign value added embodied in final goods exports; $\sum_{t \neq i}^{N} \sum_{j \neq i}^{N} V_t B_{ti} A_{ij} \left(I - A_{jj}\right)^{-1} Y_{jj}$ is the foreign value added embodied in gross exports of intermediate products; and $\sum_{j \neq i}^{N} V_t B_{ti} \left(I - A_{jj}\right)^{-1} E_{j*}$ is the double-counted value added of intermediate goods produced abroad.

Eventually, the decomposition of gross exports may be formulated as follows:

$$\begin{aligned}
\mathrm{DCP} = & \left[\underset{(1)}{V_i \sum_{j \neq i}^{N} B_{ii} Y_{ij}} + \underset{(2)}{V_i \sum_{j \neq 1}^{N} B_{ij} Y_{jj}} + \underset{(3)}{V_i \sum_{j \neq i}^{N} \sum_{t \neq ij}^{N} B_{ij} Y_{jt}} \right] + \left[\underset{(4)}{\sum_{t \neq i}^{N} \sum_{j \neq i}^{N} V_t B_{ti} Y_{ij}} \right. \\
& \left. + \underset{(5)}{\sum_{t \neq i}^{N} \sum_{j \neq i}^{N} V_t B_{ti} A_{ij} \left(I - A_{jj}\right)^{-1} Y_{jj}} + \underset{(6)}{\sum_{j \neq i}^{N} V_t B_{ti} \left(I - A_{jj}\right)^{-1} E_{j*}} \right] \\
& + \left[\underset{(7)}{V_i \sum_{t \neq ij}^{N} \sum_{j \neq i}^{N} B_{ij} Y_{ji}} + \underset{(8)}{V_i \sum_{t \neq ij}^{N} \sum_{j \neq i}^{N} B_{ij} A_{ji} (I - A_{ii})^{-1} Y_{ii}} \right. \\
& \left. + \underset{(9)}{V_i \sum_{j \neq i}^{N} B_{ij} A_{jt} (I - A_{ii})^{-1} E_{i*}} \right]
\end{aligned}$$

Using the results of decomposition at the country sector level, an index can be drawn that helps to determine whether a country is likely to be upstream or downstream of the GVC in any sector. It can also be used to create a separate index that determines the extent to which a country sector is involved in the GVC.

For an index to represent a country's position (upstream or downstream), it is possible to compare that country's exports of intermediates in that sector that are used by other countries with that country's use of imported intermediates in the same sector. If a country is upstream in the GVC, it produces inputs for others by providing raw materials (such as Russia), supplying manufactured intermediates (such as Japan), or both; its indirect value-added exports (IV) share in gross exports would be higher for such a country than its FV share. Compared with the situation of a country that lies downstream in the GVC, it can be seen that it will use a significant amount of intermediates from other countries to produce final products for exports, and its FV share will be higher than its IV share.

This method applies a country sector level index for the position in GVC as the log ratio of a country sector's supply of intermediates used in exports from other countries to the use of imported intermediates in its own production. Following the framework and definitions by Koopman et al. (2014), the GVC relative position index was constructed:

$$\text{GVC\_Position}_{ir} = \text{Ln}\left(1 + \frac{\text{IV}_{ir}}{E_{ir}}\right) - \text{Ln}\left(1 + \frac{\text{FV}_{ir}}{E_{ir}}\right).$$

If the country sector lies upstream in the GVC, the numerator tends to be large. However, if it lies downstream, then the denominator tends to be large. If the relative position in GVCs is higher than 0, it means that the country is located in the upstream market. If the relative position in GVCs is lower than 0, it means that the country is located in the downstream market.

Other sectors can have the same values of the GVC position index but have very different levels of participation in GVCs. Hence, the position index must be used in conjunction with another index that summarizes the significance of the global supply chain for that country segment. Finally, a participation index for GVCs can be defined as follows:

$$\text{GVC\_Participation}_{ir} = \frac{\text{IV}_{ir}}{E_{ir}} + \frac{\text{FV}_{ir}}{E_{ir}}.$$

If a country is located in the upstream segment in the GVC (advanced stages of production), it is likely that it has a high value of forwards participation relative to backwards. This means that the country is more dependent on its own production. If a country specializes in the non-advanced stages of production (downstream segment), it is likely that it imports many intermediate goods from abroad and, therefore, it has high backwards participation. The GVC position index is constructed in such a way that states with high forwards relative to backwards participation record a positive value. The more general approach indicates that upstream economies produce raw materials or knowledge assets at the beginning of the production process (e.g. R&D or design tend to create more value added than assembly), while downstream economies assemble processed products or specialize in customer services.

4 Role of Services in Trade Links of CEE

Due to the transformation and growth of integration between CEE economies and EU countries, CEE states recently entered not only merchandise GVCs but also services links. The evolution of CEE and EU plans to invite these countries encouraged EU-based companies to invest to reduce production costs, particularly labour costs, and to exploit the comparative advantages of CEE (so-called efficiency-seeking investments). Certainly, lower labour costs compensated for the considerably lower productivity of employees in the CEE economies compared to the EU-15. For many investors, these markets become the extension of the domestic market and their production links. Furthermore, these countries in themselves were perceived as sufficient and very attractive locations for FDI from the EU.

Unfortunately, the streak was short-lived, and the CEE countries started to deteriorate their relative positions in manufacturing GVCs. Furthermore, these economies have faced strong competition from developing Asian countries, in particular China and ASEAN economies, that are determined to increase the links between manufacturing products and develop capabilities in knowledge-intensive manufacturing.[2] Therefore, CEE countries need a new activity that will be competitive and will lead them to the upstream market in GVCs. This activity could be in the service sector, especially more advanced services. According to the latest available data from the World Bank, the Baltic States, Latvia (63.5%), Estonia (62.7%), and Lithuania (61.6%), were characterized by the highest share of the service sector value added in GDP. In Hungary, services created only 56.6% of value added in GDP, which was the lowest result among the analysed states. However, all these countries relied their national production on the service sector mainly (World Bank, 2021).

The CEE countries mainly characterized a significantly high share of foreign value added embodied in their gross exports (FVA) in the years examined (2005, 2009, 2014, and 2018). After the global crisis in 2008, FVA in total gross exports fluctuated significantly. In all countries analysed, except Croatia, it peaked in 2014 and then fluctuated or sometimes showed a downwards trend. In 2018, Latvia and Croatia were characterized by the lowest FVAs (23.55% and 23.66% of gross exports, respectively), while Slovakia and Hungary relied the most on FVAs (48.1% and 46.29%, respectively). Statistics show that FVA surged significantly in Czechia (by 7.73% between 2005 and 2018) and decreased in Romania (by 3.15%). It is worth noting that except for Romania, all countries experienced an increase in FVA (Appendix, Table 1).

Generally, all the economies analysed are highly integrated within the value chain of the EU. Integration is particularly high in manufacturing, particularly in

[2] Since the financial crisis, manufacturing became more concentrated in CEE especially for Czechia, Hungary, Poland, and Slovakia. Nevertheless, most of employment and production in manufacturing is still located in the EU-15 countries, the importance of manufacturing for the CEE states should not be overstated. Since their accession to the EU, low factor costs attracted manufacturing in this region, but the employment share remained fairly constant approximately 20%, However, not all regions in CEE attracted manufacturing industries to the same extent (e.g. the Baltic States did not) (Stierle et al., 2018).

Table 1 Domestic and foreign value added of CEEs in selected years (in %)

		2005	2009	2014	2018	2005	2009	2014	2018
Czechia	Total	34.43	39.39	46.61	42.16	25.52	23.0	21.30	21.81
	Manufacturing	40.60	40.05	45.59	49.35	25.41	25.13	21.25	21.14
	Services	17.70	17.19	22.04	20.88	25.59	28.07	23.84	23.71
Hungary	Total	44.01	39.91	47.31	46.29	19.91	18.7	18.38	15.06
	Manufacturing	52.32	53.98	56.03	56.86	18.29	17.31	14.50	13.85
	Services	16.78	19.23	21.87	23.81	25.41	22.34	17.60	17.74
Poland	Total	24.68	27.89	32.98	31.03	31.45	20.5	28.57	26.24
	Manufacturing	32.01	31.71	35.57	39.96	34.93	32.96	32.08	28.42
	Services	13.15	12.49	13.74	17.72	26.07	25.97	23.56	23.07
Slovakia	Total	42.99	44.35	48.19	48.01	17.90	17.9	20.14	17.74
	Manufacturing	51.67	51.14	53.81	57.78	17.17	21.00	19.10	16.38
	Services	20.45	15.75	19.50	19.75	19.60	20.15	19.65	21.98
Slovenia	Total	33.28	37.52	36.11	36.80	21.48	18.20	23.91	19.65
	Manufacturing	40.64	37.82	41.41	45.34	21.28	23.49	20.50	18.65
	Services	16.85	16.91	19.47	21.71	22.02	22.15	21.06	21.41
Estonia	Total	30.41	27.82	36.94	35.35	23.54	24.22	22.11	23.18
	Manufacturing	39.06	37.82	48.17	46.05	25.94	26.20	23.20	23.74
	Services	22.77	18.56	23.49	24.82	21.37	22.25	20.73	22.56
Latvia	Total	21.37	18.75	22.20	23.55	26.17	28.25	27.94	26.02
	Manufacturing	28.35	24.82	29.58	30.01	33.46	36.92	31.98	31.31
	Services	15.69	15.09	16.01	18.78	20.19	23.38	24.46	22.11
Lithuania	Total	29.49	26.81	32.58	30.78	18.45	22.78	16.85	20.57
	Manufacturing	40.87	39.85	43.48	42.20	20.32	23.75	19.08	21.56
	Services	13.83	11.83	18.17	19.45	15.33	20.31	12.39	19.29
Bulgaria	Total	32.40	31.72	37.27	36.80	24.47	25.80	23.42	23.51
	Manufacturing	45.51	43.27	49.55	49.20	25.44	27.48	23.29	23.75
	Services	23.32	19.32	21.33	21.31	24.82	24.28	24.95	24.19
Croatia	Total	22.31	19.01	19.02	23.66	23.73	25.03	25.13	23.17
	Manufacturing	31.59	27.73	27.80	35.26	27.81	30.34	30.13	26.56
	Services	15.80	13.18	13.06	17.66	21.17	21.79	21.88	21.77
Romania	Total	27.56	19.77	23.59	24.41	23.94	25.82	32.35	28.92
	Manufacturing	33.71	25.00	28.82	29.75	25.19	26.87	32.41	30.79
	Services	13.37	12.76	17.51	18.77	21.31	24.33	33.16	27.38

Based on OECD's Inter-Country Input–Output Database, 2021

the electronics and transport equipment industries. Slovakian and Hungarian manufacturing were the most dependent on FVA (57.78% and 56.86% of gross exports, respectively), while Romanian and Latvian manufacturing were the least (29.75% and 30.01%, respectively). In Czechia, the largest increase in FVA was seen (by 8.75% between 2005 and 2018), while Romania reduced its dependence by 3.96%. Generally, in all analysed economies, except for Romania, FVA in manufacturing increased (Appendix, Table 1).

In turn, in the services sector of CEE, the FVA appeared to be much lower than in manufacturing in all the years analysed. This derives in part from the nature of services, which are less tradable than manufacturing products. However, currently, this type of activity has become an important part of GVCs. In 2018, such a low level of FVA in services persisted in Croatia (17.66% of gross exports), followed by Poland (17.72%), Romania (18.77%), and Latvia (18.78%). In 2018, Estonia had the largest dependence on FVAs in services (24.82%), which was still much lower than the FVA in manufacturing. The level of FVA services between 2005 and 2018 remained quite steady. The most significant growth in FVA services was observed in Hungary (by 7.03%), and the most noticeable reduction in FVA was in Bulgaria (by 2.01%). Unlike services, FVA in manufacturing growth showed a greater upwards tendency. In 2018, the largest gap (difference) between manufacturing and service FVA was observed in Slovakia and Hungary, where manufacturing certainly dominated. The lowest contrast in FVA was in Romania (Appendix, Table 1).

In the case of the total domestic value added embodied in the gross exports of trade partners (IVA) of the CEE countries, it is difficult to indicate a uniform trend. Recently, most of the countries analysed have reduced their total IVA shares or have remained at a similar level in the best case scenario. The exceptions were Lithuania and Romania, where IVA grew between 2005 and 2018. The largest reduction in IVA was observed in Poland (by 5.21% between 2005 and 2018). The lowest share of IVA in gross exports in the analysed period occurred in Hungary (15.06% of gross exports). In Romania, there was the most significant increase in IVA (by 4.98% between 2005 and 2018). The highest IVA was observed in Romania (28.92%) in 2018 (Appendix, Table 1).

In terms of IVA manufacturing, there was a similar situation as in total IVA—most of the CEE countries reduced their IVA significantly between 2005 and 2018. Only Lithuania and Romania increased their IVA in manufacturing (by 1.24% and 5.60%, respectively). The decline in IVA in manufacturing was much more noticeable than a drop in total IVA. Most CEE states became less important to their trade partners in manufacturing. The CEE countries are also losing their contractors in the field of transport equipment, which is their flagship industry. In general, according to the study, they relied more on foreign added value than they provided that value to their trading partners in total manufacturing (Appendix, Table 1).

When examining the service sector, the situation of IVA seems to be more complicated. There are CEE countries such as Slovakia, Estonia, Latvia, Lithuania, Croatia, and Romania where IVA in services increased between 2005 and 2018. The largest increase was observed in Romania (by 6.07%). Other countries did not improve their IVA. Surprisingly, among these economies were three of four Visegrád countries.

Moreover, no relation was observed between the increase in IVA and the contribution of services to GDP (Appendix, Table 1).

When IVA was analysed in the manufacturing and services sectors, there were two surprises. First, it was predicted that IVA should grow faster in services than in manufacturing when integration with the EU is deepening. This was dictated by the assumption that most CEE countries are connected to the EU's GVCs and that the service sectors are developing rapidly in their economies. The calculations showed that this tendency did not occur almost anywhere. In most countries, this growth was almost the same between 2005 and 2018. Only in Romania, Croatia, the Baltic States, and Slovakia did the fastest significant growth of IVA occur in services, not in manufacturing. In some economies (e.g. Czechia, Hungary, or Poland), the IVA in services decreased in the analysed period (Appendix, Table 1).

Second, it was expected that IVA in services would dominate IVA in manufacturing with time. This explicit conclusion cannot be drawn from the analysis. Moreover, the levels of IVA in services did not differ much from the levels of IVA in manufacturing. Only in five economies (Czechia, Hungary, Slovakia, Slovenia, and Bulgaria) was the difference between services and manufacturing positive. In other countries, IVA manufacturing outpaced services IVA (Appendix, Table 1).

Generally, in 2018, the largest participation of GVCs in total production was in Slovakia (65.75% of gross exports), while the lowest was in Croatia (46.83%). Almost all economies, except for Hungary, increased their participation in GVCs, especially Slovakia (4.86% growth between 2005 and 2018). The participation of GVCs of CEE countries differs depending on the sector. It should not be surprising that in manufacturing, there were much larger levels of participation. CEE economies, especially their automotive and electronic industries, are highly connected to GVCs; unfortunately, they are stronger in the downwards market than in the upwards market. In manufacturing, all countries, except for Latvia, increased their participation in GVCs. The largest participation was observed in Slovakia (74.16%), and the lowest was observed in Romania (60.54%). In services, these participations were not only much lower but also more balanced. In two countries (Hungary and Bulgaria), GVC participation in services decreased, but not significantly. The other countries increased their participation in GVCs in terms of services, especially Romania (by 11.47% between 2005 and 2018). The service sector in Estonia indicated the tightest links to GVCs (47.38%), while Lithuanian services were the least connected to GVCs (38.74%). It is worth mentioning that the participation indexes in services were on average twice as low as those in manufacturing (Appendix, Table 2).

The FVA and IVA values are directly reflected in the relative position in GVCs. In terms of total production, most CEE states deteriorated their positions, except for Lithuania and Romania. Most of the countries are located in the downstream market. The only exceptions are Latvia and Romania. Latvia was in the upstream market throughout the entire period (including the years not quoted in Table 2). An interesting case, however, is Romania, which when entering the EU was considered to be one of the least developed countries (along with Bulgaria). At the time of accession to the EU, the country was located low in the downstream market, but every year it grew to be rated the highest among the CEE countries in relative position in

Table 2 Participation of CEE economies and their relative position in GVCs in selected years

		Participation (% of gross exports)					Relative position			
		2005	2009	2011	2014	2018	2005	2009	2014	2018
Czechia	Total	59.95	62.39	68.44	67.91	63.97	– 0.07	– 0.13	– 0.19	– 0.15
	Manufacturing	66.01	65.18	67.97	66.84	70.49	– 0.11	– 0.11	– 0.18	– 0.21
	Services	43.29	45.26	46.94	45.88	44.59	*0.06*	*0.09*	*0.01*	*0.02*
Hungary	Total	63.92	58.61	67.55	65.69	61.35	– 0.18	– 0.16	– 0.22	– 0.24
	Manufacturing	70.61	71.29	72.8	70.53	70.71	– 0.25	– 0.27	– 0.31	– 0.32
	Services	42.19	41.57	40.5	39.47	41.55	*0.07*	*0.03*	– 0.04	– 0.05
Poland	Total	56.13	48.39	61.94	61.55	57.27	*0.05*	– 0.06	– 0.03	– 0.04
	Manufacturing	66.94	64.67	69.54	67.65	68.38	*0.02*	*0.01*	– 0.03	– 0.09
	Services	39.22	38.46	38.24	37.3	40.79	*0.11*	*0.11*	*0.08*	*0.04*
Slovakia	Total	60.89	62.25	68.22	68.33	65.75	– 0.19	– 0.2	– 0.21	– 0.23
	Manufacturing	68.84	72.14	73.23	72.91	74.16	– 0.26	– 0.22	– 0.26	– 0.3
	Services	40.05	35.9	39.95	39.15	41.73	– 0.01	*0.04*	0	*0.02*
Slovenia	Total	54.76	55.72	59.02	60.02	56.45	– 0.09	– 0.15	– 0.09	– 0.13
	Manufacturing	61.92	61.31	64.23	61.91	63.99	– 0.15	– 0.11	– 0.16	– 0.2
	Services	38.87	39.06	41.24	40.53	43.12	*0.04*	*0.04*	*0.01*	– 0.002
Estonia	Total	53.95	52.04	59.39	59.05	58.53	– 0.05	– 0.03	– 0.11	– 0.09
	Manufacturing	65	64.02	71.4	71.37	69.79	– 0.1	– 0.09	– 0.18	– 0.17
	Services	44.14	40.81	42.88	44.22	47.38	– 0.01	*0.03*	– 0.02	– 0.02
Latvia	Total	47.54	47	49.75	50.14	49.57	*0.04*	*0.08*	*0.05*	*0.02*
	Manufacturing	61.81	61.74	62.34	61.56	61.32	*0.04*	*0.09*	*0.02*	*0.01*
	Services	35.88	38.47	39.13	40.47	40.89	*0.04*	*0.07*	*0.07*	*0.03*

(continued)

Table 2 (continued)

		Participation (% of gross exports)					Relative position			
		2005	2009	2011	2014	2018	2005	2009	2014	2018
Lithuania	Total	47.94	49.59	52.78	49.43	51.35	– 0.09	– 0.03	– 0.13	– 0.08
	Manufacturing	61.19	63.6	65.5	62.56	63.76	– 0.16	– 0.12	– 0.19	– 0.16
	Services	29.16	32.14	31.66	30.56	38.74	*0.01*	*0.07*	– 0.05	– 0.001
Bulgaria	Total	56.87	57.52	63.06	60.69	60.31	– 0.06	– 0.05	– 0.11	– 0.1
	Manufacturing	70.95	70.75	74.31	72.84	72.95	– 0.15	– 0.12	– 0.19	– 0.19
	Services	48.14	43.6	45.92	46.28	45.5	*0.01*	*0.04*	*0.03*	*0.02*
Croatia	Total	46.04	44.04	45.3	44.15	46.83	*0.01*	*0.05*	*0.05*	– 0.004
	Manufacturing	59.4	58.07	59.95	57.93	61.82	– 0.03	*0.02*	*0.02*	– 0.07
	Services	36.97	34.97	34.73	34.94	39.43	*0.05*	*0.07*	*0.08*	*0.03*
Romania	Total	51.5	45.59	52.62	55.94	53.33	– 0.03	*0.05*	*0.07*	*0.04*
	Manufacturing	58.9	51.87	51.83	61.23	60.54	– 0.07	*0.01*	*0.03*	*0.01*
	Services	34.68	37.09	57.7	50.67	46.15	*0.07*	*0.1*	*0.13*	*0.07*

If the relative position in GVCs is higher than 0, it means that the country is located in the upstream market. If the relative position in GVCs is lower than 0, it means that the country is located in the downstream market
Based on OECD's Inter-Country Input–Output Database, 2021

GVC (0.04). In 2018, Hungary had the lowest total production (− 0.24) (Appendix, Table 2).

Taking into account manufacturing in 2018, almost all CEE countries, except for Latvia and Romania, were on the downstream market. The lowest position was held by Hungary (− 0.32). All the economies analysed, except Latvia and Romania, deteriorated their positions between 2005 and 2018 (Appendix, Table 2).

In contrast to the relative positions of GVC manufacturing, in services, a more favourable situation occurred. Most of the CEE economies were located in the upstream market in all the years analysed (Czechia, Poland, Slovakia, Latvia, Bulgaria, Croatia, and Romania). In other states, the situation changed depending on the year. For example, Hungarian and Lithuanian services were located in the upstream market in 2005 and 2009, Slovakian services in all years except for 2005, and Czech services in all analysed years (Appendix, Table 2). When comparing fluctuations in relative positions in GVCs in services to manufacturing, there were lesser standard deviations. Unfortunately, there were only two cases where the relative positions in services GVCs of CEE countries increased between 2005 and 2018 (Slovakia and Bulgaria); in other economies, these positions deteriorated in this period. However, the service sector seemed to be more promising than manufacturing for strengthening CEE's position in global production linkages.

5 Role of ICT Services in CEE's Value-Added Links

Due to the great importance of services in shaping the position of CEE countries in GVCs, it was decided to analyse this sector in more detail. The results of this study revealed wide variations in the compositions of FVA and IVA in ICT in CEE. Furthermore, a comparison of 2005 and 2018 shows some tendencies.

In most of the countries analysed, an upwards trend in FVA in ICT services was clearly visible (Czechia, Hungary, Latvia, Lithuania, Poland, Slovenia, Croatia, and Romania). Between 2005 and 2018, the largest increase in FVA occurred in Poland (by 8.88%); a slightly smaller increase was recorded in Slovenia (by 8.14%) and Hungary (by 7.07%). Only in Estonia (by 1.92%), Slovakia (by 2.96%), and Bulgaria (by 7.26%) did FVAs drop. The largest decrease in FVA was observed in Bulgaria, which can be explained by having one of the highest levels of FVA among the analysed countries in 2005. Generally, Slovenia relied the most on FVAs in ICT services in 2018 (27.06%), while Bulgaria relied the least (13.23%) (Appendix, Table 3).

Unfortunately, the positive trend in ICT services' IVA between 2005 and 2018 appeared only in Lithuania (increase by 8.96%) and Romania (by 6.64%). The rest of the countries noted a sharp decrease in IVA, especially Slovenia (drop by 9.17%). In 2018, Lithuania had the largest IVA (26.58% of gross exports), while Latvia and Estonia had the lowest IVA (15.05% and 15.84%, respectively). It is worth adding that as in the case of general positions in GVCs, CEE countries gained importance after the 2008 crisis, and such a phenomenon was not noticed in ICT services at

Table 3 ICT services and their subgroups in GVCs in selected years (%)

	Foreign value added embodied in gross exports (FVA)				Domestic value added embodied in partners' gross exports (IVA)			
	2005	2009	2014	2018	2005	2009	2014	2018
Czechia								
ICT services	17.05	17.25	20.23	20.25	25.54	24.75	20.85	16.57
Telecommunications	13.38	13.92	23.25	25.99	15.73	15.19	16.06	13.37
Computer programming, consultancy and information services activities	16.24	16.43	17.28	13.83	24.09	23.87	17.25	12.60
Estonia								
ICT services	23.24	16.97	22.17	21.32	17.87	16.01	14.93	15.84
Telecommunications	25.50	20.83	26.55	25.22	13.95	14.38	15.22	14.33
Computer programming, consultancy and information services activities	21.59	11.71	19.95	18.65	17.63	15.65	13.96	13.74
Hungary								
ICT services	14.54	18.39	18.67	21.61	23.27	18.96	15.11	17.97
Telecommunications	12.15	15.61	19.67	19.63	18.72	19.40	18.40	17.32
Computer programming, consultancy and information services activities	15.57	17.66	14.93	16.57	25.32	16.85	12.23	12.02
Latvia								
ICT services	10.98	11.77	11.74	16.17	22.86	26.60	25.25	15.05
Telecommunications	10.22	12.66	14.56	16.53	18.69	25.17	33.33	17.51
Computer programming, consultancy and information services activities	10.97	8.97	8.85	13.04	25.88	22.48	18.72	9.46
Lithuania								
ICT services	9.64	9.76	11.51	15.19	17.62	20.83	24.90	26.58
Telecommunications	9.62	8.11	11.12	13.15	7.72	11.76	18.43	23.70
Computer programming, consultancy and information services activities	8.75	13.06	10.52	11.29	30.15	28.77	24.94	24.55

(continued)

Table 3 (continued)

	Foreign value added embodied in gross exports (FVA)				Domestic value added embodied in partners' gross exports (IVA)			
	2005	2009	2014	2018	2005	2009	2014	2018
Poland								
ICT services	12.46	13.63	15.00	21.34	27.98	29.08	24.08	19.99
Telecommunications	12.01	14.73	15.51	21.73	24.50	28.94	34.95	27.71
Computer programming, consultancy and information services activities	12.51	13.18	13.79	20.04	26.03	26.55	18.52	15.92
Slovakia								
ICT services	21.55	15.27	18.76	18.69	23.78	20.11	20.73	19.26
Telecommunications	15.82	14.06	15.71	14.90	14.60	18.15	19.07	18.32
Computer programming, consultancy and information services activities	21.17	14.49	20.06	19.50	22.97	16.99	18.69	16.13
Slovenia								
ICT services	18.92	19.68	21.88	27.06	26.56	25.83	20.83	17.39
Telecommunications	18.90	21.25	24.11	30.33	22.73	22.94	17.98	14.81
Computer programming, consultancy and information services activities	15.75	15.60	15.13	18.01	23.82	20.31	17.67	16.15
Bulgaria								
ICT services	20.49	15.99	14.41	13.23	20.94	22.56	20.81	20.78
Telecommunications	19.92	13.78	16.42	12.88	19.30	19.09	20.09	25.42
Computer programming, consultancy and information services activities	22.36	17.27	13.07	13.09	25.04	25.84	20.33	19.37
Croatia								
ICT services	16.35	13.35	13.55	17.63	23.72	23.58	26.83	19.81
Telecommunications	12.94	10.46	12.96	14.29	18.93	18.50	26.02	20.58

(continued)

Table 3 (continued)

	Foreign value added embodied in gross exports (FVA)				Domestic value added embodied in partners' gross exports (IVA)			
	2005	2009	2014	2018	2005	2009	2014	2018
Computer programming, consultancy and information services activities	15.66	12.85	12.41	18.13	25.97	22.49	20.01	17.71
Romania								
ICT services	13.92	11.39	14.21	14.44	14.76	15.87	28.53	21.40
Telecommunications	12.65	12.65	16.50	20.74	11.77	14.32	28.40	30.15
Computer programming, consultancy and information services activities	15.79	10.17	13.44	12.43	18.11	16.76	28.41	18.51

Based on OECD's Inter-Country Input–Output Database, 2021

all. The crisis had little impact on the role of CEE in GVCs, except for Lithuania, Romania, and Bulgaria (Appendix, Table 3). However, increasing the importance of these countries in services GVCs was not the direct consequence of the crisis but rather the internal policy of states aimed at attracting foreign investors and aimed at transforming countries into important outsourcing centres in Europe.

The Visegrád countries became some of the most specialized in software and ICT services, R&D centres, or data centres in Europe. In Global Innovation Index 2021, these countries were located quite low—Czechia ranked the highest (24th place) (WIPO, 2021). In the Global Competitiveness Report 2020, in terms of transformation readiness, the Visegrád countries were still located low (WEF, 2021). In Visegrád, countries have located their affiliates with many well-known international companies from the ICT industry. These countries have also played the role of outsourcing centres (mainly IT support) for many companies. Moreover, the Visegrád economies have established their own companies in ICT sectors. In this region, special IT clusters or zones with preferential politics operate. Although the states analysed are important for the location of international firms, their position in the 2021 Global Service Location Index dropped again (AT Kearney, 2021). They are losing their importance at the cost of other CEE states. European countries transferred some outsourcing centres from these countries to the Baltic States, Romania, Bulgaria, Latin America, or Southeast Asia due to lower costs and sometimes better facilities.

In Visegrád economies, there was a relatively uniform tendency to increase dependence on foreign countries, visible in the growing FVA, and a decrease in the importance of ICT services for exports of foreign partners in general. Particularly, unfavourable changes were observed in Poland, which experienced high increases in FVA and a significant drop in IVA in total ICT services, as well as in computer programming, consultancy and information services activities. It was related to the move of China and other developing countries up the value chains. Nevertheless, other Visegrád countries did not perform much better. In terms of telecommunications, Czechia relied the most on FVA (25.99%), while Poland relied the most on computer programming, consultancy and information services activities (20.04%). IVA was the largest in Poland in terms of telecommunications (27.71%) and in Slovakia in computer programming, consultancy and information services activities (16.13%). In turn, the lowest levels in IVA were noticed in Czechia in telecommunications (13.37%) and in Hungary in computer programming, consultancy and information services activities (12.02%) (Appendix, Table 3).

The unfavourable changes in FVA and IVA in the Visegrád countries are reflected in the deteriorating relative position in GVCs. Poland and Slovakia are countries in the upstream market, both in telecommunications and Slovenia in total ICT services. Visegrád countries recorded a deep decrease in relative position in GVCs among the 11 countries surveyed. They lost their positions very quickly. Czechia and Hungary were ranked in the downstream market in all subgroups of ICT services (Appendix, Table 4).

Exports of ICT services from the Visegrád countries became quite dependent, as in all EU-11 countries, on the value added of the EU, especially the German FVA. Only in Slovakia did China surpass Germany as the main supplier of FVA to ICT services.

Table 4 Relative position in GVCs in ICT services in 2005–2018

	2005	2009	2014	2015	2018
Czechia					
ICT services	*0.07*	*0.06*	*0.01*	− 0.02	− 0.03
Telecommunications	*0.02*	*0.01*	− 0.06	− 0.08	− 0.11
Computer programming, consultancy and information services activities	*0.07*	*0.06*	0	− 0.02	− 0.01
Estonia					
ICT services	− 0.04	− 0.01	− 0.06	− 0.04	− 0.05
Telecommunications	− 0.1	− 0.05	− 0.09	− 0.08	− 0.09
Computer programming, consultancy and information services activities	− 0.03	*0.03*	− 0.05	− 0.04	− 0.04
Hungary					
ICT services	*0.07*	0	− 0.03	− 0.06	− 0.03
Telecommunications	*0.06*	*0.03*	− 0.01	− 0.07	− 0.02
Computer programming, consultancy and information services activities	*0.08*	− 0.01	− 0.02	− 0.07	− 0.04
Latvia					
ICT services	*0.1*	*0.12*	*0.11*	*0.11*	− 0.01
Telecommunications	*0.07*	*0.11*	*0.15*	*0.14*	*0.01*
Computer programming, consultancy and information services activities	*0.13*	*0.12*	*0.09*	*0.08*	− 0.03
Lithuania					
ICT services	*0.07*	*0.1*	*0.11*	*0.07*	*0.09*
Telecommunications	− 0.02	*0.03*	*0.06*	*0.02*	*0.09*
Computer programming, consultancy and information services activities	*0.18*	*0.13*	*0.12*	*0.07*	*0.11*

(continued)

Table 4 (continued)

	2005	2009	2014	2015	2018
Poland					
ICT services	*0.13*	*0.13*	*0.08*	*0.09*	– 0.01
Telecommunications	*0.11*	*0.12*	*0.16*	*0.11*	*0.05*
Computer programming, consultancy and information services activities	*0.11*	*0.11*	*0.04*	*0.07*	– 0.03
Slovakia					
ICT services	*0.02*	*0.04*	*0.02*	0	*0.005*
Telecommunications	– 0.01	*0.04*	*0.03*	– 0.01	*0.03*
Computer programming, consultancy and information services activities	*0.01*	*0.02*	– 0.01	– 0.02	– 0.03
Slovenia					
ICT services	*0.06*	*0.05*	– 0.01	*0.02*	– 0.08
Telecommunications	*0.03*	*0.01*	– 0.05	– 0.01	– 0.13
Computer programming, consultancy and information services activities	*0.07*	*0.04*	*0.02*	*0.03*	– 0.02
Bulgaria					
ICT services	0	*0.06*	*0.05*	*0.06*	*0.06*
Telecommunications	– 0.01	*0.05*	*0.03*	*0.03*	*0.11*
Computer programming, consultancy and information services activities	*0.02*	*0.07*	*0.06*	*0.08*	*0.05*
Croatia					
ICT services	*0.06*	*0.09*	*0.11*	*0.1*	*0.02*
Telecommunications	*0.05*	*0.07*	*0.11*	*0.11*	*0.05*
Computer programming, consultancy and information services activities	*0.09*	*0.08*	*0.07*	*0.05*	– 0.004

(continued)

Table 4 (continued)

	2005	2009	2014	2015	2018
Romania					
ICT services	*0.01*	*0.04*	*0.12*	*0.07*	*0.06*
Telecommunications	– 0.01	*0.01*	*0.1*	*0.11*	*0.08*
Computer programming, consultancy and information services activities	*0.02*	*0.06*	*0.12*	*0.06*	*0.05*

If the relative position in GVCs is higher than 0, it means that the country is located in the upstream market. If the relative position in GVCs is lower than 0, it means that the country is located in the downstream market

Based on OECD's Inter-Country Input–Output Database, 2021

It should not be surprising that Germany plays an important role in the linkages of Visegrád economies to GVCs. Geographic proximity, cultural similarities, and substantial labour cost differentials are among the most important factors that led many German companies to shift large parts of their production to these countries and are responsible for closer economic integration between Germany and the Visegrád economies.

Among all EU-11 countries, the Baltic States are perceived as some of the most economically stable IT outsourcing destinations. This optimistic picture also proves international indexes and indicators (e.g. Global Innovation Index, Bloomberg Innovation Index) (Bloomberg, 2020; WIPO, 2021). These countries are characterized by high levels of adoption of digital solutions and effective legislation that ensures data security and efficient business operations (European Commission, 2020). Estonia is well known in the world as an e-country with a developed digital society based on it. In turn, Latvia is one of the leading European economies for investment and revenue in the ICT industry. Meanwhile, Lithuania has the largest ICT industry in the Baltic States. This can be attributed to innovative practices and a stable, well-trained, and highly productive workforce. The ICT industry in Latvia has experienced significant growth in recent years. The ICT sector is expected to become a leading industry in the Baltic States. It is responsible for approximately 20% of their exports. The Baltic ICT services have been dominated by service, computer programming, consulting, and telecommunications (UNCTAD, 2021).

The Baltic States are known as the birthplace of many digital companies. Moreover, the Baltic States are home to a wide array of foreign companies that opened their R&D centres there. It is difficult to see a uniform tendency in the case of the Baltic States in terms of FVA and IVA. Latvia and Lithuania were characterized by much lower FVAs than the Visegrád states and higher IVAs as well. In turn, Estonia seemed to be more similar to the Visegrád countries with respect to FVA and IVA. Each of these countries shapes their GVC connections differently (Appendix, Table 3).

Estonia is characterized by declining FVA values for ICT services in general and in the subgroups. Estonian ICT services and their subgroups had the highest FVA among the Baltic States. At the same time, IVA in Estonia decreased in total ICT services and computer programming, consultancy and information services activities. There was a slight increase in IVA in telecommunications, but its share was not high in comparison to other analysed countries. Generally, the Estonian IVA was very low. In Latvia, export dependence on foreign countries' value added increased in all ICT services. Unfortunately, in terms of IVA, a decrease was observed in ICT services and their subgroups. In Lithuania, the situation was more optimistic. Although FVA in all ICT services increased, the share stayed relatively low. Moreover, the share of IVA in total ICT services and telecommunications increased significantly. Computer programming, consultancy and information services activities noted a drop in IVA, but Lithuania was still in a favourable position (Appendix, Table 3).

When analysing the relative positions of the Baltic States in the GVCs, the picture of Estonia was the least optimistic: the country occupied downstream positions in all industries analysed in 2018, and during most of the period analysed, it was positioned in the downstream market. In 2018, only Lithuania was in the upstream market;

however, its positions deteriorated slightly in computer programming, consultancy and information services activities between 2005 and 2018. Latvia ranked in the upstream market only in telecommunications, but it is highly unlikely that this economy would keep an upwards position in future (Appendix, Table 4).

The Baltic States were also strongly connected with EU markets in terms of ICT services exports, but these ties seemed to be weaker than in the case of Visegrád states. The largest dependence was observed in Estonia. The Baltic States were also the only ones that did not have Germany among the most important suppliers of value added in ICT services; instead, they cooperated with neighbouring countries. Latvia and Lithuania cooperated primarily with the Russian Federation, while Estonia cooperated primarily with Finland. The Baltic States (especially Lithuania and Latvia) cooperate significantly with each other in the field of ICT services, which demonstrates the high share of the value added from EU-11 in exports (UNCTAD, 2021).

Generally, the Baltic States maintain close economic ties with neighbouring countries but sometimes enlarge their cooperation with Asian economies, e.g. China or ASEAN. Estonia was a source of ICT services value added for Finland, Sweden, and Latvia. Latvia cooperated in ICT services with Estonia, Germany, and Lithuania. Lithuania, in turn, was characterized by two top partners from Europe, Germany, and Estonia, and a partner from Asia, Singapore (OECD, 2021).

The last group of analysed countries is a heterogeneous group and consists of Slovenia, Bulgaria, Croatia, and Romania. The rapid development of ICT services in these countries is a result of systematic human development, well-developed ICT infrastructure, and government commitment to boosting this industry in these economies. Four countries are perceived as modest innovators in Europe with great prospects (European Commission, 2020). As the largest economy among these states, Romania has created the ICT industry as a primary growth driver. Generally, the concept of Industry 4.0 is very popular in Romania (12,000 ICT companies, each year 2000 new companies operate in this country; 202,000 ICT specialists) (Investromania, 2020). Similar to Romania, the Bulgarian ICT sector is characterized as stable and constantly growing, making it one of the most profitable sectors in this country. Bulgaria has a long tradition in the ICT (as well as in electronics sectors) and is still known as the Silicon Valley of Southeast Europe.

Slovenia and Croatia characterize a smaller ICT industry. However, this sector is actually doing quite well and continues to grow in both countries (Investcroatia, 2020; Investslovenia, 2020). Slovenia, Croatia, Bulgaria, and Romania have located affiliates of many well-known international companies from the ICT industry. In particular, Romania is considered the IT and outsourcing leader in CEE. Its comparative advantage is based on the highly skilled labour force, geographical and cultural proximity to Western Europe and the welcoming business environment (Cieślik, 2021).

As in the Baltic States, in Slovenia, Bulgaria, Croatia, and Romania, it is quite difficult to find any uniform tendency in FVA and IVA. Between 2005 and 2018, Slovenia became more dependent on foreign value added. Generally, Slovenia reached the highest level of FVA in ICT services and their subgroups and noted a significant increase in this dependency. A similar situation occurred in Croatia, which increased its FVA in all analysed groups of ICT services. The opposite tendency was observed in Bulgaria, which decreased its dependency on foreign value added in all ICT services subgroups. In Romania, the tendencies were mixed depending on the ICT services subgroup (Appendix, Table 3).

A similar, ambiguous result occurred in IVA. In Slovenia, IVA dropped in all industries analysed, while in Romania, it climbed significantly. Bulgaria and Croatia were characterized by mixed tendencies, e.g. Bulgaria increased its IVA level in telecommunications but noted a significant drop in computer programming; consultancy and information services activities reached the highest level of IVA in computer programming, consultancy and information services activities; Croatia noted a slight increase in telecommunications, while other segments experienced a severe decrease (Appendix, Table 3).

When analysing the relative positions of Slovenia, Bulgaria, Croatia, and Romania in the GVCs, all of these countries, except for Slovenia in all analysed groups and Croatia in computer programming, consultancy and information services, are positioned in the upstream market. Moreover, the picture of their relative positions in GVCs seemed to be optimistic—except for Slovenia, all countries occupied the upwards market in total ICT services during the entire analysed period. There was no downwards tendency in many analysed groups (Appendix, Table 4).

All four economies were strongly connected to the EU markets in terms of ICT services exports, as well as the Visegrád countries. The largest dependence on the added value of Europe could be observed in Romania. Furthermore, Romanian ICT services were the most tied to European value added among the 11 countries. As in the Visegrád states, Germany was also the leader among FVA suppliers to these four countries. They cooperate significantly with the other EU-11 countries in this field as well, which proved the quite high share of value added in exports (Cieślik, 2021).

Analysing the main recipients of IVA from this group of countries, the EU also leads. Croatia cooperated mostly with Slovenia, Austria, and Italy. Romanian ICT services were directed to Germany, France, and Italy. In turn, Slovenian and Bulgarian ICT services went to Germany, Austria, and Italy (OECD, 2021).

6 Conclusions

The CEE countries have recently changed their role in the global economy; unfortunately, most of them have changed it into worse with time. The EU-11 economies needed to recover and modify their production patterns significantly because the linkages of manufacturing to production networks became unfavourable for most of them. This situation forced these economies to join the global economy with a more sophisticated and advanced offer, which included ICT services.

There is a significant difference between the dependence of services and manufacturing in CEE on added value from abroad. The service sector is not only less dependent on the value added from foreign countries but also does not show significant increases in this level between 2005 and 2018, which is promising. The situation is ambiguous when the exports of trading partners are dependent on the added value from the services of CEE countries.

This chapter examined whether services, and especially ICT services, have become the new channel of improvement of the positions of CEE nations in GVCs. The analysis shows that the hypothesis could not be true for all CEE countries because some of them differed markedly between each other with unfavourable connections in GVCs in ICT services.

In the case of the countries of the Visegrád Group, it is difficult to perceive ICT services as an engine of growth and the field that shapes their positions in GVCs. These countries, although at the beginning of their accession to the EU, were also strongly associated with services' GVCs within the upstream market, with time beginning to lose their advantage. The hypothesis that ICT services took over the role of a new channel allowing for the improvement of the position of the Visegrád countries in GVCs has not been confirmed in the case of all countries, except for Poland.

In the case of the Baltic States, there is a similar ambiguity as in the Visegrád states—Latvia and Lithuania used ICT services to improve their position in the GVCs, while Estonia did not. Lithuania and, to some extent, Latvia were constantly developing the ICT sector and trying to rely on FVA as little as possible.

The last group turned out to be the most heterogeneous: Bulgaria, Croatia, Romania, and Slovakia. The ways in which these countries joined GVCs of ICT services were also different. However, it can be stated that, apart from Slovenia, other countries confirmed the hypothesis presented in the study.

As highlighted in the literature review section, the analysis enriches the scholarly knowledge on the current role of CEE economies in GVCs in terms of services. It supports and extends the prior observations of the literature cited. To the author's knowledge, such a comprehensive analysis of CEE economies has not yet been carried out. It enhances the academic understanding of the trade relations of CEE in terms of services and, in a broader dimension, might suggest some changes in the foreign policy of these economies (e.g. the attitude of a given nation to the role of trade with the EU, as well as the role of FDI connected to FVA inflows, fields of trade cooperation that should be developed and limited due to great dependence, etc.).

The study has practical implications as well. It not only highlighted the changes taking place in the connections of CEE countries in GVCs in services but also allowed the identification of those areas of advanced services where positions in GVCs are deteriorating. This may indicate the low effectiveness of the economic modernization strategies introduced. Moreover, this may provide the impetus not only for changes in government Industry 4.0 strategies but also for changes in the behaviour of companies providing or importing such services. In addition, the study showed the main competitors among CEE in advanced services.

At the end of the discussion, a number of limitations of the study and areas for future research should be mentioned. First, the limited availability of statistical data, especially value-added flow statistics, was a serious obstacle. It is possible that access to more detailed data would identify additional types of services in which CEE economies have a strong position in GVCs. Second, the study relied on particular methods, and it cannot be ruled out that applying different methodologies would lead to different conclusions. However, this method appeared to the author to be the most accurate of the other methods. Third, this study should be repeated in the following years to confirm the results, especially after the COVID-19 crisis and the war in Ukraine. It is plausible that the data for these years would disrupt past trends. However, this does not equate to a possible improvement in places by the CEE economies in the GVCs. Fourth, the study needs a more detailed examination of the interconnectivity of GVCs between ICT services and other industries, structural factors of the services and manufacturing of CEE, such as the size of the market and stage of development, trade and investment policy, logistics, infrastructure, innovation policy and IPRs. This would come closer to answering questions about the determinants affecting countries' positions in GVCs in terms of services. Finally, the study can be extended to other economies (e.g. European countries or Asian countries) to compare their position in GVCs with CEE countries. Such a comparison will help to identify benchmark countries for the role of ICT services in GVCs. Furthermore, it may result in corrections of ineffective strategies or innovation tools introduced in CEE countries.

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Appendix

See Tables 1, 2, 3, and 4.

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The Era of Innovation for Sustainability-Oriented Logistics: A Systematic Literature Review of European Studies

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Abstract Logistics has traditionally been seen as a poorly innovative sector and an ancillary business function aimed at reducing costs, and with severe impacts on the environment due to the emissions generated by the logistics processes. However, with new services, logistics is today becoming a strategic source of competitive advantage for organizations. In this evolution, it is unclear how innovation has driven the rise of logistics as a strategic function, and the role of innovation in the logistics sector—especially in the light of understanding the implications for sustainability. In this chapter, a Systematic Literature Review on the current state of the art of the debate around innovation management in the logistics sector is presented, with special emphasis on the scientific literature related to European countries. To shed light on this topic, we combine the Systematic Literature Review with bibliometric tools, and we identify approaches and areas where innovation in logistics has been introduced. Sustainability-oriented innovation emerges as a key topic, along with technology, transport-related innovations, and the customer's role within innovation processes.

Keywords Technological innovation · Sustainable practices · Logistics · Freight transport · Outsourcing

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1 Introduction

The logistics industry, among various sectors, accounts for a significant environmental impact and is responsible for a substantial rate of global pollution in terms of emissions of pollutants in air and water, noise, as well as resource consumption. The great concern surrounding the degraded state of the environment, driven by the tangible effects of climate change and social inequality, urgently calls for initiatives and innovative solutions across the world economy to address these environmental issues (Almeida et al., 2013).

Logistics creates a set of negative impacts on the environment and society (Kohn & Brodin, 2008; Mangiaracina et al., 2016), caused primarily by freight transport (Evangelista et al., 2017). Besides being under the spotlight for its environmental impacts, the logistics industry in Europe is also a matter of interest because it represents a key sector in the economy of the continent. In 2019, in fact, the European third-party logistics market generated revenues to the value of 177.6 billion US dollars, with a steady increase equal to + 12.5% from 2010 to 2019 (Statista, 2021). Tackling the environmental issues through innovative solutions able to overcome the externalities caused by the logistics industry would bring considerable benefits to the planet Earth, but still innovation in the logistic industry is largely neglected, despite a number of innovations in logistics technologies (for instance, RFID) and in the organization of logistics processes (for instance, cross-docking) and their roles in logistics operations (Busse & Wallenburg, 2011, 2014; Cui et al., 2010; Grawe, 2009). Innovation efforts in the industry seem to be addressed to reduce the resources needed to operate activities related to materials and information handling (cost-cutting nature of innovations, Grawe, 2009). As a consequence, the potential contribution of the logistics industry to the improvement of sustainability of its operations through innovative initiatives is still underexplored (Andersson & Forslund, 2018; Björklund & Forslund, 2018; Chu et al., 2018).

The relative novelty of the topic and the necessity to shed the light on the role of innovation in the logistics sector—especially in the light of understanding the implications for sustainability—provides the rationale for the study presented in this chapter, where a Systematic Literature Review on the current state of the art of the debate around innovation management in the logistics sector is presented, with special emphasis on the scientific literature related to European countries.

Findings show that the topic of innovation in the logistic sector obtained certain attention from the scientific community, and it is possible to identify several thematic clusters. One of the most relevant of those clusters is related to sustainability-oriented innovation, which is emerging as a prominent research area—and this is our first key result. Second, we identify the most relevant technological innovation foci in the logistics industry. Third, we find that research is still strong on economic and environmental innovation rather than on the social side dimension from a triple bottom line perspective (economic, social, and environmental sustainability).

This chapter is organized as follows: in Sect. 2, some basic concepts and definitions are provided, in Sect. 3, the research methodology is presented, Sect. 4 is devoted to the presentation of the results, and Sect. 5 is devoted to the discussion and conclusions.

2 Basic Concepts and Definitions

2.1 The Logistics Industry

The Council of Supply Chain Management Professionals (CSCMP) defines logistics as "the process of planning, implementing and controlling the efficient and effective flow and storage of raw materials, semi-finished and finished products and related information from the point of origin at the point of consumption with the aim of satisfying customer needs". The definition (CSCMP, 2013) highlights the key components of the logistics operations and allows for isolating the traditional objective of logistics as "getting the right product to the right customer at the right time and the lowest cost" (CILT UK, 2019). Consequently, logistics has traditionally been considered as a support function aimed at reducing costs to yield higher profits for the business, in other words, an ancillary activity within organizations (Mentzer & Williams, 2001). Therefore, the logistics sector has been for a long time oriented towards making the best possible use of resources to operate activities related to the delivery of products and management of information at the lowest possible cost.

However, over time, a set of driving forces have changed the role of logistics, making it become a source of sustainable competitive advantage (Mellat-Parast & Spillan, 2014). Among these, globalization, the evolution of technology, the push towards sustainability and decarbonization and above all, the practice of the outsourcing of logistics activities. This last element has driven the development of the logistics sector since an ever-increasing number of companies have been progressively looking to externalize logistics activities to achieve a higher level of customer satisfaction and survive in a strong competitive environment by focusing on their core business and devolving the management and execution of logistics processes to specialists, the so-called "third-party logistics service providers" or 3PL providers (Raut et al., 2018). All of these, combined with the evolution of the business-to-consumer processes driven by the changing requirements of consumers (who have progressively demanded faster, more customized, and more complex logistics services), have led the logistics sector to the necessity to identify new drivers besides the pure cost optimization to attain competitive advantage in the marketplace (Vlachos & Dyra, 2020).

Hence, logistics has shifted its role towards a more strategic function within organizations and a lever for building competitive advantage for companies. In this scenario, the evolution of logistics and the widening range of opportunities that logistics can create for organizations in terms of competitiveness lead to question the traditional view according to which logistics is a “black box”, a static cost-saving-oriented business function, in which 3PL providers are “box movers” rather than partners that can co-create solutions.

2.2 Sustainability, Innovation Management, and Sustainability-Oriented Innovation

Sustainability is a fundamental concept that embodies the responsible and balanced approach to meeting the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland, 1987). Its relevance roots in the growing recognition within the scientific community, businesses, and society as a whole about the detrimental effects of human activities on the environment that lead to excessive resource consumption, leading to a progressive deterioration of environmental conditions and an increase in societal issues, such as social inequity.

At a corporate level, the concept of sustainability is based on the “three pillars” or “triple bottom line—TBL”, namely: economic, social, and environmental areas. The first is the ability of the company to pursue the return on investment and profitability, the second is the ability to guarantee conditions of human well-being (safety, health, education, etc.), and the third is the ability to preserve the quality and reproducibility of the natural environment. Sustainable is a product, a process (or even the entire company) able to combine the achievement of targets in the three areas. Sustainability is becoming more important for all companies, across all industries. About 62% of executives consider a sustainability strategy necessary to be competitive today, and another 22% think that it will be in the future (Haanaes, 2016). If all companies aim to reach profit targets, the other two areas are less prioritized. On the one hand, at the environmental level, according to the scientific journal “Environmental Sustainability”, we are on pace to produce 27 billion tonnes of solid waste by 2050 due to a business environment that maximizes rapid production and turnover of products to boost profits. Among the others, this is one of the causes for uncontrolled CO_2 emission. These are expected to contribute to a four-degree Celsius temperature rise by 2100 (two by 2050), which will result in sea-level rise and an increase in catastrophic weather events (Carrington, 2013). According to the Paris Climate Agreement, “businesses can have a major impact and account for 60% of emissions reductions by 2030” (Maryville University, 2019). On the other hand, at a social level, contemporary business is forced to move towards adopting social good practices; in this sense, key factors include equity and equality, poverty, health, education, delinquency, demographics, culture; and most of them can positively be impacted by businesses and their practices beyond the borders of the company. According to the UN Global Compact, social sustainability should be “a critical element in any business as it affects the relationships with stakeholders” (ADEC Innovations, 2020). Social sustainability can be considered as a way of managing and identifying business impacts on employees, workers in the value chain, customers, and local communities.

In this landscape, businesses have been encouraged to achieve economic growth in a more sustainable way, orienting and pushing the development of innovation efforts to target higher levels of sustainability. Therefore, a central and challenging role is played by innovation, which "is here broadly defined to encompass a range of types, including new product or service, new process technology, new organization structure or administrative systems, or new plans or programme pertaining to organization members" (Damanpour, 1996). The management of innovation in business organizations (i) is a complex and multi-faced issue, largely debated in the last two decades and a number of books and manuals have been published (for instance, Schilling (2019) or Trott (2017) and many others), and (ii) it requires specialized competences, a proper corporate culture, and organization of resources. The typical areas of interest in the innovation management of a corporation are as follows (adapted from Schilling, 2019):

- **Intelligence phase**. It has the aim of collecting information and data from the company itself and from the external technological and competitive environment, in order to provide the most complete set to support the following decision-making phase. It includes the analysis of industry dynamics of innovation, potential sources of innovation, types and patterns of innovation, and standards and design dominance.
- **Strategic phase**. It is the aim of setting the strategic direction followed by the company and its implications on innovation management. Main decisions, along with the definition of the organization's strategic direction, are about the timing of entry and the formulation of a coherent innovation strategy.
- **Implementation phase**. It is the practical translation of the previous phase, and all tasks are needed to make innovation effective for business application and exploitation. Among the main tasks: choosing innovation projects, definition of collaboration strategies, open innovation, and technology adoption, protecting innovation, organizing for innovation, and managing the innovation process and team.

The aforementioned phases can lead to some minor improvements (incremental innovation), major improvements (radical innovation), or even to more systematic improvements on how the company is conducting the business (business model innovation). Several authors (for instance, Bessant et al., 2005) emphasize how these renewals are core in creating and sustaining value and competitive advantage, and when it comes to sustainability, the profitability and even the survival of the business are increasingly dependent on them. The same author stresses "Innovation represents the core renewal process in any organization. Unless it changes what it offers the world and the way in which it creates and delivers those offerings it risks its survival and growth prospects".

It is not surprising that, from the two previously mentioned streams, a new research area is born, namely sustainability-oriented innovation (SOI), which "involves making intentional changes to an organization's philosophy and values, as well as to its products, processes or practices, to serve the specific purpose of creating and realizing social and environmental value in addition to economic returns" (Adams et al., 2016). So, the previously mentioned innovation management topics and tools are addressed to a precise scope. A misconception is to refer SOI to just green and environmental oriented innovation, and differently SOI is wider and can be related to the three dimensions stated before in order to pursue economic, social, and environmental objectives. One of the challenges that businesses have to face to implement SOI is the changing of the focus of activities and, from time to time, the business culture. The implementation of sustainability-oriented innovation involves all the functions and people inside the business, creating a SOI culture where the individual purpose and corporate purpose are connected, focusing on creating, with a long-term time horizon, a better society (Adams et al., 2016). This implies that businesses develop new processes and evolving business models to bring benefits to the three TBL dimensions on a large scale, not only relating to disruptive innovations and technologies but also to reduce the impact that existing solutions have (Plieth et al., 2012). The approach to introducing changes in the business culture should be followed by a proper engagement of employees in the corporate sustainability effort (Polman & Bhattacharya, 2016). So, speaking about culture, what can executives and managers do to bring sustainability-focused innovation to their organizations? There are five necessary elements (Geradts & Bocken, 2019).

- **Clear direction**: articulate the goals to employees. This involves explaining how sustainability-oriented innovation supports strategy and is incorporated into day-to-day operations;
- **Budget and resources**: provide an adequate budget and other resources (employees with the right economical resources for projects) to pursue the goals. Here, the goal is to help employees connect with the right experts;
- **Room for collaboration**: the importance of collaborative relationships with other parts of the organization of partners to address gaps in skills and resources. This collaboration could be done through behavioural incentives;
- **Positive reinforcement**: it is important to motivate employees who get involved in SOI projects;
- **The need for accountability**: organizations that want to promote SOI need to institute measures of accountability for the creation of value under a social and environmental logic. To encourage investment in sustainability-oriented innovation, 30% of the long-term incentive bonus of top managers is tied to the company's performance in an index developed by RobecoSAM, a Swiss investment firm that focuses on sustainability (Geradts & Bocken, 2019).

We can conclude by saying that sustainability-oriented innovation helps companies become more competitive and serves to identify new markets by responding to the needs of the whole world (Geradts & Bocken, 2019).

The implementation of SOIs can affect every aspect of the business, reaching all elements of the value chain from the organizational structure to the logistics. SOI implementation can be performed as a:

- **Process innovation**: focused on the production of goods and services with a particular focus on improving eco-efficiency (Huber, 2008) using managerial and different outputs to reach an effective efficiency of business operations (Altham, 2007);
- **Organizational innovation**: reorganization of businesses' structure implementing new management forms and focusing on engaging people within the organization to think and work for a more sustainable business (OECD and Eurostat, 2005);
- **Product innovation**: improvements or development of new technologies and services oriented to reduce the use of polluting materials, with longer durability and a more sustainable production process (Hart & Milstein, 2003).

To sum up, we can refer to SOIs with every action that has as objective the implementation of new elements that can have a better impact on the organization from a sustainability point of view. Additionally, when we refer to SOI, we can differ between incremental and radical innovations (Benner & Tushman, 2002).

3 Review Methodology

The adopted research methodology is the Systematic Literature Review (SLR), which can be defined as "a specific methodology that locates existing studies, selects, and evaluates contributions, analyses and synthesizes data" (Denyer & Tranfield, 2009, p. 671). This methodology is composed of the steps reported in Fig. 1.

The first step is "Question formulation", aimed at defining the study's scope to avoid ambiguity and formulating the research questions that drive the research and its development (Rousseau et al., 2008).

In the second step, "locating studies", keywords related to the investigated topic and the objective of this study were identified. The keywords are used to generate search strings that can be applied to search databases for retrieving papers. The papers were retrieved from the Scopus database, which is the largest database of peer-reviewed literature, including over 57 million records (https://www.elsevier.com/en-gb/solutions/scopus). We also explored retrieving papers from the database Web of Science. However, we found that the number of retrieved papers was smaller than what we found in Scopus, and these articles were already included in the sample from Scopus. Hence, we decided to rely entirely on a single database, i.e. Scopus. In the literature, there are other examples of the choice to rely on a single database (e.g. Kim et al., 2018).

In the third step, "Study selection and evaluation", several inclusion/exclusion criteria were defined to ensure the reliability and replicability of the search process and select relevant papers only. First, we decided to include peer-reviewed papers published in scientific journals and in conference proceedings to enhance the level of quality of the selected papers (Ali et al., 2017; Newbert, 2007). Additionally, papers were selected with restriction on publication year: only papers published

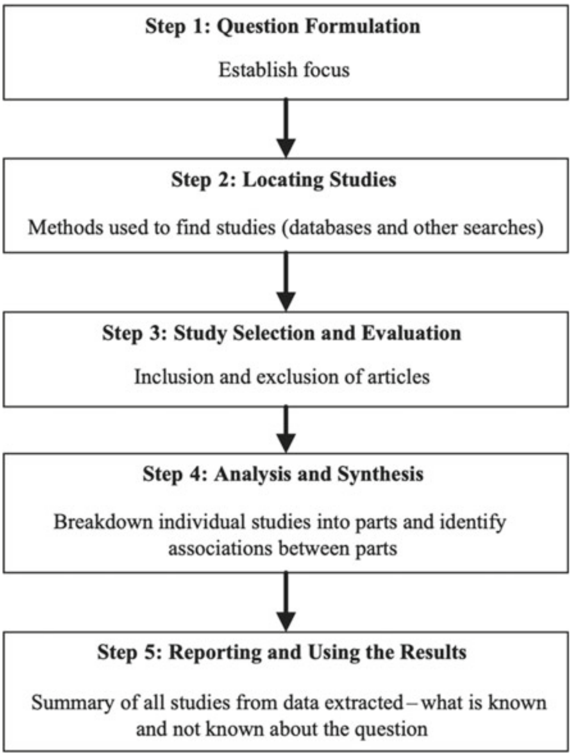

Fig. 1 Steps for conducting an SLR. *Source* Denyer and Tranfield (2009)

after 2011 were taken into consideration. The rationale for this choice is that the topic of innovation requires focusing on the most recent developments only and a 10-year review of the literature allows for a satisfactorily comprehensive analysis of the studied area. The selection of papers was then refined by excluding papers classified according to Scopus subject areas not aligned with the purpose of this study, e.g. medicine. Finally, only papers published in English were selected, since English is the dominant language in the field of logistics and innovation management research.

Within Step 4, "Analysis and synthesis", besides the content analysis of the retrieved papers, we performed a keyword co-occurrence network analysis to visualize and discover the research trajectories by examining the links among keywords (Radhakrishnan et al., 2017). With the adoption of elements of bibliometric analysis (see, for example, Colicchia et al., 2019), this choice represents an alternative approach compared to content-based literature reviews, which are usually based on two stages, the first one being a systematic review of the literature and the second one a narrative overview of the results (see, for example, Green et al., 2006; Salgado & Dekkers, 2018). We relied on the software package VOSviewer, a well-established tool to conduct such analysis (Van Eck & Waltman, 2017). VOSviewer uses the "Visualisation of Similarities (VOS)" clustering technique that provides a mapping of keywords based on the Smart Local Moving (SLM) algorithm, as described in detail in Van Eck and Waltman (2013).

Finally, Step 5 "Reporting and Using the Results" synthesizes the evidence gathered from the analysis and allowed to derive insights for discussing the outcome of the review.

The study aims to answer the following overarching review question: *how does innovation take place in the logistics field and what are the areas where 3PLs/logistics companies have been more innovative?*

To retrieve papers, the following search string was defined by combining keywords through operators and Boolean logic and applied in the Scopus database:

(("logistics service" OR "logistics management" OR "freight transport*" OR "logistics industry" OR "logistics provider*" OR "third party logistic*" OR "logistics outsourcing") AND "innovation")*

The keywords were selected according to an iterative process, which included refining their definition through two focus groups conducted by the researchers with a panel of experts composed of academics working in the fields of logistics and innovation and of industry professionals from the logistics sector.

Since the focus of our research is innovation in the logistics field, the string was designed to find relevant papers for the overlap between the area of innovation management and logistics. The search was carried out in April 2021, resulting in 799 retrieved papers.

The undermentioned inclusion/exclusion criteria were used to select relevant papers. The initial pool of 799 papers has been later refined; in particular, we excluded 319 papers based on:

(i) The title and the abstract analysis.
(ii) The full-text analysis to ensure the relevance of the topic investigated by the papers.
(iii) Publication year (since 2011).

This led to obtaining 480 papers as a search outcome.

Among these papers, taking into consideration the countries of affiliation of authors, 129 contributions emerge from European authors. This allows to state that the topic has received certain level of attention among authors affiliated to European institutions (Fig. 2).

In the next sections, we present the results of the last two steps of the applied methodology in terms of co-occurrence analysis of keywords and the analysis of the resulting clusters of keywords. Since the main goal of this research is to investigate the aforementioned trends in Europe, only 81 papers (Appendix) have been selected, i.e. those focused on the "European" context (we selected those having "Europe" as a keyword assuming that the presence of such a keyword would ensure a specific focus on this geographical context).

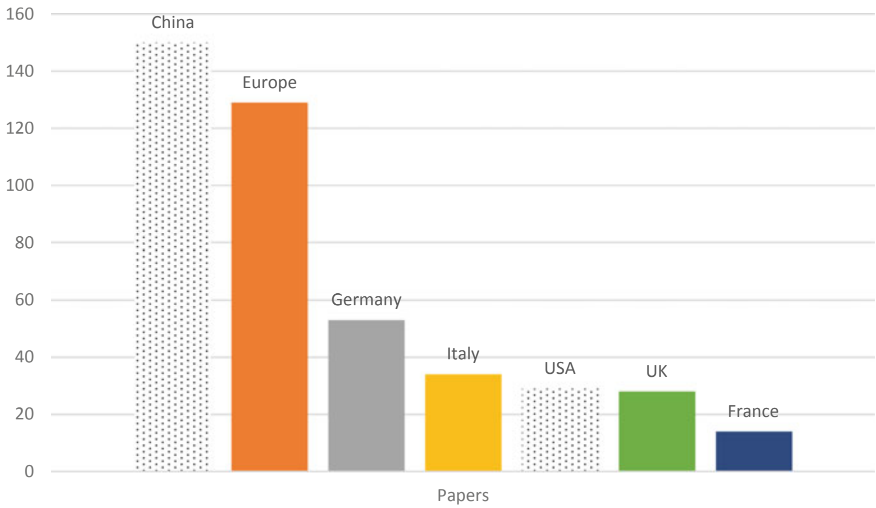

Fig. 2 Countries of affiliation of the authors of the contributions analyzed

4 Results

4.1 Co-occurrence Analysis of Keywords

The analysis of the co-occurrence network of keywords (authors' keywords and index keywords) is useful to identify the main research areas and patterns within the topic under study. The nodes of the network represent keywords and the links among them the number of times that keywords appear together in the same papers included in the analysis. The assumption is that the keywords can be used to position the papers with respect to research areas and other papers, by well representing the content of the papers themselves (Ding et al., 2001).

A total of 609 keywords were extracted from 81 papers (Appendix) of which 12 keywords occurred five or more times as represented in Fig. 1. The threshold value of five excludes the keywords with low frequencies and results in a more concentrated network. The keywords are grouped by the VOSviewer algorithm in five clusters (see Table 1). Clustering determines how related keywords are. The more articles in which two keywords appear together, the stronger the link between the two terms. The size of the circle representing each keyword in the figure reflects the number of times the keyword appears in the articles. Keywords with a higher rate of co-occurrence tend to be closer together as the distance between them indicates the relatedness of the keywords (Van Eck & Waltman, 2007). The overlay visualization of the network provides information on the temporal appearance of keywords to detect research trends and trajectories (Figs. 3 and 4).

Table 1 Keywords in each cluster

Cluster 1	City logistics, freight transportation, transportation, urban freight transport, and urban transportation
Cluster 2	Last mile, supply chain, and logistics
Cluster 3	Freight transport, Europe, innovation, and sustainability

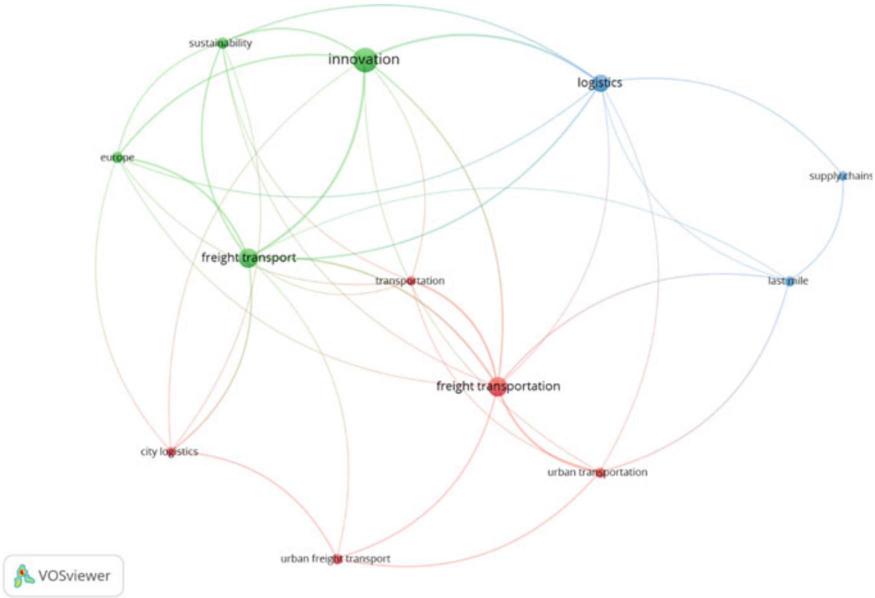

Fig. 3 Co-occurrence network of keywords

4.2 Results from the Cluster Analysis

In this section, we present the main insights from the analysis of the three clusters of keywords emerging from the bibliographic database. Each cluster reveals an area of research: the first two (clusters 1 and 2) show how contributions are always addressing the traditional key topics of the logistics industry, while the third (cluster 3) is surprisingly interesting, showing how the keyword “Europe” is combined with “innovation”, “sustainability”, and “logistics”. Hereafter, some insights from the clusters are presented.

Cluster 1

The first cluster has—among the most recurring words—those relating to the theme of urban areas. These keywords are also discussed in relation to economic factors such as costs and new business models (e.g. crowdsourcing). The recent research in transportation is focused on solving the last-mile problem: the growth of e-commerce

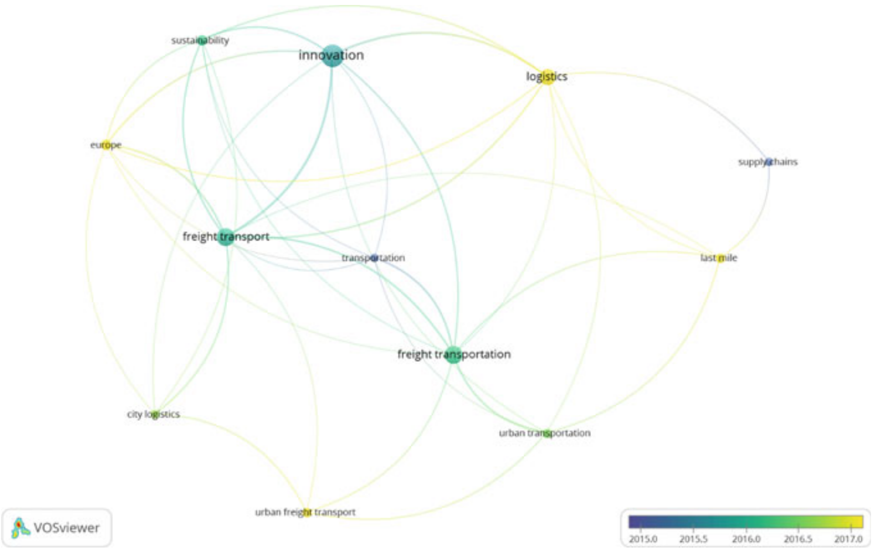

Fig. 4 Co-occurrence network of keywords (overlay visualization)

has increased on the one hand customer demands and transportation volumes and on the other hand the traffic and externalities in cities (Vakulenko et al., 2019). New technologies, such as autonomous vehicles, are now introduced to reduce the labour required to move goods, further reducing the cost of operations (Simpson et al., 2019). It is possible to say that despite the high potential of autonomous vehicles in last-mile delivery, logistics service providers must know how to introduce them in such a way the public finds acceptable. It is believed that autonomous vehicles are very risky means of transportation: in fact, autonomous vehicles involve potential risks such as that for safety when driving autonomously on public road networks (falling of a package on people) or the risk of performance during the delivery of parcels (for example, risk of technology malfunction) (Kapser & Abdelrahman, 2020), and this constitutes an interesting matter of debate.

Among the business models, the most novel and emerging theme in logistics is the so-called crowdsourcing, as shown by the very recently published papers dealing with this theme. Crowdsourcing belongs to the realm of the "sharing economy". The central idea is the optimization of under-used assets—both physical (e.g. cars, apartments) and intangible (e.g. skills, knowledge)—by sharing them through digital platforms (Buldeo Rai et al., 2021). The aim is to achieve economic benefits for all stakeholders and shareholders in a very innovative way commonly thought of as "Uber for logistics" (Buldeo Rai et al., 2021). Among the benefits recognized, crowd logistics can increase environmental sustainability (Buldeo Rai et al., 2021). This is one of the reasons why the growth of interest in the crowd logistics: crowd logistics is presented by scholars as one of the solutions to reduce the social and environmental negative impact of transportation in particular in the urban context.

However, crowd logistics is still an underdeveloped topic. Indeed, it has some critical issues not solved yet: first, the network, including crowds of customers and crowds of carriers is the crucial resource and must be maintained permanently; second, the return on investment can only be positive in the long run, making investments in crowd logistics which is currently very risky (Frehe et al., 2017).

Cluster 2

In the second cluster, the recurring themes and keywords are related to the introduction of new technologies and new trends in the broader logistics, supply chains, and again, last mile. In this cluster, scholars focus their attention on finding new solutions or new ways to exploit new technologies creating or add new services.

The research focus on the logistics and supply chain topics, look at technologies as a strategic lever to improve their competitive advantage. Evangelista (2013) explain how to add value to logistics services using ICT. Large companies have implemented ICT to manage information flows along the entire supply chain and have achieved positive results (Pokharel, 2005): the creation of end-to-end visibility, the reduction of cycle times and inventory, the minimization of the bullwhip effect, the decrease of CO_2 emissions, and the improvement of the overall effectiveness of distribution channels (Vanpoucke et al., 2009; Zailani et al., 2011). Technology is also used to improve LSP's performance: Barilla et al. (2020) find out that innovation in the logistics industry is a strong element in driving LSP's productivity.

In this cluster, a strong role is played by new delivery vehicles (e.g. electric or autonomous vehicles)—to improve the performances and, at the same time, to minimize some issues (see Monios & Bergqvist, 2020; Andaloro et al., 2015; Kapser & Abdelrahman, 2020; Mangano & Zenezini, 2019). Indeed, in this case, the new technologies adopted are aimed to reduce the negative impact on the environment (in terms of emissions) and society (in terms of work conditions).

In addition, several contributes to focus on the world of the Internet of Things (IoT) (e.g. Zhong et al., 2015; Hopkins & Hawking, 2018; Hsu & Yeh, 2017; Lin & Gao, 2014; Omarova et al., 2019; Rongfei & Yiyong, 2017; Xu et al., 2015; Yang et al., 2013; Yerpude & Singhal, 2020; Zhang et al., 2020). IoT is one the most important technologies developed within Industry 4.0 and it is also applied to the logistics field and included in the Logistics 4.0 paradigm (Barreto et al., 2017). IoT is usually associated with information technology, Internet, industrial engineering and is applied in the e-commerce sector. According to Hsu and Yeh (2017), the adoption of IoT by Logistics Service Providers (LSPs) should consider several critical factors related to three dimensions: technological dimension (i.e. technology benefits), organizational dimension (i.e. technical competence and capabilities), and environmental dimension (i.e. external pressure). The most critical factors in the introduction and utilization of IoT are related to IT expertise, top management support, government policy, competitive pressure, and security issues to be the most important influences. IoT makes the exchange of goods and services in global supply chain networks easier, creating at the same time concerns related to the security and privacy of the information of stakeholders. From this perspective, managers should orient their attention to the improvement and promotion of these dimensions as they are the core among all the dimensions.

In addition to the adoption of IoT, other technologies and innovations are getting more and more attention by LSPs, such as using IoT as a tracing method for the real-data management of the supply chain to the installation of Automated Parcel Station (APS) as a collection point for customers (Hofmann & Osterwalder, 2017). The focus on the introduction of technologies in the LSP sector is guided through the aim to reach cost leadership and better customer service level. Logistics literature recognized that to reach a certain level of both, requirements of certain importance must be given to both expertise in terms of training and experience as managers and a certain level of knowledge and expertise in IT (Karia & Wong, 2013). The need for skilful, knowledgeable, and experienced people to implement organizational strategy, especially when it comes to cost reduction, is essential.

Cluster 3

The third cluster is the less expected. Although the text string used to perform the research about innovations in the logistic sector did not contain any keywords related to sustainability, the results include a considerable amount of information and articles about it. This shows the importance of this topic, highlighting how in recent years where more technological innovation efforts by companies is addressed to environmental and social factors. Moreover, it is also the cluster where the keyword Europe emerges, stressing how the sustainability-oriented innovation is pursued with great force in European countries more than in other parts of the world.

Taking a deeper look in the papers of the third cluster, the theme of sustainability-oriented innovation is addressed mainly to environmental issues and moderately to social issues. Indeed, it deals with environmental impact, sustainable development, product, or process innovations with the aim of being environmental compliance and sustainable. Sustainability is a topic that is becoming increasingly relevant within companies, leading to a change in the competitive landscape and the main driver for the development of innovation (Centobelli et al., 2020). LSPs, just like other businesses that compose supply chains, are shifting their focus to the sustainability topic, adopting new and different initiatives to reach a competitive advantage or at least a competitive parity (Hazen et al., 2011). Top management is changing the way to manage and execute activities, orienting to a rethinking of how to perform activities and practices in a more green and sustainable way. These activities are related to Green Supply Chain Management (GSCM). Related to the GSCM, it is essential to also introduce Green Reverse Logistics (GRL) topics. The concept of GRL is related to the management of products with different sustainable activities to reduce pollution creation. GRL activities identified by Hazen et al. (2011) are:

- Reusing;
- Remanufacturing;
- Recycling.

While suppliers and manufacturers are not the only contributors in facilitating green processes, LSPs are also required to redefine their processes by adopting green logistics practices that have to affect the entire supply chain from upstream activities to the downstream ones (Gupta & Singh, 2020), introducing green innovations. LSPs can implement green logistics practices in their processes in both inbound and outbound activities (Sarkis, 2012) with a focus not only on environmental issues but with a focus on other dimensions such as economic and social.

From a managerial perspective, it emerges that a flexibility-oriented organizational structure helps LSPs when undertaking green innovation as a response to environmental concerns presented by customers. Referring to flexibility-oriented organizations, "it means that the organization is oriented to the emphasis of spontaneity and creativity" (Chu et al., 2018). Pressure from customers' environmental concerns works as a strong incentive for LSPs to adopt green innovations. Green innovations are a risky bet that can result in long-term competitive advantages from an environmental perspective (Centobelli et al., 2020).

Another important concept that must be mentioned regards sustainable urban freight transport (SUFT), which is connected to the outbound logistics activities for LSPs and influences all the previously indicated dimensions: social, economic, and environmental. One of the challenges that SUFT presents to LSPs is the necessity to identify innovative solutions that can adapt to the cities' development agendas on sustainable development systems and have the minimum impact on the total costs for logistics providers (He & Haasis, 2020). However, all these themes are indirectly related to the hottest topic in transportation literature: environmental sustainability. Reducing the factors that generate externalities ensures a better quality of human life and better management of resources sustainably. Ranieri et al. (2018) stated that "to reduce the costs of these transport externalities, it is possible to identify five main categories of innovations: innovative vehicles, stations or proximity points, collaborative urban logistics, optimization of transport management and routes, and innovations in public policies and infrastructures". Combining these innovations, a smart logistics city would be created (He & Haasis, 2020). City logistics projects are those of thinking from a sustainable perspective by minimizing negative impacts by ensuring an efficient movement of goods in urban areas. The increase of freight vehicles in cities contributes to congestion, air pollution, noise, and the increase in logistics costs and therefore in product prices. As regards the rationalization of the flow of goods, the Urban Logistics initiatives focus on consolidation in single delivery and collection points to avoid crowding (as parcel lockers).

As far as Europe concerns, different works are studying the characteristics of the transportation infrastructure from the sustainability and innovation perspectives. The several numbers of contributions by European countries, on one side, are promoted by the investments that European Union is making in the sector (Gkoumas & Christou, 2020) and on the other side comprehensible, given the superior pressure of the European citizen and sensitivity of the European companies on these topics.

5 Final Remarks

5.1 *Discussion of Findings*

The topic of innovation in the logistics field, addressed in this chapter, is novel (Björklund & Forslund, 2018) and relevant for the European countries, being either a key sector in the economy of the continent and one of the main sources of negative externalities for the environment and the society. For understanding the approach of the logistics companies to these issues, we investigated their innovation directions and, despite the cliché, old-fashioned, and traditional industry, the logistic sector shows a significant pace of technological innovation, and the in-depth literature review allows clustering the most relevant foci of innovation in three clusters:

(1) Urban logistics innovations.
(2) Logistics providers- and transport-related innovations.
(3) Sustainability-oriented innovations.

The analysis of each cluster has proposed several possible lines of further research, highlighting at the same time what innovations have already been investigated by available contributions (see Sect. 4). The analysis of the clusters allows discussing the following insights.

First, two of the clusters are basically expected to emerge since these are clearly driven by the innovations in industry-specific technologies and operators and as a direct consequence of the keywords adopted. Indeed, the cluster (1) and the cluster (2) show the innovations directly affecting the main actors and the main business processes characterizing the industry (logistics providers and transport companies) and how innovation is strategically leveraged. The analysis showed how the two clusters have been well developed by previous contributions and how these research streams are well populated.

Second, one of the three clusters, namely (2) is expected too since this confirms that two relevant technological innovations (IoT and ICT) have also impacted this industry even if received less attention by the scientific community. For what concerns these two clusters more studies are needed to assess the impact on the industry of some of the recent technologies (such as, for instance, Digital Twin and Blockchain) which diffusion appears as limited, the rate of adoption very low, and the application can have more potential than a concrete phenomenon. In this sense, additional contributions can shed light on the impact of several coming technological innovations on the logistics industry, with space for empirical experiments and tests as well for case studies.

For what concerns cluster (3), although the text string used to perform the research about innovations in the logistics sector did not contain any keywords related to sustainability, the results include a considerable amount of information and papers in this subject area (i.e. two clusters (1) and (2) cited the sustainability indirectly, while one cluster (3) directly touches the topic). These are the most recent ones as it emerges from the keywords overlay analysis (see Fig. 4). As stated before, this shows the importance of this topic, especially in recent years, and how more often actions or innovations by companies are triggered by environmental constraints or opportunities. In cluster (3), there is a predominance of environmental issues while social issues have been mostly neglected. Even if the term "sustainable" has substantially replaced the term "environmental" or "green", the actual initiatives and the focus of the analysis of the reviewed contributions are largely related to the environmental side of sustainability only, without embracing all its dimensions. Due to the evident importance of this topic and due to the relevant impact of such industry on the ecosystem, that is another area with a great potential for further studies since companies will be soon required to be more effective and to minimize and offset their impact on the environment and the whole society. The presence of such gaps in the literature suggests matching the state of the art in the logistics industry with the stream of SOI (sustainability-oriented innovation), which seems to be the most promising current area of analysis for the logistics industry.

Furthermore, looking horizontally at the clusters, it appears evident that the typical innovation and technology management issues that emerge from the SLR are not broadly discussed and deeply studied as it happens in other industries (for instance, pharma, ICT, and automotive industries have been already deeply studied, and their specificities highlighted).

5.2 Concluding Remarks

In conclusion, the findings of this study highlight the importance and the types of innovative sustainable practices in the logistic sector addressing environmental challenges and fostering a more resilient and equitable future.

Moreover, this chapter sheds light on new and overlooked research directions that hold implications for scholars and researchers. These include:

- Exploring sustainability-oriented innovation in the logistics industry.
- Examining innovations and practical applications through case studies.
- Delving into technology and innovation management practices within logistics firms, such as the innovation process, open innovation, evaluation and selection of innovation projects, organization of research and development, and other related topics.

These avenues of research offer promising opportunities for further investigation and contribute to the advancement of knowledge in the field.

While a review of the grey literature can provide a more comprehensive understanding of real-world developments, it is important to note that the present research also offers valuable insights for managers and entrepreneurs. The findings of this study present practical implications and potential opportunities that can guide decision-making processes in the business world. By examining the results and recommendations of this research, managers and entrepreneurs can gain valuable insights to inform their strategies, enhance operational efficiency, and adapt to the dynamic landscape of their respective industries:

- Risk-taker managers, start-uppers, and first movers can easily find pioneering technologies and free-market spaces.
- Managers underestimating the emerging role of innovation and technology management in a mature industry, such as logistics, can review the business priorities.
- Practitioners, in general, should be aware of the coming wide impact of sustainability in the logistics industry, exceeding the more usual discussion (limited to few environmental topics often associated with mere green marketing, greenwashing or concurrent cost minimization) and be inspired to go farther beyond.

Known limits are associated with the Systematic Literature Reviews—which can be a powerful tool for identifying and synthesizing existing research—because their usefulness: (i) can be limited by the keywords and search terms used in the review process, and (ii) it depends on how up-to-date the research is.

For what concern the former, if the search terms are too narrow, relevant studies may be missed, while overly broad search terms can result in an overwhelming number of studies to be screened. Additionally, different search terms can lead to different results, so the choice of keywords can impact the overall conclusions of the review. The potential impact of different search terms should be carefully considered when conducting a systematic review, and multiple searches using different combinations of keywords or databases may be necessary to ensure a comprehensive review of the literature. In our case, for instance, to avoid an excessive expansion of the search area, search terms as "supply chain management" and "supply networks" have been employed. While we did not use a formal keywords' cleaning process, as mentioned we built our search string through an iterative refinement process involving a panel of experts, which helps in limiting potential bias in the search. As for the use of multiple databases, as explained in the methodological section, even if we reported the results of the search on Scopus only, we actually also interrogated an alternative database (i.e. Web of Science)—which returned a smaller number of papers already included in the sample from Scopus. This helped in avoiding an incorrect representation of the field of study. Additionally, when the research on which the analysis is based is not recent, significant limitations in the reliability and validity of the results obtained may arise. This is because knowledge and technology advance rapidly and older research may no longer be relevant or generalizable to current contexts. Additionally, the results of an SLR based on non-recent research may not be representative of the most up-to-date knowledge in the field. Therefore, we consider the limitations that the use of non-recent research can have on the results of the analysis.

Further, updated, investigations can overcome the aforementioned limitations. For example, addressing the new search terms could enable researchers to generate additional findings, and new update analysis can include the most recent contributions. Additionally, future research could explore alternative approaches or methods that could better capture the complexity of the phenomenon under investigation. Overall, addressing the limitations identified in the current article could lead to a deeper understanding of the research topic and inform the development of more effective managerial decisions and policies.

Appendix

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Comparing Organisational Patterns for Innovation Between Scottish and French Firms: An Exploratory Study

Rob Dekkers and Laure Morel

Abstract Traditional indicators, such as R&D expenditures and patent applications, are not necessarily the most relevant to measure the innovative capability of companies. Hence, this study aims at understanding how the conversion of ideas and inventions into commercialisation of products and services is managed, with an emphasis on internal processes and structures. To this purpose, a question sheet and a guide for semi-structured interviews have been developed derived from the model for the dynamic adaptation capability. Surprisingly, the findings from five French and five Scottish firms point to differences in innovative capabilities between French and Scottish firms that can be understood from autopoietic principles (following the law of parsimony) and the myopic versus dynamic approach for the context of the national innovation system. Additionally, the extent of the instrument indicates that a major effort is required to understand the innovative capabilities of firms and that this cannot be reduced to simplified measures as traditionally done.

Keywords Firm behaviour: empirical analysis (D22) · Business objectives of the firm (L21) · Firm performance: size · Diversification and scope (L25) · Innovation and invention: processes and incentives (O31) · Management of technological innovation and R&D (O32)

1 Introduction

Although the innovation gap for national economies has captured the attention of many scholars (e.g. Fischer, 2001; Freeman, 2002), the position of firms has been looked at in less detail. Godin (2009) shows that studies on national innovation

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systems by the OECD during the 1950s and 1960s preceded works, such as Dosi et al. (1988), Freeman (1987), Lundvall (1992) and Nelson (1993), which gave an impetus to other researchers to study science and innovation policy at national level but also at regional level (e.g. Cooke, 2001; Pittaway et al., 2004). Within these writings on innovation systems, the attention has been mainly on institutional settings (e.g. Cooke et al., 1997; Lundvall, 2007; Taylor, 2004), determinants (e.g. Furman et al., 2002), comparative studies (e.g. Martin & Johnston, 1999; Patel & Pavitt, 1994) and specific case studies (e.g. Intarakumnerd et al., 2002; Motohashi, 2005; Mowery, 1992). These studies tend to evaluate the innovative performance of firms merely at an aggregate level; such aggregation might lead to loss of detail about firms since it limits a search to common attributes for innovation capabilities [interpretation of Timpf (1999, p. 130) on aggregation] rather than accounting for contingencies [as advocated by Damanpour (1996)]. In this respect, Patel and Pavitt (1994, p. 91) characterise the national innovation systems of the UK and USA as myopic and those of Germany and Japan as dynamic, indicating that firms have different approaches to the challenges of innovation management. This loss of detail at the level of national innovation systems corresponds with the fact that fewer works have examined practices in companies as principal constituent elements of national innovation systems. For this reason, the onus of this paper is on examining the actual practices for innovation management within firms and how these practices are related to national innovation systems.

1.1 Background for Research

Immediately it raises the question: How to measure a single firm's contribution to innovation at a national level? However, metrics derived from the aggregate level of national innovation systems could be considered less adequate for assessing the innovative capability of individual companies:

- Patent applications show that research efforts will lead to inventions but only a few of these inventions reach the marketplace [e.g. the innovation funnel (Dunphy et al., 1996; Stevens & Burley, 1997)]. Furthermore, not all inventions are patented (Arundel & Kable, 1998; NESTA, 2006, p. 5), and some sectors, such as the construction industry (Bosch-Sijtsema & Postma, 2009, p. 60), hardly ever file patent applications.
- Neither R&D expenditures nor resource allocation to R&D activities relate directly to successful innovation outcomes, as is shown by Bougrain and Haudeville (2002, p. 743) for 313 SMEs and by Jaruzelski et al. (2006) in a study carried out on a thousand companies. As Jaruzelski et al., (2005, p. 55) state: 'It's the process, not the pocketbook'.
- Companies are embedded in networks of knowledge providers, specialised suppliers, distribution channels, user-led innovation and other collaborative efforts

to create and manage innovation. These networks lead to inbound knowledge acquisition and outbound knowledge dissemination (Enkel et al., 2009, pp. 312–313).

These three arguments indicate that traditional metrics derived from research into national innovation systems poorly measure the innovative capability of individual companies, even though widely used; this position is confirmed by recent studies that question the use of traditional metrics for assessing the innovative capabilities of firms (Becheikh et al., 2006; NESTA, 2006). Consequently, more academic research should be aiming at developing methodologies that assess the capability of companies to master their innovation processes. To capture the innovative capabilities of firms, a detailed understanding of internal mechanisms is necessary [corresponding with Delbridge et al.'s (2006, p. 19) generic call for looking inside the 'blackbox' of companies]. Particularly, management of innovation based on dedicated organisational schemes seems to influence the capability to successfully bring inventions to the market (e.g. Boer and During, 2001; Börjesson & Elmquist, 2011; Lekkerkerk, 2012; Menguc & Auh, 2010). The resulting methodologies for the assessment of innovative capabilities should also represent the impact of technology, even though it might only account for part of the success (e.g. Targeting Innovation, 2008, p. 5), and the dependency on integration into total business activities (both internally and externally). Hence, the onus of our research is on organisational patterns that determine the capability for innovation.

1.2 Research Objectives

This research project therefore aims at understanding how the innovation process—the conversion of ideas and inventions into new product and service launches—is managed, with an emphasis on the impact on the business model (see Johnson et al., 2008) and the structures, including the organisational structures and the networks necessary for innovation. For this purpose, we follow Burgelman et al., (1996, p. 8) who define innovative capabilities as 'the comprehensive set of characteristics of an organisation that facilitate and support innovation strategies'. Additionally, the research investigates the differences between companies operating in the Anglo-Saxon context—Scotland—and the Nippon-Rhineland model—France [following the notion of Patel and Pavitt (1994, p. 91) on myopic and dynamic national innovation systems]. This will indicate to what extent the national environment contributes to the approach by firms to innovation management. Henceforth, the exploratory study has two main objectives:

- To develop a framework for assessing the innovative capabilities that focus on the organisational patterns for the innovation processes (related to managerial interventions);

- To compare those organisational patterns of a sample of Scottish firms as representing the Anglo-Saxon perspective with those of a sample of French firms typifying the Nippon-Rhineland approach to identify potential influences of national innovation systems (assuming that basic internal processes are similar).

This explorative study may only lead to research directions to address more specific questions that arise.

1.3 Scope and Outline of Paper

The emphasis of the paper on the innovation processes and related organisational patterns to comprehend innovative capabilities of firms differs from earlier studies, such as Adams et al. (2006) who relied on the opinion of academic experts, Chiesa et al. (1996) who conducted a narrative literature review and Radnor and Noke (2002) who present an innovation compass based on determinants. In this respect, Morel et al. (2008) mention that studies into innovative capabilities are numerous and diverse. By concentrating on overall modelling of innovation processes, this study aims at revealing organisational factors that influence innovative performance. Therefore, the focus will be on models that allow studying the complex interactions resulting from the relationship between strategy and technology, and from the organisational relationships between actors to achieve innovation.

The paper will proceed as follows. In Sect. 2, we will continue by reviewing extensively the literature to develop a framework for assessing the innovative capabilities of firms, building on a generic framework for innovation processes. In Sect. 3, the research methodology for the empirical research (case studies) will be introduced. This will be followed by an analysis of the data at the level of firms and influence of national innovation systems in Sect. 4. The paper is concluded in Sect. 5.

2 Literature Review for Developing Framework

Taking as starting point that no sufficient, comprehensive (qualitative) model for innovation capabilities exists, the first step in this study is the search for a framework that describes internal innovation processes. This argument for modelling is supported by Greca and Moreira (2000, p. 8). Contrastingly, research into innovative capabilities so far has been mostly restricted to quantitative analysis of databases (e.g. Hagedoorn & Duysters, 2002) or questionnaires and surveys (e.g. Buganza & Verganti, 2006; Romijn & Albaladejo, 2002), which according to Shah and Corley (2006, p. 1822) do not lend themselves to investigating detailed research questions as do qualitative studies. Such qualitative studies should rely on modelling mechanisms, in our case, those underpinning organisational patterns for innovative capabilities, instead of qualitative research taken as interviews. In addition, the focus on modelling processes follows the reasoning by Nelson and Winter (1977, 1982) that organisational routines constitute the base for innovation, a proposition confirmed by Felin and Foss (2009, p. 158). Hence, the framework should describe internal innovation processes in such a way that organisational patterns and managerial interventions can be studied.

2.1 Searching for a Generic Framework

A generic framework based on innovation processes that have validity for a wide range of cases and that form a sufficient base for organisational patterns and managerial interventions will provide a more structured approach to studying firms' innovative capabilities. For the selection of this generic framework, models have been evaluated that describe internal innovation processes:

- The coupling model (Rothwell, 1994, p. 9).
- The model for the dynamic adaptation capability (Dekkers, 2005, pp. 308–319).
- The 'innovation arena' (Janszen, 2000).
- The life-cycle model (ten Haaf et al., 2002, pp. 162–312).
- The interrelationships between major innovation activities (Burgelman & Sayles, 1986).
- The interactive innovation model [Kline and Rosenburg (1986) in Gunsteren (1992)].
- The innovation model (Tidd et al., 1997).

All of these seven models distinguish similar phases for the innovation and new product development processes. From the seven frameworks, the model for the dynamic adaptation capability (Dekkers, 2005, pp. 308–319) appears most appropriate because of describing not only the innovation processes as iterative and continuous but also the presence of internal control processes (which allows managerial interventions); the approach is also consistent with innovation practices as proposed by Morel and Boly (2008). Earlier work of Chiesa et al. (1996) and Adams et al. (2006) on innovative capabilities and other works (e.g. Blumentritt & Danis, 2006; Lawson & Samson, 2001; Zott & Amit, 2008) that refer to these capabilities is less comprehensive. For assessing strategic renewal processes, this model for the dynamic adaptation capability (Fig. 1) captures the extent of strategic renewal defined by Ravasi and Lojacono (2005, pp. 52–54) both as corporate transformation and as continuous innovation and, additionally, provides the interrelationship between those two by its concept of innovation impact points; this integral model for strategic renewal covers: sensing the environment, strategy formation, master plan, resource allocation, implementation of innovation, feedback and dynamic capabilities.

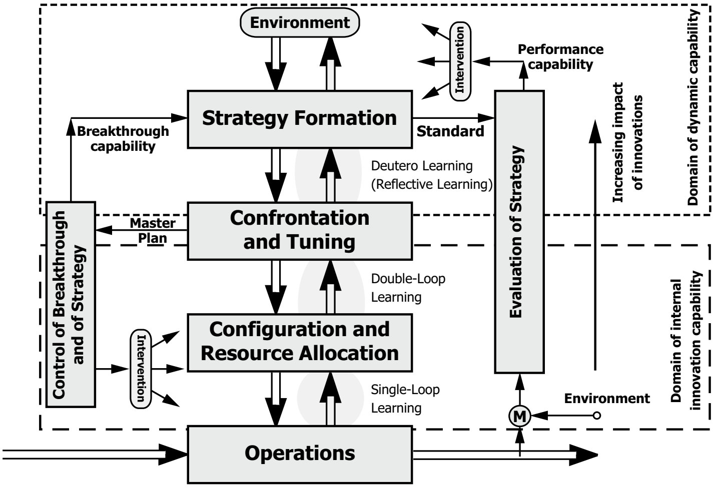

Fig. 1 Model for dynamic adaptation capability. Expanding on the breakthrough model with the innovation impact points, this particular model distinguishes the internal innovation capability and the dynamic capability with its external orientation

2.2 Sensing the Environment

The first process to consider for innovative capabilities and organisational patterns is the sensing of the environment. Interpretation of the environment is driven by the concept of bounded rationality (Alchian, 1950; Simon, 1947, pp. 39–41) and interaction with the environment. Particularly, cognitive limitations impact on the sensing of the environment by being less receptive to changes and to information from the environment (Choo, 1996, p. 334); in other words, an organisation is dependent on its members to interpret information that is externally provided (Glynn, 1996, p. 1088). Boer et al., (2006, p. 451) remark that bounded rationality rules out that all changes are explicitly identified let alone evaluated. Organisations and their members respond to this challenge by satisficing behaviour and simplifying the decision process (Choo, 1996, p. 331). This corresponds with the notion that organisational systems behave as autopoietic systems (see Dekkers, 2005, p. 147; Luhmann, 1995). The environment plays but a marginal role in the autopoietic perspective of internal processing of information; external stimuli can only limitedly determine the entity’s responses [external stimuli to be taken as potential triggers of innovation, following Tidd et al. (2005, pp. 170–171)]. Rather, how the organisation is structurally coupled in combination with the capability for processing external stimuli will determine responses (if happening at all). The distinct communication within a firm in order to interpret relations to the environment is distinguishable by different modes of interpretation, decision rules, objectives and specific internal communicative processes (Kaufmann & Tödtling, 2001, p. 794). Hence, for innovative capabilities the interpretation of stimuli from the environment acting on the organisation and the corresponding internal communication (and dissemination) to adapt is key to a viable long-term orientation for guiding new product development.

This leads to the question as to what stimuli should be monitored. In this respect, the first strand of phenomena relates to population ecology, dividing firms into so-called generalists and specialists (based on Hannan & Freeman, 1977, p. 958). Organisations can also become both specialist and generalist by partitioning the resources towards niches in the market, in order to enhance competitiveness (e.g. Mezias & Mezias, 2000; Swaminathan, 2001). And this distinction in strategies has been linked to entry into markets through innovation (e.g. Lambkin, 1988), competence-destroying innovations (e.g. Aldrich & Martinez, 2007) and industry structure (for instance, Utterback & Suárez, 1993). A second strand of research has focused on incumbents versus entrants in product-market combinations. For example, Chandy and Tellis (2000) show that the so-called incumbent's curse is not always valid and Aghion et al. (2009) study responses to entrants. Generally, it seems that entrants might be more successful when they introduce radical innovation, even though Hill and Rothaermel (2003) present some countermeasures for incumbents. This connects to a third strand of literature that has investigated industry dynamics related to technological trajectories. In these technological trajectories not only technological considerations play a role at the individual level (Andersen, 1998, p. 25), but also social–economic forces (e.g. Geels, 2002). This strand of literature also covers dominant design, even though dominant designs might only be known in retrospect [Anderson and Tushman (1990) cited in Murmann and Tushman (1998, p. 238)]. Hence, the make-up of a sector divided into generalists and specialists, its susceptibility to entrants with potential radical innovation, technology cycles and alternating dominant designs determines the direction of technological developments.

This puts the focus on how the turbulence caused by technological developments and competitive forces can be monitored. The study by Reger (2001) sheds some light on which sources might be used to gather information. Lichtenthaler (2005, p. 398) places these in the perspective of time horizons; for example, scenario analysis and Delphi studies have a long-term orientation, and technology roadmapping, expert panels and patent citation a mid-term horizon. But relevant sources of innovation also determine interaction with the environment (Kaufmann & Tödtling, 2001); in this respect, national innovation systems emphasise supplementary and complementary resources. Nosella et al., (2008, p. 332) remark that the pace of technological change might also determine the way technological developments are monitored (as technology-push or market-pull). In addition, they identify the R&D efforts as influencing the systematic approach to monitoring (in terms of proactive and advanced). Even though the future might be uncertain, companies should be able to monitor technological developments and competitive pressures through a wide variety of sources and methods (while accounting for time horizons) in order to respond to moves by competitors, to shifts in the markets and to technological trajectories.

Based on these deliberations, the components for the organisational patterns as part of innovative capabilities derived from sensing the environment can be found in Table 1 (the table also lists the internal processes that will follow in Sects. 2.3–2.9).

Table 1 Overview of main components for the question sheet and the interview guide

Category	Topics	Main sources	Components
Sensing the environment	Bounded rationality	Simon (1947)	• Time horizon for strategic and technology planning • Information sources used (compared to available) • Cognitive limitations
	Organisations as allopoietic systems	Dekkers (2005), Tidd et al. (2005)	• Interaction with environment, sources of innovation • Selection of relevant information • Dissemination of information from environment in organisation
	Population ecology	Hannan and Freeman (1977)	• Generalists vs. specialists • Incumbents vs. entrants • Technology trajectories and cycles (incl. dominant design)
	Monitoring	Kaufmann and Tödtling (2001), Lichtenthaler (2005), Reger (2001)	• Range of sources technological developments and competition • Time horizons of methods • Interaction in national systems of innovation
Strategy formation	Competitive strategy	Mintzberg (1988)	• Differentiation in market
	Strategic attitude	Conant et al. (1990), Miles and Snow (1978)	• Classification for strategic attitude
	Methods	Lichtenthaler (2005), Dekkers (2005)	• Time horizons of methods • Scenario planning
Confrontation and tuning, master plan	Portfolio management	Cooper et al. (2001), Mikkola (2001)	• Portfolio programmes and projects • Different type of innovations

(continued)

Table 1 (continued)

Category	Topics	Main sources	Components
	Technology roadmapping	Groenveld (2007), Kostoff and Schaller (2001), Phaal et al. (2004)	• Time horizon for combining technologies and products • Monitoring technological developments
Resource allocation	Collaboration	Harris et al. (1996)	• Collaboration matrix • Firm characteristics • Position in networks • User involvement
	Project and programme autonomy	Engwall and Jerbrant (2003)	• Project structure (coordination, matrix, autonomous) • Multidisciplinary teams • Transparency resource allocation
Implementation	Concurrent engineering		• Degree of novelty • Multidisciplinary teams
	Transition to operations	Leonard-Barton (1988), Schuh et al. (2005), Tyre and Orlikowski (1993)	• Launch teams • Adaptation cycles combined with freezing/unfreezing
Feedback	R&D and NPD performance measurement	Brown and Svenson (1998)	• External vs. internal measurements • Outputs vs. behaviour
	Learning from projects	Williams (2008), von Zedtwitz (2002)	• Project evaluation
Dynamic capabilities		Dekkers (2005)	• Innovation impact points • Learning cycles
Additional measures	Organistic and mechanic structures	Burns and Stalker (1961), Patel and Pavitt (1994)	• Characteristics of organisations • Dynamic and myopic systems
	Generations of innovation processes	Rothwell (1994)	• Five generations
	Life cycle of firms	Greiner (1998)	• Five phases

For each of the components of the model for the dynamic adaptation capability, the text has highlighted topics and sources. The main sources have been used to construct the question sheet and the interview guide

2.3 Strategy Formation

For the next process of the model for the dynamic adaptation capability in Fig. 1, strategy formation, the sensing of the environment is considered the input. Following this model, strategy formation is split into competitive strategy (output) and processes (methods, including scenario planning). It is also proposed to include the strategic attitude, which builds on the arguments surrounding the allopoietic behaviour of organisations. Hence, the three main aspects for strategy formation are: competitive strategy, strategic attitude and methods for strategy formation.

For assessing a competitive strategy (taking a product-market combination as the unit of analysis), one could denote that newer theories for strategy may serve as an indicator. One of those newer theories is the resource-based view, which has been linked to alliances and networked organisations (e.g. Verona, 1999) and knowledge management (e.g. Wu & Ragatz, 2010), but has been heavily criticised (e.g. Priem & Butler, 2001). As another theoretical base, the approach of core competencies has been viewed as determinant for in-house activities versus outsourcing (e.g. Prencipe, 1997), for competence development (e.g. Danneels, 2002) and for competence acquisition (e.g. Hull & Covin, 2010). Finally, the dynamic capabilities perspective has been related to knowledge management (e.g. Jantunen, 2005) and alliances (e.g. Hagedoorn & Duysters, 2002) in the context of innovation management. With the exception of the dynamic capabilities perspective (e.g. Lee & Kelley, 2008; Menguc & Auh, 2010), captured already by the model for the dynamic adaptation capability in this study, these newer approaches to competitive strategy are insufficient for describing the position of firms in their product-market domain(s). However, four more traditional models for the competitive strategy have been found that do so: Abell's (1980) competitive strategies, Miles and Snow's (1978) classification, Mintzberg's (1988) differentiation strategies and Porter's (1980) generic competitive strategies. A large number of studies use one of these models as point of departure, whereas only a few evaluate their applicability (e.g. Chrisman et al., 1988; Smith et al., 1989) that leads Bowman (2008) to argue that that these generic strategies do not substitute case-specific business scenarios. Within the context of this research, the main criterion is the link of competitive strategies to innovation, for which the classification of Miles and Snow provides better insight than the other three (as mentioned by, e.g., O'Regan & Ghobadian, 2005; Weisenfeld-Schenk, 1994; Zahra & Pearce, 1990). Additionally, Kotha and Vadlamani (1995) find that Mintzberg should be preferred above Porter that aligns with Hoopes et al. (2003) who stress heterogeneity as the basis for competitiveness. For this study, that means that Miles and Snow's typology for the strategic attitude (see also Laforet, 2008; O'Regan & Ghobadian, 2005; Slater & Mohr, 2006) should be combined with assessing competitiveness according to Mintzberg's concept for differentiation.

Next to defining the competitive strategy, the classification of Miles and Snow (1978) also looks at the strategic attitude. Within this classification, so-called prospectors are able to develop disruptive innovations and to eventually supersede prior industry leaders (Slater & Mohr, 2006, p. 32). Their strategy contrasts with defenders

(Laforet, 2008, p. 761), who use functional organisational structures combined with inexpensive forms of coordination for a single narrow market domain. Analysers operate in two types of product-market domains, one relatively stable and the other dynamic. In turbulent markets, top managers of analysers monitor competitors closely and rapidly adopt the most promising concepts, deploying their marketing capabilities and incremental innovation (Slater & Mohr, 2006, p. 29). Reactors lack a consistent strategy–structure relationship; they seldom make adjustments of any sort until forced by environmental pressures. Hence, prospectors and analysers could be defined as being more active in innovation, particularly by searching for heterogeneity in the marketplace, whereas reactors and defenders would show lower levels of engagement [concurring with O'Regan and Ghobadian's (2005, p. 93) classification]; this constitutes the second aspect for strategy formation that might be relevant to innovative capabilities.

The final aspect of strategy formation is regarding which methods companies should deploy to shape their competitive strategy. Frost (2003, p. 54) presents an overview of strategic methods and tools; only a subset would be applicable to innovation management. He contends that only a fraction of the tools is used in small- and medium-sized enterprises (SMEs); this might be of interest since innovation could reside in SMEs [as is the case for the German economy, where the 'hidden champions', typically SMEs, are its drivers (Venohr & Meyer, 2007)]. In the context of strategy as mid-term and long-term perspectives, in Lichtenthaler's (2005, p. 398) overview two methods emerge as suitable for the long term (Delphi studies, scenario analysis), whereas expert consultation (expert panels, flexible expert interviews), benchmarking, roadmapping and monitoring technological developments (patents, publications, conferences) are supporting mid-term strategy development; at the same time, he denotes that some instruments might be more suitable for specific industries (ibid., p. 400). Hence, the use of methods should be linked to the time horizon and potentially to specific industries.

2.4 Master Plan for Innovation Management and Monitoring

An additional dimension of strategic planning, derived from Fig. 1, is the process of 'confrontation and tuning', which could be taken as portfolio management for the innovative capabilities akin to 'coherent management' (Practice 4 as found in Morel & Boly, 2008, p. 387). A study by Cooper et al. (2001) shows that financial methods are most popular in practice but may yield the worst results, whereas top-performing firms rely more on non-financial approaches—strategic and scoring methods. In this perspective, Mikkola (2001, p. 433) asserts that portfolio management assists in systematic R&D project selection, market and technological dynamics of projects, identifying risks and gaps, and prioritisation with respect to resource allocation. Some research has been done using optimisation approaches, such as Stummer and Heidenberger (2003) and Wang and Hwang (2007); Beaujon et al. (2001) contend that the key value of optimisation methods is restricted to exposing, balancing and managing constraints rather than project selection. Additionally, Jonas (2010, p. 828) even makes the case that portfolio management may constitute a new role as intermediary between line management and project management in matrix organisations. Hence, it can be inferred that a portfolio approach is of paramount importance to developing a long-term perspective on innovation and new product development.

As an additional approach, technology roadmapping may support the identification of potential projects and aid the selection process. Methods for technology roadmapping have been proposed by Groenveld (2007), Kostoff and Schaller (2001) and Phaal et al. (2004). Groenveld (2007, p. 58) remarks that organisations with a functionally oriented culture may have difficulty with implementing roadmapping since they are more directed at drafting independent functional maps rather than integrated ones necessary for products. Additionally, Lichtenthaler (2005, p. 399) finds that pure technology roadmaps tend to lead to linear thinking and lack of market orientation. Ideally, technology roadmapping and portfolio management (or a combination of both; see Oliveira & Rozenfeld, 2010) should result in a master plan that sets out programmes, projects and their interdependencies; a master plan should allow monitoring and verifying progress (feedforward).

2.5 Resource Allocation and Configuration: Project and Programme Management

The master plan, as part of the fourth process—resource allocation and configuration—also guides which activities should be depending on collaborations (Practice 12 as found in Morel & Boly, 2008, p. 387) and which should be considered for internal new product development. A key issue is the relationship between the impact of technological developments and arrangements between partners (e.g. Nassimbeni, 1998, p. 539; Pyka, 2002, p. 161; Teece, 1986). However, the first step seems to be the assessment of internal technological capability for technologies, sometimes called absorptive capacity (Cohen & Levinthal, 1990; Harris et al., 1996), which can provide the strategic foundation of make-buy-or-collaborate decisions (see Table 2). Also, the size of companies plays an important role, according to Veugelers and Cassiman (1999, p. 76); larger firms are more likely to combine internal and external sourcing, whereas smaller firms explicitly choose one of these. This view shows that internal technological capabilities and size determine the potential contractual relationships between firms in an innovation network; for example, see Prencipe (1997) for product development at Rolls-Royce aero-engines.

Furthermore, insight from complexity science informs that embeddedness is driven by positions in the network [Riccaboni and Pammolli (2002, p. 1415) even speak about 'popularity being attractive'], technological distance (e.g. Gilsing et al., 2008; Nooteboom et al., 2007) and network density (Gilsing & Duysters, 2008, p. 704); closeness may be related more to emphasis on incremental innovation and

Table 2 Outsourcing and partnering matrix (adapted from Harris et al., 1996)

Competitive impact of technology	Internal technological capability		
	Weak	Moderate	Strong
Emerging	Scan	Scan or collaborate	Collaborate
Pacing	Collaborate	Share risks	In-house
Key	Optimise	Optimise	In-house
Base	Outsourcing	Outsource or exchange	Sell or exchange

Depending on the competitive impact of a technology and the internal technological capability, decisions can be made with respect to keeping the technological capability in-house or to collaborate in any form

larger distances may facilitate more radical innovation. In that respect, the study by Sorenson et al., (2006, p. 1009) indicates that distance may only be an advantage in the case of moderately complex knowledge. Similarly, Gay and Dousset (2005, p. 1472) find that the engagement in alliances can be explained as small-world properties. This resembles the writings about user centricity (e.g. Dinet et al., 2003), customer-centric business strategy (e.g. Berger et al., 2005) and user involvement (e.g. von Hippel, 2005, 2007). In the context of innovation of information systems, user-centred design can be traced back to the end of the 1990s (Bødker, 2000; Kontogiannis & Embrey, 1997; Moyes & Baber, 1999). Furthermore, close proximity to lead users or customers may gravitate companies towards incremental innovation (Veryzer, 1998), whereas others advocate a user-centred approach for the development of new products (Diederiks & Hoonhout, 2007). Hence, the capability to exploit available resources, internal and external to the firm, depends on the network position and to what purpose and extent external knowledge is used for generating innovations; in that sense, Faems et al., (2005, p. 248) even propose a portfolio approach towards collaboration.

Another dimension for new product development constitutes project and programme autonomy. Even though matrix structures are frequently used, organisations with heavyweight project management or engineering teams with higher authority tend to have fewer engineering hours and shorter lead times than teams with lower authority or mainly functional authority (Barczak, 1995; Bstieler, 2005, pp. 280–281; Clark et al., 1987, p. 767; Dyer et al., 1999; Larson & Gobeli, 1988, p. 189; Lee et al., 2000, p. 507). When the approach of concurrent engineering is used, reduction of engineering team authority and autonomy is also associated with lower team performance (Gerwin & Moffat, 1997). This suggests that powerful project teams will deliver more successful results for organisations following market leadership strategies. The evidence of a positive contribution of project autonomy for companies pursuing innovation leadership is mixed (Gemünden et al., 2005, p. 371). In terms of efficiency, however, powerful project managers tend to hinder resource and parts sharing and this can result in increased costs which may be an issue for organisations following a cost leadership strategy (Nobelius & Sundgren, 2002, pp. 66–69); in addition, Engwall and Jerbrant (2003, p. 408) state that resource allocation in a multi-project environment (Practice 7 as found in Morel & Boly, 2008, p. 387) may be subject to a process of politics, horse trading, interpretation and sense-making and be far more complex than traditionally discussed. Finally, the use of a multifunctional team that has central responsibility during the whole project appears to result in better performance regardless of the company's strategy (Bstieler, 2005, pp. 280–281; Cooper & Kleinschmidt, 1993, pp. 108–109). Hence, project and programme autonomy should depend on the innovation strategy and, in any case, multifunctional teams with central responsibility may contribute to a positive overall performance.

2.6 Implementation of Innovations

As a way to link innovation management to operational processes (i.e. the implementation of innovation), cross-functional collaboration—particularly concurrent engineering—has a positive influence on integral performance criteria (Haque et al., 2003; Hong et al., 2004; Nihtilä, 1999; Swink et al., 2006). Concurrent engineering positively affects product innovation, but has only an indirect effect on product quality (Koufteros et al., 2001, p. 112). Other studies show that concurrent engineering reduces cycle time and increases quality in case of incremental innovations (Handfield, 1994; McDermott & Handfield, 2000, p. 54; Valle & Vázquez-Bustelo, 2009). McDermott and Handfield's (2000) study extends this to suppliers. There are more studies that have signalled the applicability of concurrent engineering. For example, von Zedtwitz and Gassmann (2002, p. 585) state that the separation of applied research and advanced engineering from development and series engineering can enable more innovative solutions, whereas integration can reduce costs and cycle time. For cross-functional collaboration, Fynes and De Búrca (2005) confirm a significant impact of design quality on conformance quality and product quality, time-to-market and perceptions of quality in the market while Rupak et al., (2008, p. 733) find that insufficient cross-functional collaboration can lead to design glitches. Hence, all studies distinctively indicate the necessity for cross-functional collaboration, albeit that radical innovation may benefit less from such approaches as concurrent engineering.

An additional point worth mentioning is the paramount importance of the transition from the new product development and engineering phase to the manufacturing stage. The use of permanent or project-specific launch teams in the automotive industry (often a launch manager position) seems to improve ramp-up time, costs and quality (Schuh et al., 2005, p. 407). In this respect, Leonard-Barton (1988) has pointed out that adaptation cycles that assess aberrations during manufacturing on their implications for product and process design and strategy may be a necessity for integrating engineering and manufacturing; note that this corresponds to the echelons of feedback in Fig. 1. Furthermore, Tyre and Orlikowski (1993) have pointed out that periods of freezing and unfreezing might be an effective mechanism for the implementation of changes. These studies point out the necessity of managing the implementation of innovation, particularly with regard to the transition of a project for new product development to manufacturing.

2.7 Feedback on Innovation Performance

Even though its importance is well-recognised, relatively little has been written about feedback from the performance of firms in the context of efforts for innovation (Practice 5 as found in Morel & Boly, 2008, p. 387). However, some have directed the feedback at R&D itself or learning from projects. For example, Kerssens-van Dongelen and Bilderbeek (1999) use the balanced scorecard approach to measure R&D performance. Brown and Svenson (1998, pp. 33–34) propose that such systems should focus on (i) external versus internal measurements; (ii) measuring outcomes and outputs, not behaviour; and (iii) measuring only valuable accomplishments and outputs. Measurement of performance of R&D and new product development should eventually ensure better coherence and relevance of product portfolios, reorientation of projects before failure, decisions on corrective actions, support for the launching decision, the enhancement of staff motivation, and facilitation of well-balanced decision-making (Godener & Söderquist, 2004, p. 216). Ojanen and Vuola (2006) contend that R&D and new product development metrics may be case-specific. As an alternative to metrics for feedback, companies can improve their innovative capabilities through learning from projects, as elaborated by Williams (2008) and von Zedtwitz (2002). Therefore, innovative capabilities include not only metrics for R&D performance, where attention should be paid to their relevance (see introduction to this paper), but also learning from projects.

2.8 Dynamic Capabilities in the Context of Innovative Capabilities

In the context of Fig. 1, the central role of portfolio management points to how firms adapt strategies and internal processes to the dynamics of the environment, in line with the concept of strategic renewal. Continuous reflection on possibilities and opportunities leads to a stream of innovations to the market [e.g. Cooper et al. (2001) and Mikkola (2001)], fed by bottom-up innovations through learning cycles and technological improvements, and embedded in dynamics of the market. To that end, the model for dynamic adaptation capability has two components: dynamic capability [similar to the concept of Teece et al. (1997)] and internal innovation capability. Portfolio management separates these capabilities (to be viewed as a decision-making connecting strategy to internal innovation initiatives). Above and including this level strategic adaptation takes place, whereas at lower levels in this model a continuous flow of innovations is generated. Ellonen et al. (2009) find that companies that had relatively strong dynamic capabilities in three areas (sensing, seizing and reconfiguration) seem to produce innovations that combine their existing capabilities on either the market or the technology dimension with new capabilities on the other dimension. Correspondingly, companies with a weaker or more one-sided set of dynamic capabilities seem to produce more radical innovations requiring both new market and technological capabilities. In this context, Wang and Ahmed (2007, p. 38) remark: ‘the more innovative a firm is, the more it possesses dynamic capabilities’. Hence, the search for adaptation and innovation is driven by the pursuit of optimisation (mostly represented by the internal innovation capability) and the quest for strategic renewal (mostly represented by the dynamic capability).

2.9 Additional Measures for Assessing Organisational Patterns

To assess the context of the organisational patterns for innovative capabilities, three more indicators have been used in this study in addition to the models that describe the internal innovation management processes and practices.

Mechanistic Versus Organic Organisational Structures

For the first additional measure, Burns and Stalker (1961) identified two kinds of organisational structures: mechanic (mechanistic) organisations and organic (dynamic) organisations. Mechanistic structures are recognised by traits such as high complexity and formality as well as centralisation; these are appropriate for repetitive functions and actions, are highly dependent on planned behaviours and react to unpredicted events relatively slowly. Organic structures are relatively resilient and adaptable and emphasise parallel relationships rather than vertical ones; in these structures, influence is based on skills and knowledge rather than status-related authorities, responsibilities are defined flexibly, and the focus is on data sharing rather than commanding. It is the organic structures that are associated with innovation. Robins (1990, pp. 180–181) shows the differences between the two archetypes of organisational structures in an extended overview. In an environment of rapid and uncertain technological change, organisations may benefit from a broad range of ‘receptors’ to the environment, as in the organic structure of Burns and Stalker (1961, p. 6). However, Harmancioglu et al., (2007, p. 421) find in their exploratory study that companies adopt more centralised structures and formalised processes in dynamic and uncertain environments, which contrasts with earlier beliefs. Van Looy et al., (2005, p. 210) state while referring to other writings, that hybrid organisational forms will therefore become a necessity, implying that no organisation has a sole mechanistic or organic structure. This argument has been advanced explicitly and convincingly by Tushman et al. (1997), among others, when elaborating on the idea of ambidextrous organisations. In that context, one could argue that the nature of organisational environment determines which structure or which mix should be applied (Mintzberg, 1979, pp. 270–272); this perspective contrasts with autopoietic views but builds on the potential instability of organisations when environmental pressures emphasise innovation.

That environment could also be characterised in Patel and Pavitt's terms (1994, p. 91) of dynamic and myopic national innovation systems. Myopic national innovation systems treat technological investments and innovation just like any conventional investment; dominating factors considered are risk and time, preferably in well-defined markets. Dynamic national innovation systems tend to include accumulated market, organisational and technological learning for subsequent investments that otherwise would be more difficult to undertake because of a lack of competencies. Please note the link with feedback of innovation performance. In this respect, the study by Wagner and Kreuter (1998, pp. 37, 40–41) into fourteen companies based in Germany, Japan and the USA. concludes that, even though all three cultures attach higher values to soft factors than to hard factors, structural measures should be taken in companies to stimulate innovation, such as project-based organisational structures, knowledge structures and evaluation mechanisms. They hardly highlight that the most outstanding distinction between the more successful and less successful companies constitutes the attention for organisational processes for innovation. This confirms the necessity to look at organisational processes and structures for innovative capabilities, a thought followed in the present study.

Generations of Innovation Processes

To this end, an additional measure taken is Rothwell's (1994) classification for generations of innovation processes. Other papers address more generic concepts [e.g. closed versus open innovation (Chesbrough, 2003; Tidd, 1995)] or they are included in Rothwell's generations (e.g. Cooper, 1994) or they take them as the point of departure (e.g. Blomqvist et al., 2004). Turning back to Rothwell's (1994, p. 8) generations of innovation processes, the first two perceive commercialisation generally as a linear progression from scientific discovery, through technological development in firms, to the marketplace or take the market served as their starting point. The third-generation process comprises technology-push and market-pull: a complex of intra-organisational and extra-organisational communication paths (Rothwell & Zegveld, 1985, p. 50). The fourth generation of innovation processes goes back to Japanese companies who in the 1980s were able to integrate knowledge of suppliers in the early stages of new product development. The fifth-generation process covers centrally, integrated and parallel development processes, strong and early vertical linkages (including reaching out to lead customers), developed corporate structures and the use of electronics-based design and information systems. These five generations of innovation processes show whether the internal processes and structures for innovative capabilities have become more sophisticated and rely more and more on collaborative networks.

Life-Cycle Model

As a third additional measure, a life-cycle model for organisations related to innovation management has been chosen. The organisation of innovation processes in a firm also depends on the stage of growth, the so-called life cycle of an organisation (e.g. Koberg et al., 1996). Although a few similar models exist (e.g. Lester et al., 2003; Lievegoed, 1993), Greiner's (1998) life-cycle model has been widely accepted as a descriptive model for the phases of growth for companies. Companies experience periods of evolution interchanged by periods of substantial organisational turmoil and change. In the preceding work, the evolutionary growth of organisational structures of companies has been connected to the stages of growth (Dekkers, 2005) and to innovation management (Koberg et al., 1996). The main feature of the model is that each stage builds on the capabilities acquired in the past and the decisions taken rather than projections of the future on the present (akin to organisations being allopoietic systems).

This position could be contested since the life-cycle approach could be seen as deterministic. Some have challenged this life-cycle model by proving that companies grow by going through stages but not necessarily through all in the same way (Kazanjian & Drazin, 1989; Miller & Friesen, 1984). Van de Ven and Poole (1995) take the life-cycle models as one of four perspectives on organisational change; the other three being teleology, dialectics and evolution. They propose that interplay between these perspectives might be more adequate; however, this leads to complex models for organisational change. Conform the life-cycle model the driver for innovation management changes too, from entrepreneurial behaviour in the first phase to systematically searching for expansion in existing markets and new product-market combinations during later stages. For the internal structures and its management in the context of innovative capabilities, the life-cycle model will merely serve as a tool for analysis and not as an absolute measure of organisational health and innovation.

3 Methodology for Empirical Research

Finally, given that components of organisational patterns have been identified during the literature review (see Table 1), and the next step is design of the research and data collection. The research rationale will be briefly explained, followed by the methods used for data collection.

3.1 Research Rationale

For this project, a mixed method for data collection—question sheet combined with semi-structured interviews—has been used. This choice for a mixed method is instigated by the exploratory character of this study; whereas some parts of innovation capabilities have been investigated, others areas are more exploratory in nature. This rationale follows the thoughts of Johnson and Onwuegbuzie (2004, pp. 21–22) and Sandelowski (2000): quantitative research (questionnaire) combined with qualitative research (interviews) for exploratory studies. This approach is also congruent with Shah and Corley's (2006, p. 1831) remark, that quantitative studies tend to lack accuracy and these need to be complemented with inquiries that go into more detail. Furthermore, Hoskisson et al., (1999, p. 447) state that the use of quantitative-based tools is not applicable to all research questions; particularly for those where detail is required. Additionally, the use of the mixed research method facilitates triangulation (Jick, 1979). Hence, the mixed research method offers advantages for this exploratory study.

To prepare for the engagement with companies, Table 3 has been derived from Table 1 and displays which components have been identified for the semi-structured interviews. Table 3 also lists the sections of the question sheet to which topics have been allocated (0: General information; 1: Characteristics of innovation; 2: Scanning of environment; 3: Strategy formation; 4: Portfolio management; 5: Collaborations; 6: Project and programme management; 7: Dynamic capabilities; 8: Culture; 9: Additional measures). The question sheet should be seen as a systematic process for collecting data and not as the basis for a traditional quantitative survey. The same table lists which of the components have been used for the interview guide. Some of its components have been listed in both columns, which facilitates triangulation.

3.2 Data Collection

Data have been collected from five French and five Scottish firms that are paradigmatic cases, following Flyvbjerg's typology (2006, p. 232), because all were seen as innovative in their respective industries; the French firms were listed in a national innovation database. Table 4 provides an overview of the companies. Particularly for Scottish firms, the evidence of an innovation gap (NESTA, 2007) raises the issue of how to enhance their innovative capabilities in order to respond to intense competition and the increasing pace of technological change (Baumol, 2004; Coombs and Bierly, 2006; Teece, 2007; Winter et al., 2003). The competitive challenge also requires an appropriate understanding of all the factors that can generate and sustain a competitive advantage, particularly those for innovation (Blumentritt & Danis, 2006; Burgelman et al., 1996; Dekkers & Thuriaux-Alemàn, 2007). Additionally, the Scottish and British economies are often compared with those of France, Germany, Japan and the USA on the national systems of innovation. This might be due to the fact that the UK industry has a broad, traditional and patchy base with typical strengths and characteristics, as outlined for instance by the DTI (2004, p. 35), Porter (1990, p. 484) and Yip et al. (2006). Hence, it would be sensible to compare Scottish companies with French ones (as one of the countries the UK is compared with), hence shedding light on Patel and Pavitt's (1994, p. 91) terms of dynamic and myopic national innovation systems.

An initial version of the combined question sheet and interview guide was distributed among three Scottish firms to obtain feedback. The response of this initial version was positive and the companies added that the structure and style assisted them into rethinking their own innovation processes and practices for innovation

Table 3 Overview of research methods

Category	Topics	Question sheet	Section	Semi-structured interviews
Sensing the environment	Bounded rationality	• Time horizon for strategic and technology planning • Information sources used (compared to available)	4 2.1 2.2	• Cognitive limitations
	Organisations as allopoietic systems	• Interaction with environment, sources of innovation • Selection of relevant information	1.3 2.1 2.2	• Selection of relevant information • Dissemination of information from environment in organisation
	Population ecology	• Generalists vs. specialists • Incumbents vs. entrants • Technology trajectories and cycles (incl. dominant design)	2.3 2.4	• Technology trajectories and cycles (incl. dominant design)
	Monitoring	• Range of sources technological developments and competition • Time horizons of methods	4.1	• Interaction in national systems of innovation
Strategy formation	Competitive strategy	• Differentiation in market	3.3	
	Strategic attitude	• Classification for strategic attitude	3.2	
	Methods	• Time horizons of methods • Scenario planning	4.1 4.2	
Confrontation and tuning, master plan	Portfolio management	• Different type of innovations	4.3	• Portfolio programmes and projects
	Technology roadmapping	• Time horizon for combining technologies and products	4.1	• Monitoring technological developments
Resource allocation	Collaboration	• Collaboration matrix • Firm characteristics • Position in networks • User involvement	5.1 + 2 0 5.3 5.4	

(continued)

Table 3 (continued)

Category	Topics	Question sheet	Section	Semi-structured interviews
	Project and programme autonomy	• Project structure (coordination, matrix, autonomous) • Multidisciplinary teams	6.1 6.2	• Transparency resource allocation
Implementation	Concurrent engineering	• Degree of novelty • Multidisciplinary teams	6.2 6.2	• Multidisciplinary teams
	Transition to operations	• Launch teams • Adaptation cycles combined with freezing/unfreezing	6.3 6.4	• Adaptation cycles combined with freezing/unfreezing
Feedback	Performance measurement			• External vs. internal measurements • Outputs vs. behaviour
	Learning			• Project evaluation
Dynamic capabilities		• Innovation impact points • Learning cycles	7.1 7.2	• Innovation impact points • Learning cycles
Additional measures	Organistic and mechanic structures	• Characteristics of organisations	8.1	
	Generations of innovation processes	• Five generations	9.1	
	Life cycle of organisations	• Phases of development of organisations	9.2	

Based on Table 1, the components have been allocated to the question sheet and semi-structured interviews. The questionnaire has been divided into sections, which have been indicated in the fourth column; the description of the sections is provided in the text.

management. The same procedure was followed by sending the question sheet to two French firms to ensure consistency. The combined interview guide and question sheet is then not only a tool for assessing the innovative capabilities of firms but potentially also a tool for improving innovation management practices.

Table 4 Overview of companies of samples

Company	Products	Characterisation
Diagnosis (France)	Healthcare products	Very small company (five employees). Flexible, niche player but market leader
Fibres (Scotland)	Glassfibre components	Used mostly in construction industry. Leading company nationally. About 35 employees
Healthy (France)	Software solutions	About 600 employees. Niche player for static, pharmaceutical market
KeepCold (Scotland)	Cooling equipment	For industrial use. Standard solutions. Trying to develop new products. About 250 employees (incl. support and service)
Manipulate (Scotland)	High-tech solutions materials handling	Niche player for specific solutions targeting at limited range of customers. About 40 employees
PackThem (Scotland)	Packaging solutions	About 100 employees
PaperWorks (Scotland)	Specialty papers	Niche player for labels, tickets/tags, thermal products, etc. Invested in new products and flexible processes to be responsive to market. About 85 employees
Tasty (France)	Food	About 80 employees. Mass-market products, focusing on specific products
TurnThem (France)	Mechanical systems	Specialist in power conversion for a wide range of applications. About 5000 employees
VideoSens (France)	Sensing solutions	Niche products for limited range of customers. About 15 employees

4 Analysis of Data

After the presentation of the results, the discussion starts by comparing the organisational patterns for innovative capabilities of both sets of individual firms before paying attention to the potential influence of the national innovation systems.

4.1 Results

From the detailed question sheet and semi-structured interviews, we have aggregated the information into the main components of Table 3 for each firm. The results from the Scottish firms are found in Table 5 and from the French companies in Table 6. Note that we have sent the question sheet first and afterwards interviewed this wide range of companies, from different sectors and of different sizes (from five to about 5000 employees); this process allowed clarification of responses and inconsistencies in the question sheet during the interviews. However, not all companies were prepared to share all information; incomplete responses have also been included in the overviews. What all companies have in common is that they are considered 'innovative' companies in their product-market domains and are hardly patenting their ideas and inventions'. Hence, they could be considered as exemplary for so-called hidden innovation; our case studies indicate that hidden innovation is found beyond the traditional sectors, such as construction (Ruddock and Ruddock, 2009) and services (Abreu et al., 2010), it is associated with. Most of the companies were also operating on a 'national' scale; that is, they were predominantly serving customers in their country of origin (with the Scottish sample interpreted as the UK).

The purposeful, rich data captured by Tables 5 and 6 allows examination of the organisational patterns for innovative capabilities of these firms and for matching those with their diversity. One example is the company Diagnosis, consisting of only five employees; hence, the processes for innovation and its management are embedded in the way of working of the entrepreneur–owner. That the phase of the life cycle is the first stage of Greiner's model is a result consistently found in other factors of this question sheet. To this end, each company's practices have been considered on consistency and have been compared with those of the other companies in both samples.

4.2 Discussion of Results

The first category of Tables 5 and 6, sensing the environment, indicates that both samples engage differently with their competitive environment. The Scottish companies rely heavily on entrepreneurship and management teams for assessing developments in the environment, whereas French companies are engaging departments (also informally) and disseminating more actively which direction to take. This is also expressed in external interactions, where French firms tap into a wider range of sources; the Scottish organisations were more geared towards interest groups, such as chambers of commerce, as an important source of interaction with the environment. The wider-ranging engagement, and the importance of scanning outlined by Barringer and Bluedorn (1999, p. 436), leads to greater awareness about technology cycles and positioning in the product-market domains, which extends beyond the link between dynamic capability and entrepreneurship (Zahra et al., 2006), and aligns with evidence provided by Mahdi (2003, p. 265) who points out that search strategies are linked to internal capabilities rather than only to environmental factors. Remarkably, it should be observed that Scottish firms depended more on serendipity (or opportunity), whereas the French ones were more aware about technology cycles and market developments; this aligns with the paradox of the Anglo-Saxon and Nippon-Rhineland model. Hence, the first finding of this study indicates that Scottish companies displayed more organisational closedness [see Dagnino (2004, p. 62) for this term] than the French ones, as well as in terms of internal engagement between (functional) departments.

With respect to the strategic aspects of innovative capabilities, some remarkable differences appeared between the two sets. Aligned with their innovative position in the market, all companies offered distinctive products, but most companies

Table 5 Overview of Scottish sample

Category	Topics	Fibres	Keepcold	Manipulate	PackThem	Paperworks
Sensing the environment	Bounded rationality	Embedded in vision entrepreneur	Embedded in vision MT	Embedded in vision MT	Embedded in vision MT	Embedded in vision entrepreneur
	Organisations as allopoietic systems	Interaction for innovation mostly limited to entrepreneur. Limited sources used for innovation	Interaction for innovation mostly limited to senior manager. Range of sources aimed at innovation	Customer orders initiate innovation. Interaction with other sources limited (e.g. universities)	Wider range of sources, some discussion at all levels. MT dominates	Entrepreneur active in networks. For some part customer-driven, for some part independent innovation
	Population ecology	Specialist, incumbent. Entrant new products	Generalist/specialist, incumbent	Specialist, incumbent	Generalist, incumbent	Specialists, incumbent. New applications
	Monitoring	None, serendipity	None, serendipity	None, serendipity		None, serendipity
Strategy formation	Competitive strategy	Price, design, quality	Price, design, quality	Design, quality		Price, image, quality
	Strategic attitude	Mostly mix of prospector and defender	Mostly analyser, with some traits of defender (internal)	External: analyser, internal: defender		Analyser
	Methods	Hardly methodical (entrepreneurial)	Hardly methodical (entrepreneurial)	Hardly methodical (entrepreneurial)	Limited tools, short time horizon	Hardly methodical (entrepreneurial)
Confrontation and tuning, Master plan	Portfolio management	Senior manager 'solely' responsibility	Senior manager 'solely' responsibility	'Owner' as sales engineer. Senior manager 'solely' responsibility	Limited systematic scanning of environment	Senior manager 'solely' responsibility
	Technology roadmapping	No	No	No	No	No

(continued)

Table 5 (continued)

Category	Topics	Fibres	Keepcold	Manipulate	PackThem	Paperworks
Resource allocation	Collaboration	N.A. (endogenous knowledge)	Some suppliers. University: casual contacts	Key suppliers. Universities: casual contacts	Collaboration with equipment suppliers (specifications)	Universities: casual contacts
	Project and programme autonomy	Implicit project management (entrepreneurial)	Project management for orders, standardised processes mostly	Order management	Order management more than project management	Implicit project management (entrepreneurial)
Implementation	Concurrent Engineering	N.A. (entrepreneurs, informal)	N.A. (centralised, informal)	N.A	Project teams, depending on novelty and size projects	N.A
	Transition to operations	Informal communication	N.A., except limitedly for series of units	N.A	Standardised process	Informal. N.A
Feedback	Performance measurement	Revenues	Revenues. Pulling 'plug' if necessary	Orders	Revenues	Revenues and profit margins monitored (improvement)
	Learning	Building of expertise but no implications	Improvement of skills and knowledge but not systematic	Learning what goes wrong but not embedded in decision-making	Building of expertise	Improvement of knowledge and skills of individuals

(continued)

Table 5 (continued)

Category	Topics	Fibres	Keepcold	Manipulate	PackThem	Paperworks
Dynamic capabilities		For new product: logistic impact considered. No formalised structures for learning, focus on corrections	Impact of new customers orders on strategy (potential markets) considered plus impact on manufacturing	Orders are sometimes matched against production capabilities, e.g. large number of identical units rather than single units		Wider impact of product or process development considered (logistics, marketing/sales. skills, administrative functions). Systematic feedback from orders
Additional measures	Organistic and mechanic structures	Centralised entrepreneurial decision-making	Hierarchical, formalised structure (also caused by regulatory requirement)	Management team: flexible decision-making, otherwise hierarchy		Centralised decision-making but striving for empowerment
	Generations of innovation processes	First generation, orders customer requirements	Third generation, but less focus on suppliers	Second and third generation. Response to customer orders	Third generation, but less interaction with suppliers for materials	First generation for technology development. Second generation for market demands
	Life cycle of organisations	Phase 1 (Creativity)	Phase 2 (Direction) with characteristics of transitions to Phase 3 (Autonomy)	Phase 1 (Creativity) with characteristics of transition to Phase 2 (Leadership)		Phase 1 (Creativity) with characteristics of transition to Phase 2 (Leadership). Expansion of market typical for Phase 3

The data in this table have been collated from the question sheets and the semi-structured interviews; the categorisations are found in Table 3

Table 6 Overview of French sample

Category	Topics	Diagnosis	Healthy	Tasty	TurnThem	VideoSens
Sensing the environment	Bounded rationality	Implicit (entrepreneur)	Implicit dissemination (workshops), monitoring by MT	Marketing, CEO; informal daily contacts. Focus on unmet demand/ markets, project initiation		Dissemination via Intranet, sensing by marketing, R&D, management
	Organisations as allopoietic systems	Intense interaction with environment by entrepreneur	Monitoring essential sources. Focused networking externally. Internal dissemination: workshops	Creativity teams with universities. External networking, hiring best people	Limited sources, input from universities	Wide range of sources, HRM practices (indicative), active networking
	Population ecology	Specialist, incumbent and entrant	Generalist, incumbent	Specialist, incumbent	Specialist, incumbent, range of product-market combinations (expanding)	Specialist (existing and new), incumbent
	Monitoring	More focused, when opportunity identified	Dominant design, but no monitoring	Monitoring, era of ferment		Technology cycle. Influencing industry
Strategy formation	Competitive strategy	Product design	Product quality	Price, product quality	Product quality and support	Product design

(continued)

Table 6 (continued)

Category	Topics	Diagnosis	Healthy	Tasty	TurnThem	VideoSens
	Strategic attitude	Prospector/ analyser, internally: traits of reactor (might be due litigation)	Analyser, prospector but internally reactor	Mixed behaviour, tending to be more reactive	Analyser mostly, functional organisation, responding to opportunities with moderate potential	Prospector/analyser
	Methods	N.A	–	–	–	5 years
Confrontation and tuning, Master plan	Portfolio management	Implicit, but step-wise approach by entrepreneur	Managerial monitoring. Portfolio analysis	Expert panels and lead users (0–2 years). No portfolio, one project at the time	Meetings, direction by senior manager	Visual representation of ideas. Publication frequency, S-curve, portfolio analysis, roadmaps. Project at system and component level, focus on incremental
	Technology roadmapping	–	Technology roadmaps for 0–2 years	–	Roadmaps and portfolio analysis	5-year roadmap, annual review?
Resource allocation	Collaboration	Managed by owner/director. Keeping contact with potential sources. More focused when identified	Wide range of collaborations and modes. Responsibility of senior manager supported by department	Time horizon: 0–2 years	Collaboration for key and emerging technologies in addition to in-house. Responsibility of senior manager	Living Lab approach, university projects. Time horizon: base 0–2, key/pacing: 0–10 years. Informs collaborations

(continued)

Table 6 (continued)

Category	Topics	Diagnosis	Healthy	Tasty	TurnThem	VideoSens
	Project and programme autonomy	N.A	Balanced matrix organisation. Resource allocation as agreement between (sub)departments. Project management with 'prototyping' and monitoring schedule and expenditures	Lightweight project management with traditional project management approach. Resource allocation: annual budgets. Considering move to stronger project management	Stage-gate process	Balanced matrix organisation, strategic importance defines resource allocation, limited tools
Implementation	Concurrent engineering	N.A	Multidisciplinary project teams			Teams limited to design, engineering, marketing, finance
	Transition to operations	N.A	Launch teams. Feedback to strategy	Restricted to purchasing		Design and engineering, marketing, feedback to operations strategy, business strategy. Freezing/unfreezing
Feedback	Performance measurement	Directly revenues	–	Number of new customers and margin after launch – > continuation and marketing		Customer acceptance

(continued)

Table 6 (continued)

Category	Topics	Diagnosis	Healthy	Tasty	TurnThem	VideoSens
	Learning	Embedded in entrepreneur	No formalised learning processes	–	Focus on direct learning primary process and customer complaints	Operational advancements
Dynamic capabilities		For new product: logistic impact considered. No formalised structures for learning, focus on corrections	Impact of new customers orders on strategy (potential markets) considered plus impact on manufacturing	Orders are sometimes matched against production capabilities, e.g. large number of identical units rather than single units		Wider impact of product or process development considered (logistics, marketing/sales. skills, administrative functions). Systematic feedback from orders
Additional measures	Organistic and mechanic structures	Centralised entrepreneurial decision-making	Hierarchical, formalised structure (also caused by regulatory requirement)	Management team: flexible decision-making, otherwise hierarchy		Centralised decision-making but striving for empowerment

(continued)

Table 6 (continued)

Category	Topics	Diagnosis	Healthy	Tasty	TurnThem	VideoSens
	Generations of innovation processes	First generation, orders customer requirements	Third generation, but less focus on suppliers	Second and third generation. Response to customer orders	Third generation, but less interaction with suppliers for materials	First generation for technology development. Second generation for market demands
	Life cycle of organisations	Phase 1 (Creativity)	Phase 2 (Direction) with characteristics of transitions to Phase 3 (Autonomy)	Phase 1 (Creativity) with characteristics of transition to Phase 2 (Leadership)		Phase 1 (Creativity) with characteristics of transition to Phase 2 (Leadership). Expansion of market typical for Phase 3

The data in this table have been collated from the question sheets and the semi-structured interviews; the categorisations are found in Table 3 are to be considered specialists, whereas the larger ones were more diversified or tended to be generalists. By offering distinct products, the companies followed Mintzberg's differentiation approach, and displayed traits of the combined prospector and analyser profiles of the Miles and Snow typology, whereas they hardly relied on the systematic application of methods for strategy formation (related to innovation management). The Scottish companies more often mentioned pricing as constituting competitive advantage than the French firms; hence, this could point towards a more financial–economic orientation in Scottish firms (induced by the perception of the competitive environment). In this respect, it is worth mentioning that a study by Bisbe and Otley (2004, p. 729) shows that management control systems in low-innovating firms might provide guidance for search, triggering and stimulus of initiatives, while having possibly negative effects in highly innovative firms; this supports the notion that a financial–economic orientation within the investigated organisations would hinder innovation rather than stimulate it (albeit a weakly supported difference between the two samples). Additionally, because we allowed respondents to identify more responses to individual questions about their profile in relation to Miles and Snow's (1978) typology, some did indicate mixed reactions. At least seven out of ten companies, across all questions for this profile, had a very mixed response in terms of this typology. Whereas they were externally oriented as an amalgamation of prospector and analyser, their internal structures showed the opposite response (a blend of defender and reactor). These mixed profiles concur with Desarbo et al., (2005, p. 62) and Laugen et al., (2006, p. 92) when they remark that the distinction between archetypes in the classification is blurred. However, this result could also be interpreted as showing that internal organisational structures are poorly aligned with external orientations; that conjecture corresponds with Boer and During's (2001) findings about a lack of integration and coordination between product innovation, process innovation and organisational innovation. Despite imbalance in the profiling, the French companies had a propensity towards a 'leading' strategic attitude (prospector rather than just analyser). In that respect, the Scottish firms displayed a stronger tendency towards 'centralisation' of decision-making and stronger control structures and cultures (again expressing the Anglo-Saxon perspective). In terms of McCarthy (2003, p. 337), the Scottish firms can be categorised as pragmatic entrepreneurs and the French as charismatic. Furthermore, the companies in both countries hardly use methods for strategy formation related to innovation management that corresponds with Frost (2003, p. 54) who finds that only a fraction of the tools are used in SMEs for (generic) strategy formulation. Rather, it seems that entrepreneurial behaviour (taken as recognising opportunities) dominates strategic decision-making; Pech and Cameron (2006) describe something similar for a case study in New Zealand. Therefore, the second finding of this comparative study's conclusion is that organisational structures poorly match with the external orientation (casting doubts on the effectiveness of the Miles and Snow typology for innovation); a third finding is that the national setting might have some impact on the way companies form and exert their strategy, particularly with respect to competitive priorities and 'centralised' decision-making.

This inclination is also found in the use of methods for managing the portfolio and managing programmes and projects. The French companies made more use of tools and methods for converting ideas, inventions and market opportunities into actual purposeful portfolios and projects, even though this potentially contrasts with the findings in the previous paragraph. Also, there was more awareness towards the importance of managing the portfolio and the development of the company (more than financial terms); this concurs with findings by Cooper et al. (2004a). To that purpose, the French firms engaged in a wider spectrum of collaborations and ways that are more formal, even though time horizons seemed mostly limited to five years. Scottish firms leaned towards more informal types of networking and more serendipity in their launch of new products and services. The results on time horizon deviates from Lichtenthaler (2005), albeit that his sample included larger firms. The relatively short time horizons could also be a result of the limitations of extrapolation, as suggested by Kappel (2001, p. 49). However, it should be noted that in both samples, respondents concluded that they did not access the potential of relevant information sources and that they did not use the full array of methods for programme and project selection, and for portfolio management (commensurate with entrepreneurial behaviour). Hence, a fourth finding of this study is that although not all potential methods for managing the portfolio and managing programmes and projects are used, French firms tend to use more formal methods, while a fifth finding is that time horizons for new product development are limited, generically speaking.

The analysis of the fourth and fifth categories of Tables 5 and 6 leads to some differences as well as similarities in resource allocation and implementation of innovations. First, the Scottish firms emphasised collaboration with suppliers, whereas the French companies seek more actively for opportunities to work together with a variety of actors, including suppliers and universities. Second, two of the Scottish companies have a more entrepreneurial style towards project management, something not found in the French companies (except the small firm Diagnosis). The French companies are using matrix organisations more rather than just plain order management. Third, concurrent engineering is limitedly used in both French and Scottish companies. This concurs with a similar notion by Dekkers and van Luttervelt (2006, p. 2); even though Koufteros et al., (2001, pp. 109–112) find positive effects for this approach in their sample which includes a substantial number of SMEs, Maylor (1997) finds that it is even more beneficial to smaller firms and widely adopted, and Portioli-Staudacher et al. (2003) provide evidence that concurrent approaches have been widely adopted. Fourth, the transition to operations happens informally or implicitly with only two French companies having a more active approach. These inferences lead to the sixth finding that most companies in our study have weakly developed formal project management structures, even though the French firms have a slightly stronger inclination for such, and to the seventh finding that French firms seek more actively for opportunities to collaborate.

For the mechanisms of feedback, constituting the sixth category of the tables, the monitoring of performance differs. The French companies also include non-financial measures like number of customers and customer satisfaction, while the Scottish focus more on revenues and profit margins. Furthermore, hardly any learning from new product development takes place. All firms link learning to the skills of individuals and entrepreneurs rather than a systematic evaluation and organisational learning process. Hull and Covin (2010, pp. 108–109) demonstrate that the learning capability influences risk-taking, innovation modes (internal, external, cooperative) and availability of technology, which is taking place implicitly in the companies studied here. Hence, this paper confirms Adams et al., (2006, p. 40) assertion that organisations will resort to ad hoc and partial metrics; this could lead to non-directional learning. Results from the study indicate a lack of sophisticated monitoring for all companies and consequently poor learning processes, an eighth finding.

In terms of organisational development, expressed in the additional measures as seventh component in the tables, the companies displayed an unbalanced picture. The French companies are mostly characterised by the third-generation process, whereas in the Scottish companies all first three generations of Rothwell were found. Nevertheless, almost all were moving in between the stages of development in Greiner's model; only one of the companies concluded that they would have to change their approach and structures to fit in with the growth of the company. Almost all other companies seemed to be unaware that their growth might require internal adaptations (processes, structure and leadership), an imbalance also found during analysis of the firms in the context of the Miles and Snow typology. Often they resorted to resolving challenges by functional structures, whereas the size and position of the company would require cross-functional integration to be implemented (that concurs with the findings on concurrent engineering). Henceforth, the tenth finding of this study indicates that French firms are deploying slightly more advanced processes in terms of Rothwell; an eleventh finding is that internal structures do not match with the developmental stages of firms.

5 Concluding Remarks

Despite the limited number of cases and the variety between the companies studied, our investigation supports the notion that organisational patterns for innovative capabilities should be studied as complementing the traditional metrics. There was a wide variety in terms of protection of intellectual property, including copyright, trade secrecies and trademarks; this confirms the existence of hidden innovation and the inappropriateness of patents as an absolute measure. In addition, the variety of processes in the investigated cases supports the argument that R&D expenditures and resources are not directly related to innovative capabilities. Therefore, the approach of strategic renewal as meta-model (expressed in the model for the dynamic adaptation capability) brings out more about what underpins the innovative capabilities in terms of organisational patterns than the canonical metrics so commonly found.

The research also supports the divide between the Anglo-Saxon business culture and the Nippon-Rhineland approach. When all findings are put together, six of the eleven conjectures put the French firms in an advantage with respect to innovative capabilities. This does not necessarily mean that the Scottish firms are less successful;

rather they rely on different mechanisms for innovation. Generally speaking, the myopic view of the Scottish companies seems to lead to more opportunity searching than systematic interaction with the environment; it implies also a focus on solving current problems (with specific) orders rather than developing a long-term vision for the firm. Although the French companies potentially spend more time on interaction with the environment and selection of initiatives, they are able to focus better on their new product (and services) development efforts. Theoretically, this should result in improved long-term performance, something that was not in the scope of this study. If the companies in both samples are sufficiently representative for the national innovation systems, then our study supports the existence of the innovation and productivity gap (NESTA, 2006, pp. 9–15) and corroborates the notion of Patel and Pavitt (1994, p. 91) on the distinction between the Anglo-Saxon business culture and the Nippon-Rhineland approach; this seems particularly true for interaction with the environment, sensing of the environment and internal dissemination processes (the twelfth finding of this study).

5.1 Implications for Research

In addition to evidence supporting the notion of the Anglo-Saxon business culture and the Nippon-Rhineland approach, the interpretation of these findings for the national innovation systems indicates the paramount importance of networking for innovation. However, this should not be interpreted as just having connections, as so many studies do (e.g. Calia et al., 2007; Malerba & Torrisi, 1992; Thorgren et al., 2009); but rather how these networks are used by companies as impetus for innovation efforts. In that respect, a difference is observed between the French and the Scottish firms.

Unexpectedly, the differences point also to the relevance of autopoietic characteristics. The findings from the study highlight the fact that companies' behaviour could be explained from an autopoietic perspective. A few others have recognised this, too, for example, Kocher et al., (2011, p. 20) relate autopoiesis to innovation projects for one case in the Swiss food industry; and Mahdi (2003, p. 243) combines it with bounded rationality for agricultural lead discovery processes. In addition, Pöyhönen (2004) underlines the importance of autopoiesis for strategic renewal (innovation could be considered as an instance of strategic renewal). The research by von der Gracht et al. (2010) could indicate that the application of allopoietic principles could be dependent on environmental settings (even though they do not use the theory itself). Hence, could allopoietic principles be Occam's razor for innovative capabilities, by integrating external sensing, organisational closedness, search processes, learning processes and dissemination processes? Other research that uses autopoietic principles to explain or support research into industry–science interaction (Kaufmann & Tödtling, 2001) or industrial networks (Zeleny, 2001), hardly covers the scope of our study. However, our findings indicate that the way companies interact in a national innovation system might be better understood in terms of allopoietic systems (as an organisational pattern) and pave the way for a new strand of research.

An additional outcome of this study is the imbalance between the external orientation and the internal structures of the organisations studied. However, alignment between external orientation and organisational structure is a poorly studied topic; the few studies that exist focus on business process re-engineering (e.g. Dekkers, 2008, p. 61), ICT (e.g. Sabherwal et al., 2001) and strategic change (e.g. MacIntosh & MacLean, 1999; Zajac et al., 2000). In this respect, Gordon et al. (2000) and Romanelli and Tushman (1994) find that incremental modifications to strategy and structures do not accumulate to fundamental transformations, but that major environmental changes (and transitions in leadership) do. However, these studies have hardly considered the implications for innovation and technology management, albeit that in Boer and During's (2001) work some indications are hinted at about the effectiveness of organisational structures for innovation. Furthermore, the findings underline the importance of entrepreneurial behaviour for innovative capabilities. That aligns with Hagedoorn's (1996) position on the link between entrepreneurship and innovation, a Schumpeterian view. Hence, the lack of alignment in relation to organisational structures for new product development constitutes a new strand of research, which could be informed by evolutionary (biological) models.

5.2 Reflections on Research Methodology

The methodology used in this study analyses organisational patterns for innovative capabilities, across a wide range of phenomena that are linked to the integrative model for the dynamic adaptation capability, depicted in Fig. 1, and Tables 1 and 3. Because of the overlap the components also contribute to triangulation. However, each of the components could be expanded by further literature and examined that would require separate studies that need to go into more detail while considering the context of innovation capabilities. In this respect, the methodology also extends beyond Adams et al. (2006), Chiesa et al. (1996), Cooper et al., (2004b, 2004c, 2004d) and Radnor and Noke (2002), partly caused by the integrative approach that we have followed in this paper. Adams et al. (2006) focus on the measurement of innovation performance, covered to some extent by the masterplan as a monitoring and verification mechanism (feedforward), the feedback mechanism as well as portfolio management, but the effectiveness of (traditional) metrics has been questioned at the beginning of this paper. The approaches of Chiesa et al. (1996), Cooper et al., (2004b, 2004c, 2004d) and Radnor and Noke (2002) rely on benchmarking, albeit that Radnor and Noke hardly disclose the literature for their determinants; but all three might suffer from drawbacks similar to conventional metrics. It may be advisable to devote a separate review to comparing these approaches to innovative capabilities. Hence, this study of organisational patterns for innovative capabilities might answer Tidd's (2001, p. 180) call for more integrated approaches to innovation management. However, weaknesses in the proposed approach are the limited inclusion of quantitative data and longitudinal aspects. However, one should note that the aspect of time (see Hultink & Robben, 1995) is partially covered by considering the portfolio for new product development (an adequate portfolio is considered an indicator of organisational fitness from an innovation perspective). It is recommended that more studies assess organisational patterns related to innovative capabilities from a holistic point of view.

The cases chosen in this explanatory study might also cause biased findings. The Scottish firms were more oriented towards custom orders than the French ones. This could lead towards an orientation of solving ‘daily’ problems related to orders rather than on focusing on specific new product (and services) development. The attention of management should in these cases lead to more centralised control for processing these orders. For this reason, in the French sample one would expect more multifunctional project teams and practices of concurrent engineering. On the contrary, the findings from Table 6 show that this is limitedly the case. It could be prudently concluded that all companies could benefit from improved practices for order processing and project management, albeit in different fashions. Preliminary secondary information that we have sought indicates that these companies are leading or considered creative for their industries. Some of our findings are not contrasted with companies that are considered less successful in innovation. Therefore, the approach and methodology of this investigation might also serve as pretexts for increasing the sample size, including less successful companies and concentrating on specific sectors. To understand the implications of innovative capabilities, the case-oriented methodology of our approach should be complemented by longitudinal studies.

5.3 Managerial Implications

Despite these theoretical considerations, the in-depth question sheet and interviews lead for almost all companies to the conclusion that they could benefit from improving their practices. In particular, the interaction with the environment could be improved by accessing more sources, more active dissemination in companies and more ‘formal’ approaches to initiating programmes and projects for new product (and services) development. Also, the monitoring of the portfolio, progress of programmes and projects, and related evaluation should be strengthened. In addition, for the dynamic capability there should be more and richer assessment of the impact of programmes and projects on organisational patterns. Hence, companies could use this approach to assess and improve their organisational patterns, albeit noting that the methodology needs further development.

With respect to the impact of the national innovation system on those organisational patterns for innovative capabilities, this study highlights some differences that explain the innovation gap. Particularly for the case of the Scottish companies, a more intense interaction with the environment could potentially result in stronger innovation trajectories. This seems to correspond with the support for the difference between the myopic view, typical for the Anglo-Saxon business model, and the dynamic view of the Nippon-Rhineland model. However, research in this paper has not reflected on the impact of the transactional environment (common versus civil law) and the influence of the national business culture [for example, see Hofstede (1994) and House et al. (2004)] on innovative capabilities. Therefore, the findings in this study should be applied with careful consideration.

5.4 A Final Thought

Nevertheless, this study has significant implications for examining the innovative capabilities of firms. First, the sample was drawn from innovative companies that poorly patented their knowledge stock for new products and services; this hints at the significance of hidden innovation, often poorly captured by traditional approaches to innovative capabilities of firms and national innovation systems. Second, the approach to innovation management by firms is influenced by the national context—in this study the Anglo-Saxon approach versus the Nippon-Rhineland model (or more precisely, myopic versus dynamic national innovation systems). Surprisingly, only a few studies, such as Dekkers et al., (2014, p. 14) and Tidd and Brocklehurst (1999, p. 241), have picked this up. Third, how companies interact with the environment in the context of innovation management may be adequately described by principles of autopoiesis; studies on this matter are scarce, with only Kocher et al. (2011), Mahdi (2003) and Pöyhönen (2004) identified. Hence, our study underpins the plea from Baralou et al. (2012) that autopoietic principles have been ignored for organisational studies but are relevant. Moreover, the current study may open new avenues for research and contemplation for practice!

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Epilogue

Epilogue: Setting Out Pathways for Research, Advancing the Research Agenda and Methodological Considerations from a European Perspective

Rob Dekkers and Laure Morel

This epilogue brings us to reflect on what this book has brought to the table for European perspectives and what it means for research into innovation management.

1 Interaction Between Idiographic and Nomothetic Research

Differing European perspectives on innovation management, based on distinct social-economics settings, implies that research may have an idiographic stance. That research can be seen as either idiographic or nomothetic and was originally introduced by Wilhelm Windelband during an address in 1894 (Oakes, 1980, p. 165). Construction of scholarly knowledge that emphasises the general is labelled as nomothetic research and that which focuses on the particular is called idiographic research. The term 'nomothetic' comes from the Greek word 'nomos', meaning 'law'; therefore, the nomothetic approach to research methodologies searches for laws and generalisations valid for a wide range of phenomena and subjects of study. 'Idiographic' stems from the Greek word 'idios', meaning 'own' or 'private'. In the context of empirical studies, it implies that the idiographic research looks into what makes a specific phenomenon or subject of study different from others. Relevant to the quest of our

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book, Bengtsson et al. (1997) point out that for business studies there is a difference between Europe and North America in terms of this classification of studies. They argue that North-American researchers are mostly nomothetic oriented, i.e. towards general observed patterns and laws, following procedures commonly found in the natural and physical sciences. European researchers are mostly ideographic oriented, i.e. understanding of particular cases. Whereas some approaches the distinction as a contrasting research paradigm, Münsterberg (1899) signalled to view the distinction as complementary views rather than a dichotomy on how knowledge is formed. Moreover, there are others that have viewed the two conceptualisations as a dichotomy, to which Robinson (2011) refers, although he attempts to reconcile, too. Without getting lost in semantics, the question remains how the idiographic and nomothetic research interacts for the domain of innovation management, considering distinct social-economic settings.

This requires first to take a closer look at how social-economic settings are embedded in both idiographic and nomothetic research into innovation management. Though a discussion about idiographic and nomothetic stances towards research in business and management studies seems to have taken place in the 1980s, it seems to have subsided later. In this debate, much emphasis seems to have gone to organisational behaviour as exemplified by Luthans and Davis (1982), which is not surprising since the utilisation of idiographic and nomothetic views is also found in psychology, a closely related domain to organisational behaviour. Notwithstanding specific views on the dichotomy, studies taking a nomothetic stance and those following an idiographic approach are interlinked. For example, Westen (1996) advances the argument that the nomothetic can be derived from idiographic (ibid., p. 411), when it shows that the individual differences can be seen as idiographic narrative accounts for nomothetic dimensions. For our quest in this book, i.e. exploring European perspectives on innovation management, the social-economic environment in which innovation takes place constitutes what should be considered nomothetic or idiographic research, leading to an epistemological stance, so to say. Since nomothetic research considers empirical studies as searching for generally valid causal relationships, social-economic settings are viewed as contingencies or convoluting factors; see Fig. 1. In empirical studies based on an idiographic stance, these social-economic settings are seen as factors influencing outcomes of processes, manifestations of phenomena and patterns. Therefore, the starting point of our book that Anglo-Saxon, East European, Nippon-Rhineland, Nordic and Mediterranean socio-economic perspectives among others may influence processes and outcomes of innovation management is captured differently by nomothetic and idiographic approaches to empirical studies.

This difference between nomothetic and idiographic approaches to empirical studies will also be reflected in research methods and methodologies. Nomothetic studies will be more likely reverting to hypothetico-deductive research methodologies; these can be quantitative or qualitative in nature but are more likely to be quantitative. Thus, typical methods are mathematical modelling, simulation studies and statistical analysis of any kind. An idiographic stance might sit better with inductive research methodologies, and therefore, gravitate towards qualitative methodologies,

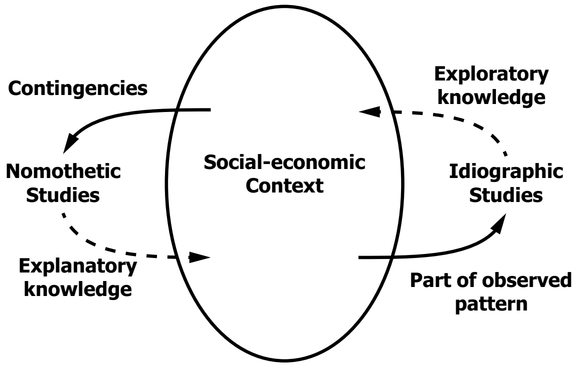

Fig. 1 Model for interaction between idiographic and nomothetic studies

though quantitative methods could also serve the purpose in specific circumstances. The idiographic stance on research methodologies comes along with case studies, focus groups, interviews and participatory methods. The use of these methods in the idiographic approach may result in challenges to theories. The differences in approaches to design of research methodologies, and consequently, the preferred choice for specific methods is also reflected in how European and US researchers undertake studies, according to Huse and Landström (1997, p. 9), albeit in their case for entrepreneurship while not discussing the contrast between idiographic and nomothetic studies. But their position reflects our quest that there is the need for a European perspective on studies into innovation management. Moreover, their distinct approaches seem to create a gap between nomothetic and idiographic studies. Some, for example, Salvatore and Valsiner (2010), have suggested this gap can be reconciled. For example, research should start with a nomothetic approach and once general 'laws of observed regularities' have been established, research can then move to a more idiographic approach. Others will see the two approaches as complementary. Without wading into the debate between proponents for either nomothetic and idiographic research, and the divergence between the openness of European researchers for methodological diversity and the orientation of US researchers to pragmatic and realistic research paradigms, it can be seen that both approaches have differing views on collecting data and interpretation of data, which could create challenges in reconciling advances in scholarly knowledge.

Similarly, the aggregation of findings and outcomes across studies will also differ between idiographic and nomothetic stances. Aggregation of findings and outcomes is commonly associated with protocol-driven literature reviews; see Dekkers et al., (2022, p. 378). When following nomothetic approaches to protocol-driven literature reviews, the social-economic institutional settings are seen as contingencies that influence the outcome of statistical analysis for innovation management. In the case of systematic reviews, such is captured by convoluting or mediating factors that co-determine statistical outcomes, whereas in systematic literature reviews there will be a search in retrieved studies to identify these factors and variables. For idiographic approaches to systematic literature reviews and qualitative synthesis, the social-economic institutes and processes are seen as context for studies. There will be a search for generalisation, or better transferability in terms of qualitative research, so that the conceptualisation of how the social-economic environment influences outcomes of innovation management can be captured.

2 Positioning European Perspectives in the Dichotomy

So, how do the intertwined cycles of studies with an idiographic and nomothetic stance work out for innovation management and how they are studied in this book with a focus on European perspectives? First, the book takes the viewpoint that there are differing contexts within Europe that influence institutional settings, social-economic policies and interactions between actors. In the call for chapters, a distinction was made between Anglo-Saxon, East European, Nippon-Rhineland, Nordic and Mediterranean socio-economic perspectives, building on the more generic classification by Patel and Pavitt (1994, p. 91) between myopic and dynamic innovation systems. An indicative overview of these perspectives is found in Fig. 2. Second, emphasis on aspects for innovation management may also vary according to stages of development of national and regional economies. Recognising confusion the term 'region' may cause, as pointed out by Freeman (2002, p. 192), the term region here is used for geographical areas within nations, whereas the perspectives refer to clusters of nations that share common traits relevant to innovation management. These clusters are not necessarily geographical labels but for the purpose here related to how national governments and institutional settings influence how innovation is incentivised for actors and achieved in a networked collaboration. Even within nations, there might be different stages of socio-economic development, different prevalent industrial sectors and different structures for knowledge development across regions; an example is the concept of 'Third Italy' (e.g. Bianchi, 1998; Biggiero, 1998). In principle, this means that evaluating studies using specific contexts will also lead to informing to what extent idiographic approaches offer additional insights and whether the premise of European perspectives holds.

2.1 Different Stages of Development

As the European perspectives are related to different regions and countries, not only their approach to innovation varies, but probably also their stages of development in terms of institutional settings and infrastructures for innovation and technology development may differ. In addition to Patel and Pavitt (1994, pp. 90–2) associating dynamic and myopic national innovation systems with Germany and Japan, respectively, UK and USA, there are others that have considered specific contexts for firms and their innovation activities. Lopez-Vega and Ramis-Pujol (2011, p. 59)

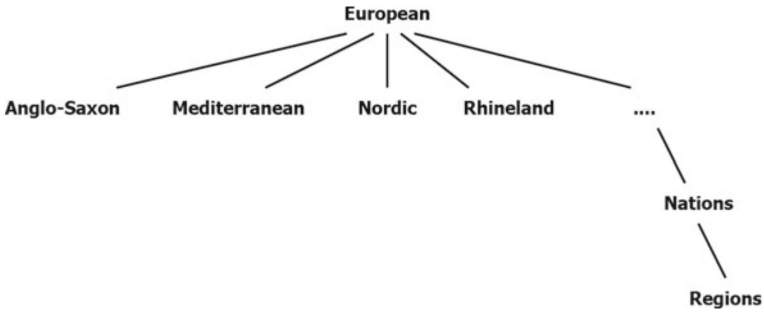

Fig. 2 Contexts for studying innovation management from a European perspective

point to characteristics of a Mediterranean innovation system, in which there is more emphasis on the development of services and business models, and a more articulated role for intermediaries; the latter's role seems to be questioned in the study. Švarc (2014) explores the national innovation system for the West Balkan countries from the perspective of the triple-helix model. This leads to warning (ibid., p. 179) about the 'Europeanisation' of policies and funding opportunities without considering the specifics of the national economies, such as the impact of privatisation on R&D being focused on low and medium technologies (ibid., p. 173) and a hesitant culture towards entrepreneurship (ibid., p. 173). Cvetanovic et al. (2014) compare West Balkan countries with 'neighbouring' countries to find that considerable differences exist in innovativeness based on indexes derived from the global innovation index and the global competitiveness index. In the same spirit, Grozdanic et al., (2012, p. 179) conclude that institutional settings in the West Balkan countries are unfavourable towards innovation; they advocate for improvements in educational systems, collaboration between actors in the national innovation system and greater participation of SMEs in funding opportunities such as the EU programmes. A critical note for Central and Eastern European countries is provided by Suurna and Kattel (2010, p. 658) when they state that 'Europeanisaton' of innovation policies has led to the adoption of some policies, but also has run into challenges with regard to administrative skills for funding, the held assumption that industry there is a growing demand in industry for R&D (implying that establishing labs is sufficient) and reliance on intermediaries. Based on practices found in French firms, Boly et al. (2014) have developed a potential innovation index in France that allows to evaluate the degree of maturity of a company in its innovation management based on best practices. These studies, except the one by Patel and Pavitt (1994), highlight how actors in national innovation systems need to collaborate, how funding is impacting actual outcomes of innovation processes, albeit that regional differences are noted.

Such variation in institutional settings and infrastructure for national innovation systems also influences innovation activities by firms. An example is the proposition by McAloone et al. (2007) for a Scandinavian model for product development, albeit they draw on a Danish case study for this matter. For this Scandinavian context, Cooke (2016) looks into the institutional settings for innovation in Denmark, Finland, Norway and Sweden. He (ibid., p. 199) calls attention to differences between the four nations, while also finding that they share common traits for innovation, such as competitiveness through quality for niche markets. In addition, Stiglitz (2015) highlights in a conceptual manner the advantages of the Nordic innovation systems over those of the USA and intimates (ibid, p. 15) that the Nordic model encapsulates policies that facilitate innovation while at the same time ensures that well-being is shared among a large group than shareholders. For the German innovation system, often reference is made to 'hidden champions'; see, for example, Venohr and Meyer (2007). It is Simon (1996) who points out that this type of firms also exists in other national settings, though they seem to be most abundant in Germany. In this sense, Cooke (2016, p. 199) also highlighted this for the Nordic countries, as mentioned a few sentences before. For the phenomenon of German 'hidden champions', Schenkenhofer (2022) provides an extensive literature review, demonstrating that it is well studied. With regard to Central and East European firms, Stojčić (2021) sets out how different forms of collaboration are associated with different outcomes, but mostly outlining that collaboration with partners is a key feature for innovation process for these firms (ibid., p. 557). Except for these few studies looking into firms within a specific context, there seems to be a gap in studies explicitly taking what we called European perspectives into consideration.

2.2 Contexts Investigated in Chapters

This raises the question whether the contexts investigated in the chapters in this edited book leads to the insight we are seeking. In the spirit of this thought, the chapters cover a broad range of countries and regions, though unfortunately not all. There is attention to firms and national innovation systems in Austria, Belgium, France, Germany, Greece, Hungary, the Netherlands, the UK, particularly Scotland, Sweden and Turkey, and as region Central and East European countries. This means that the Mediterranean and Nordic regions somehow are underrepresented in the chapters; with this in mind, we reflect on the findings of studies in the context of national innovation systems for innovation management.

2.3 Main Findings for Contexts

A first point of reflection is that some chapters draw attention to behaviour of firms and actors in regional or national innovation systems being influenced by their settings, perhaps even determined. An excellent example is the contribution by Börjesson et al. in Chap. 4. The Scandinavian region is already home to the use of participatory methods for new product and service development; see Kyng (2010, pp. 53–4). But this chapter by Börjesson et al. extends the participatory approach to the management of the company with the aim to increase its innovativeness, perhaps as a deviant case or critical case in Flyvbjerg's (2006, p. 229–30) terms, depending on how the transition appeals to the reader. As outlined by Kyng Kyng (2010, pp. 53), participatory design originates in the socio-technical approaches in the 1960s and 1970s. From the latter perspective, Lekkerkerk's Chap. 2 builds on the model for innovation and organisation structure. Commensurate with socio-technical design of organisations in the Low Lands, the model also draws on systems theories for both processes, structuring and interactions. In other chapters, too, there is attention to participatory approaches. Bary and colleagues in Chap. 13 use a systematic literature review to identify competencies of individuals for innovation in living labs drawing on studies in European countries. This leads them to conclude that training of both individuals and facilitators is necessary. They also find that creative thinking and an orientation towards the future are less reported than other skills such as relationships and networking, including maintaining these. In Chap. 12, written by Boly and others, comes to the fore that stimulating participatory takes are found in initiatives in Grand Est (France) and Styria (Austria). Participatory approaches to new product development are reported in Chap. 8 by Koukou and Dekkers, showing that it takes different forms in terms of how firms interact with end users. The observed relevance of customer involvement for achieving innovation also emerges in the systematic review with bibliometric analysis by Baglio et al. (Chap. 18) when do look into innovation in logistics. Finally, Chap. 7 by Hertwig et al. underlines the importance of participation by designers and engineers as collaborative network in their concept of crowd engineering. Consequently, these chapters covering a broad range of topics underline the importance of participatory approaches, widening access to more actors and customers in innovation trajectories and new product development, albeit coming along with conditions such as development of competencies and skills, perhaps indicating a typical European perspective.

Besides this potentially common characteristic of purposefully seeking for participation, some chapters also point to the diversity in approaches across countries and cluster of countries in Europe. For example, Chap. 19 by Dekkers and Morel adds the context by considering Patel and Pavitt's (1994, pp. 90–2) dichotomy of dynamics and myopic national innovation systems; their findings indicate differences on a few points between the French and Scottish case studies. Particularly they indicate the relatively short-term orientation of the Scottish companies and the interaction with the environment (from an autopoietic point of view). Somehow, the short-term orientation is also reflected in the work by Roberts (Chap. 6) as she notes the challenges of firms in the Scottish Med-Tech sector to allocate time for technology valorisation as a core concept for enabling open innovation. Differently, Segers and co-authors refer to Belgian context, mentioning uncertainty avoidance, in their case for energy transition in Chap. 16 that had to be overcome. In this respect, it was already noted by Mokyr (1994) that technological progress was related to the diversity of Europe from a historical perspective. This leads to the inference that there is evidence that settings embedded in characteristics of national innovation systems and socio-economic prevailing perspectives influence practices, processes and structures for innovation management and capabilities in the European context.

This also shows that both chapters demonstrate that firms may interact differently with customers, suppliers and knowledge providers (such as universities). In this respect for knowledge providers, Segers et al. (Chap. 16) show how the university takes a leading role for energy transition of educational buildings, though they later question whether the engagement by the university served as catalysator. From a different perspective, Erdös and Bedö describe in Chap. 15 the case of how a Hungarian university is embedded in an entrepreneurial (regional) ecosystem. They highlight that the mechanisms for interaction in this system are fragmented and poorly interlinked, thus missing out on opportunities and making the university a less effective actor and catalysator for innovation and entrepreneurship. When inferring such they note that their case may not be representative for all universities in the Central and East European economies. And, Spitzley et al. (Chap. 14) identify ten characteristics that influence successful collaboration between universities and industry. Aligned with Chap. 15 they demonstrate in Table 14.2 the multiple interactions but also remark that universities often serve as initiator of projects that are funded at European, national and regional levels. However, the intense collaboration may also be seen as a typical German phenomenon, perhaps extending to countries associated with the Nippon-Rhineland model; for example, these types of collaborations are not uncommon in France, as indicated in Chap. 12 (Boly et al.) for the Lorraine Fab Living Lab. The chapters mentioned here confirm that settings embedded in regional and national innovation system in Europe determine not only determine to some extent the behaviour of firms and other actors, and the university also play a key role though differing from university to university and country to country; for universities, there is also a search in studies how they can best contribute to national and regional innovation systems, (industrial) ecosystems and innovation by firms and start-ups.

A further point that comes to the fore is that not only regional and national innovation systems are diverse by also that they represent a complex of interactions with multiple actors where aggregation in overarching categories may do injustice to the diversity. For example, in Chap. 12 Boly et al. find numerous practices related to digitisation, with an overview in Table 12.1. The diversity in observed practices in three European regions (Austrian, French and Swedish) also clearly indicates interactions between actors in a regional innovation system are multiple and complex. Erdös and Bedö describe in Chap. 15 the numerous interactions of a university in its regional ecosystem, as do Spitzley et al. in Chap. 14 for interactions between universities and industries in a German setting. Chap. 11 brings to the table that small- and medium-sized enterprises are diverse in their approaches to innovation. Furthermore, Bröring and Ohlert write in Chap. 10 about converging industrial sectors as opportunity in traditionally coal mining regions in Germany. A particularly noticeable role in the economic transition plays larger firms that facilitate start-ups in accelerators. From the perspective of appropriation of intellectual property, Dekkers in Chap. 9 also refers to the diverse roles and manifestations of non-practicing entities (aka non-producing entities). Perhaps, these diversities in interactions and how roles can be fulfilled points to the necessity to revert to idiographic studies rather than nomothetic studies, again taken the manifestation of innovation trajectories being diverse in Europe.

2.4 Some Other Notable Points

Building on these findings there are three approaches presented for diagnosing innovative capabilities by firms. Pasin et al. (Chap. 3) identify factors, based on a somewhat nomothetic approach developed in the Turkish context. However, it is not clear whether their approach has characteristics that are typical to this context. But some of their factors are. Lekkerkerk (Chap. 2) focuses on processes and structures using principles from a Low Lands' viewpoint on socio-technical design of organisations. However, its emphasis on structuring positions could indicate is not necessarily an idiographic starting point but could have nomothetic tendencies. Dekkers et al. (Chap. 5), though propositional, highlights what difference a specific context may make based on Patel and Pavitt's (1994, pp. 90–92) dichotomy of dynamic and myopic national innovation systems. Dekkers and Morel (Chap. 19) consider a broad range of input, classifications and models for their assessment too, including the dichotomy by Patel and Pavitt (1994). Subtle differences between French and Scottish firms include how they engage with knowledge providers such as universities and consider time horizons for technological developments. Moreover, French firms in the sample tend to undertake more projects for innovation and new product development with uncertainty, whereas the Scottish firms tend to respond to (commercial) opportunities. In Table 1, the three approaches to diagnosing firms are compared.

Another point that attracted attention is innovation in logistics, related to advances in information and communication technologies. In Chap. 18, Baglio and co-authors

Table 1 Overview of instruments for diagnosis

	Lekkerkerk (Chap. 2)	Pasin et al. (Chap. 3)	Dekkers and morel (Chap. 19)
National innovation system as context	Low Lands approach to socio-technical design for organisations		Building on Patel and Pavitt (1994)
Description of instrument	Model for innovation and organisation structure (process-oriented)	Benchmarking by six dimensions and 20 key indicators	six categories based on breakthrough model, dynamic capabilities and three models for organisation development
Sampling	17 Dutch cases	129 firms (but no evidence provided in chapter)	Five French cases and five Scottish cases

find that one of three clusters identified in their systematic literature review how European countries, firms and logistics service providers are actively pursuing innovation to make the logistics sector more sustainable; as they note, this seems to be more prevalent in comparison to other regions. Particularly of interest are the emphases on reusing, remanufacturing and recycling, and urban logistics. Perhaps, this is closely linked to the study by Cieślik, found in Chap. 17, who looks at the information and communications technology sector in Central European countries to find that their development leads to joining global value chains; however, she observes differences for countries and clusters, such as the Visegrád countries, in her multiregional input–output model. Thus, this probably indicates that at present innovation and development of logistics services go hand in hand with strengthening of services with the dual aim to become part of global value chains and to achieve sustainable services for logistics.

2.5 'One Size Does Not Fit All'

One of the principal outcomes of the exercise in the book and this epilogue is that there is no one size that fits all. Across the chapters, there is variety of approaches, whether it be directed at firms in specific contexts, or regional or national innovation systems. For example, Chap. 11 by Dreher and colleagues takes the heterogeneity of small- and medium-sized firms in how they engage with innovation as starting point for evaluating economic policies based on preceding studies. There are various reasons for this variety in approaches and interactions. In literature, this argument for diversity in approaches is found, too. For example, Verganti (2010) postulates that even innovation practices, processes and management require different approaches, called innovation as well, even by the same firm, to remain effective, although referring to others. In this spirit, Kearney et al., (2019, p. 1950004/19) find critical differences between high-tech and low-tech industries using factor analysis and a regression model for survey data obtained from firms in a northern region of the Netherlands. Also, Günzel and Holm's (2013) study points to different approaches towards business model innovation in the Danish newspaper industry based on three cases. Another argument for observed variety arises from systems theories, less getting attention from those looking into innovation economics and management. The principle of equifinality (Dekkers, 2017, p. 55) implies that a particular state of system may be reached through different pathways. This implies that there are no distinct practices, processes and structures to achieve specific innovation outcomes. The principle of equifinality has been recognised by studies into innovation management, with Cabrilo and Dahms (2020, p. 849), Kapsali (2011, p. 405) and Spraggon and Bodolica (2021, p. 1437) cases in point albeit with slightly different interpretations related to the topics at hand. However, Cirillo et al., (2019, p. 913) seem to contest the idea of equifinality when relying on a traditional factor analysis for a comparison of national innovation systems (European countries, Japan and the USA), indeed with an approach that is associated with nomothetic studies. The converse of equifinality is multifinality (e.g. Dekkers, 2017, p. 57), similar starting points result in different states of systems. This concept has gotten lesser attention by studies into innovation management, but is found in Zhou et al., (2023, p. 122592/9) when they relate it to the validity of exploration and exploitation as dichotomy for processes used in innovation management. Some do not get it right; for instance, Felício et al., (2022, p. 112) seem to refer multiple outcomes rather than the more common interpretation found in systems theories. Interestingly, Chap. 11 by Dreher and co-authors also refers to the principles of equifinality and multifinality as backdrop for deliberations on the heterogeneity of small- and medium-sized firms. The recognition does not one size fits all for innovation economics, management and practices and the principles of equifinality and multifinality also lead to the inference that nomothetic studies most likely look at matters from a higher level of abstraction than idiographic studies to arrive at observed patterns, laws of observed regularities and theories (for the latter, mid-level theories rather than generic theories as explanatory frameworks).

This also raises the question whether ISO 56002 (Innovation Management System) allows for idiographic stances. Published in July 2019, it provides a common framework and language to develop and deploy innovation capabilities, evaluate performance and achieve intended outcomes. It positions itself as a point of reference that can be deployed to all industrial sectors and all types of companies. By the way, and following the recommendations proposed in the standard, for each country, specificities can be highlighted from one industrial sector to another, contributing to idiographic research. However, practices, processes and structures of firms in the same industrial sector could differ, concerning the way they manage innovation. However, the stance in this book is that this divergence may be larger than incremental differences.

3 Pathways for Research into European Perspectives on Innovation Management

From a European perspective on innovation economics and management, there is a need to include the context more explicitly in studies, particularly through idiographic studies. For example, the interactions between universities and firms differ across countries and national innovation systems. This accounts for knowledge transfer, emphases on where radical or incremental innovation takes place (and how), and networked collaboration, including participatory approaches. The differing contexts for innovation depend also strongly on the capabilities present in networked collaboration, regional and national innovation systems. In this respect, think about the transition of the regions in Germany, traditionally reliant on coal mining that is phased out (see Chap. 10). In this respect, not only empirical studies should consider the context but also protocol-driven literature reviews; Dekkers et al., (2022, pp. 124–5) present some formats for formulating review questions that include the context, but they are not limited to. Therefore, this edited book calls strongly, perhaps more than strongly, for inclusion of context in studies into innovation economics and management, also in an effort to bridge outcomes of nomothetic and idiographic studies from a European perspective.

A particular place in this type of research is the participatory approaches related to innovation, new product and service development, and design and engineering. Participatory approaches in the edited book are found in chapters relating them to living laboratories (Chaps. 12, 13), firms (Chap. 4), new product development (Chap. 8), and design and engineering (Chap. 12). However, participatory approaches in the context of national or regional innovation systems are mostly studies on information and communications technologies, see Huse and Landström (1997) among others. Building on what is presented in the aforementioned chapters, how participatory approaches are implemented depends on context, objectives to be achieved, how process for product and service development are organised. Again, evidence on participatory approaches in specific contexts, objectives that need to achieved, and how they are embedded in the process for innovation, new product and service development can be aggregated using protocol-driven literature reviews, in which the quality of evidence (Dekkers et al., 2022, pp. 219–23) should play a role to synthesise scholarly and practical knowledge; the adequacy of synthesised scholarly knowledge can then be used to identify further well-specified studies. Moreover, such systematic literature reviews may also have to cover so-called grey literature due to potential publication bias in academic journals and the likelihood that a substantial number of idiographic studies are reported in different forms. For search strategies related to grey literature, see Irvine et al., (2022, pp. 184–8). All this indicates a further need to look at participatory approaches innovation systems by considering a variety of contingencies, and not to forget, contexts from the European perspective, using both empirical studies and systematic literature reviews to advance understanding.

Perhaps already embedded in the call for more studies into participatory approaches, the complexity of interactions in national, regional innovation systems, including living laboratories, and innovation by organisations needs more attention. This includes the regeneration of regional innovation systems. Here empirical studies can be complemented by modelling and simulation based on principles of complex adaptive systems to better understand the impact of interventions on collaboration, including participatory approaches, technological trajectories and innovation outcomes. Modelling also allows to explore the impact of scenarios, with the need for achieving higher degrees of sustainability and resilience with the aim to build a more inclusive socio-economic fabric.

Furthermore, the benchmarking and diagnosis of organisations need to be expanded to include the context. As shown in Table 1, this edited book presents three distinct approaches to diagnosis on innovation performance of firms, embedded in four national contexts. However, there are more approaches and tools for diagnosis, with Chiesa et al. (1996) being a case in point. This points to the need to compare these tools on their coverage, particularly from the perspective of the different contexts as mentioned in this book (and this chapter) and how such affects innovation outcomes. A particular instrument used is the Community Innovation Survey from the European Union. As set out here in the book, the contexts are missing though being relevant to understand the impact of interventions and policies, and many points raised here are not included. Hence, a modification of the Community Innovation Survey is necessary if it were to capture the European perspectives on innovation management at different levels, such as firms, collaborative innovation networks (e.g. living laboratories), value chains and the impact of heterogeneity in decision-making by firms and how innovation can be achieved (e.g. the heterogeneity in how small- and medium-sized companies achieve innovation, see Chap. 11). Hence, our book points to the need to better include the socio-economic context for both analysis and diagnosis to do justice to the different perspectives on innovation and technological trajectories in Europe and play to the strengths of this diversity.

Harbouring this diversity also provides an opportunity for how research into innovation management is conducted, particularly in the current environment of uncertainty and ambiguity. It calls on working together in research on managing innovation that can enable us to pivot and adapt to change, e.g. sustainability and resilience, and to find ways to seek out opportunities even under adverse conditions. The European perspectives here present different viewpoints, different interactions and different strengths, related to socio-economic systems. When they meet in studies on innovation economics and management, researchers standing for the distinct perspectives cannot only build on what unites but also use the dissimilarities that sharpen insight in an idiographic fashion. Therefore, the recognition of European perspectives is not only a call for the design of research methodologies by considering specifics but also entails how research should be conducted by scholars and practitioners representing various schools of thought embedded in socio-economic systems.

4 Some Final Thoughts

Perhaps the debate in the 1980s about idiographic and nomothetic approaches to research methodologies has been replaced by the discussion about the quantitative–qualitative divide rather than considering the intricacies of European perspectives. Somehow, Tsoukas (1989, p. 555) seems to hint as this when observing that the introduction of the case study methodology caused contention in a positivistically inclined social science. In this vein, Bengtsson et al., (1997, p. 486) deliberation on the nomothetic approach to empirical studies, influenced by the dominance of a positivist research paradigm, fitting in with the US approach to business and management studies might also be influenced by the lesser diversity in settings, in our book here the national innovation systems. As noted, there are differences in national innovation systems within Europe, regionally bound. These differences also impact how actors—firms, policymakers, universities, intermediaries and consumers—interact. Moreover, a characteristic of studies into innovation economics and management is that research often involves multiple levels of analysis—individual, teams, departments, organisations, collaborations by organisations and sectors (or for the latter regional and national innovation systems)—, which is reflected in the chapters in this book. Consequently, each level of analysis serves as context for a lower level in this hierarchy, something that should be explicitly accounted for in studies. This leads to the thinking here and in other works that European perspectives on innovation management are not only found in the approach to topics but also in the research methods that are (and should be) deployed.

In this sense, the existence of an ISO standard on innovation management today is challenging the idiographic stance towards innovation management brought about in this book. If we accept that there is now a worldwide consensus about how to consider the management of processes for innovation, i.e. a nomothetic approach, this will lead to interesting new avenues for research based on observations and usefulness of the standard in order to support organisations to improve their innovativeness. However, the stance here is that there are considerable differences between settings of national innovation systems and related practices in firms. The question becomes then whether ISO 56002 will become a straightjacket and thus stifle innovation, or it will allow sufficient leeway for national and regional differences and enhance the capabilities of firms and other actors in national innovation systems; only time will tell.

One of our takeaways from the exercise in this book is the diversity in European regional and national innovation systems, together with the complex of interactions, heterogeneity of actors (even within categories), multiple trajectories and approaches to innovation, and multiplicity of innovations. Some would see this variety as weakness, but historically this has been a mainstay of the European success. The diversity creates an environment in which initiatives are possible, with regional and national contexts for innovation systems playing to variation in strengths. Perhaps it is the diversity that unites European countries, something that needs to be held dear and encouraged, even in times of seeking for rule of even-handedness when experiencing contemporary, pressing and challenging developments.

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