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Knowledge Spillovers in Regional Innovation Systems

A Case Study of CEE Regions

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Editorial

Technology change is related to knowledge accumulation, which is inevitable to ensure innovation. A number of studies (e.g., Acemoglu et al. 2012; Wang and Wang 2012; Boons et al. 2013; Camisón and Villar-López 2014) have analyzed the impact of knowledge and innovation on economic growth, company performance, competitiveness, or sustainable development (Péti 2012). The activation, application, or utilization of knowledge has been the subject of extensive research since 1970, when an effort was made to link social research and policy making and to understand the spatial dimension of knowledge spillover mechanisms and innovative activity. Geographic location and economies of agglomeration are vital for knowledge generation, dissemination, spillover, and application (Song et al. 2005). Taking these findings into account, a vast variety of theories have been developed looking for the sources of knowledge and innovation as well as the mechanism that helps firms draw upon their core competencies and transform them into performance outcomes (Doran and Ryan 2014).

Capello et al. (2011) have classified studies on innovation, knowledge, and regional growth into three different approaches. The first approach focuses on the production of pure knowledge and concentrates more on explaining knowledge creation, spillovers, and linking knowledge inputs to knowledge outputs using a classical production function (including the theory of technological spillovers). The second important approach to the role of knowledge in regional growth includes theories linking knowledge to regional growth; these take into consideration that regional economic performance increases when knowledge is produced. This is the field richest in conceptual and applied analyses of innovation and regional growth; it comprises (i) the innovative milieu theory, (ii) learning regions, and (iii) regional innovation systems, for example.

The third and the most recent approach is concentrated on analyzing a region's intangible capacity for translating innovation into increasing profits from economic growth. The main benefit of this approach lies in the analysis of territorially embedded elements, enabling a region to grasp the opportunities provided by innovation creation, spillover effects, and new knowledge and to achieve increased profits from economic growth based on these factors.

It is clear that regions are endowed with different territorial capital (the territorial conditions that allow economic development to accelerate). Therefore, the availability of public, private, material, immaterial, and knowledge assets varies significantly between regions and includes infrastructure as well as private, human, and social capital (Fratesi and Perucca 2014).

The countries of Central and Eastern Europe (CEE) have undergone comparable historical changes since World War II, marked by the socialist period after the World War II, transition to a market economy at the end of twentieth century, and integration into the European Union. Nationalization or government takeover of private companies during the socialist era followed by privatization during the transition period has had a significant impact on their national and regional economies, resulting in increased regional disparities and substantially different trajectories for development, including those for research, development, and innovation at the beginning of the twenty-first century. Western European models of innovation systems have been implemented within the still centralized models of operation for research and development, often resulting in weak, formal, or artificial types of innovation systems, knowledge transfer, and knowledge exploitation. Even nearly 30 years after reintegration into the European economy, the CEE countries display low level of trust and cooperation between regional triple helix entities (knowledge institutions, industry, and the public authorities) as well as poor innovation and patent performance.

Moreover, less developed social capital and the reluctance of the regional stakeholders to work in partnerships result in mutual misunderstanding and difficulties in sharing information and strategic planning. As widely accepted, social capital in innovation networks emerges often as a result of network actors sharing some of values and norms, and network embeddedness has positive effects on regional innovation outcomes (Westlund 2006). A mental lock-in has its consequences: the CEE countries are losing out on the ongoing culture of centralization and central planning, which is reflected in central management of the sectoral policies, distrust of civil society, and underfunding of lower territorial self-governments.

It is necessary to emphasize that individual CEE countries are to a large extent export economies, primarily depending on the performance of the economy of Germany and other Western countries. There is only a tentative regional knowledge spillover mechanism existing in parallel with the organized external knowledge spillovers. Efforts of CEE countries to build economic development on the territorial assets are still under way and, instead, reliant on external exogenous knowledge transfers, and foreign capital prevails to stimulate growth. Domestic companies (with some exceptions) are less competitive because of their lower innovative potential. Technology and equipment are mostly imported. The impact of foreign capital inflow and knowledge acquisition on innovation performance is limited by the insufficient absorptive capacity to assimilate and integrate external knowledge. A similar problem exists in the utilization of knowledge transfer acquired from the massive EU funds.

The results of many studies show that external resources bring positive effects only to advanced economic systems, which embody focused public structural policies, effective law enforcement institutions, trust between cooperating entities, and increasing workers' knowledge potential (including creativity and the capacity to innovate). Moreover, ineffective take-up and redistribution of EU funds have led to crowding out of foreign investment in several CEE countries. The flow of European funds often causes the low-hanging fruit effect, which adversely affects business environment, corporate culture, and the willingness of companies to cooperate on creating innovative outputs.

On the other hand, it is worth pointing out that the CEE countries have shown distinct progress over the last 20 years. Two decades of economic growth and catching up with western EU countries were based on lower wage costs. The progressive growth model should be changed to be driven by innovation to confirm the global competitiveness. The individual countries enact various public policies on innovation support resulting in implementing innovation system policies and supporting a positive innovation environment. The public resources of the CEE countries and the EU have been used to build industrial innovation zones, innovation and competence centers, technology and research parks, etc. Likewise, considerable attention has been given to soft infrastructure in the area of supporting science, research, and education.

As Radosevic demonstrated in his studies (1999b, 2002), the complicated transition period significantly influences the long-term economic growth of the CEE countries. He pointed out that long-term growth depends on the sustainability of economic recovery in the economies of Central and Eastern Europe and on the reconstruction of innovation systems (intercompany, sectoral, regional, national, or global). Well-tailored innovations systems should emerge through the interaction of factors that are specific to microeconomics or the given sector, nation, or region. This is not an easy task, as the ineffectiveness and inefficiencies of current innovation systems are caused by the path dependence of the old centrally planned and sectoral model.

CEE countries have applied different kinds of strategies to rebuild their innovation systems. A variety of policy combinations have strongly focused on (i) increasing in-house company R&D, (ii) attracting foreign companies and providing them with incentives to innovate, (iii) enhancing public institutions' R&D capacities—to cooperate with (partner) private companies, and (iv) creating institutions that support and enable knowledge creation and transfer (Edler 2009). Krammer (2009) analyzed the drivers of innovative activities in transition economies. Countries of Eastern Europe and the former Soviet Union (EECs) have been experiencing a painful transition since the early 1990s, and this difficult conversion has also impeded their innovative capacities. Even though, there is still a lack of studies analyzing and evaluating innovative activities and the application of tools supporting knowledge capital within Central and Eastern European countries.

Radosevic has focused extensively on patterns of innovative activities in CEE countries between the years 1999 and 2002 and has pointed to some significant findings (Radosevic and Auriol 1999; Radosevic 1999a, b, 2002). The systemic changes in transition economies in the early 1990s have not brought about fundamental shift in the perception of policy makers. They continue to implement mostly linear models of innovation processes (Varblane et al. 2007). Drivers of regional growth certainly require the involvement of several sectors, which is hardly possible in existing vertical and sectoral system of organization and given internal objectives. Communication and coordination are inefficient without breaking out the policy silos.

The detailed look at the state of innovation systems and their performance at the turn of the century show that the position of the CEE countries is at the bottom of the EU countries, reflecting the limited scale of their innovative activities. The initial situation in the CEE innovation system can be characterized by several R&D and innovation differences:

- The percentage of enterprises with R&D activities was significantly lower in the CEE than in the EU countries.
- Extramural R&D organizations played a stronger role in the innovation systems than intramural ones.
- The innovation expenditures were relatively higher on more embodied technology, patents, and licenses.

This set of publications may serve as a benchmark or indicative basis for comparison after 15 years, as presented in this book. The book consists of four parts, with the ambition to cover a large number of CEE countries and to present more dimensions, thus creating a space for deeper understanding of developments, changes, and processes in the field of knowledge and innovation.

Today, a long list of literature is already devoted to national and regional innovation systems, knowledge spillovers, innovation networks, knowledge bases, absorption capacity, etc. The vast majority of key results are based on the more developed North American and Western European countries, though their evolutionary basis and institutional framework are very different from the group of catching-up postcommunist countries of Central and Eastern Europe, with different historical experience and discrepant socioeconomic characteristics. This is why the introductory part provides an overview of key concepts and results on the underlying topic of this book—knowledge spillovers in knowledge environment as well as the ways of classification and measuring spillover effects. The chapter entitled "The Effects of Cooperation and Knowledge Spillovers in Knowledge Environment" of Part 1 summarizes the current knowledge gained almost exclusively by the study of the regional innovation environment in Western Europe and USA and the factors of cooperation and rivalry in relation to the creation and exchange of knowledge as a precondition for economic growth. Hence, the new paradigm has brought the shift from traditional to knowledge factors of development. Newer theories of regional development are strongly based on the knowledge and institutional economic factors such as knowledge workers, R&D, innovation, social capital, and spillovers. The most significant theoretical approaches of cooperation and knowledge spillovers are explained and classified in the chapter entitled "The Effects of Cooperation and Knowledge Spillovers in Knowledge Environment." All the following chapters almost exclusively deal with CEE countries, which can always be considered in terms of consistency and differences with the "Western-founded" theoretical framework in the chapter entitled "The Effects of Cooperation and Knowledge Spillovers in Knowledge Environment." As an arena for the knowledge transfer and spillovers, the concept of regional innovation systems (RIS) is used. RIS is considered in general to consist of two subsystems of knowledge production and knowledge exploitation, and its efficiency can be evaluated in terms of inputs and outputs.

Part II builds on the theoretical Part I, comprising three chapters dealing with evaluation and assessment of the regional innovation systems by the authors from Lithuania, the Czech Republic, Slovakia, and Poland. The assessment of regional innovation systems is based on several factors (absorption capacity, intellectual capital, etc.) and is realized using several methods (data envelopment analysis, fuzzy cognitive maps, and the weighted sum model) providing a multifaceted view of CEE regions and enabling better understanding of the keystones of their innovation performance. Absorptive capacity, which refers to the ability to attract and absorb external innovative ideas, is an essential characteristic of RIS. Absorptive capacity assessment methodology is applied to the Lithuanian regions, also highlighting the context of small countries. Another weighted sum method (WSM) is based on the principle of utility maximization of RIS level assessment. The set of Czech RIS characteristics is divided into four layers: companies, support organizations, environment and infrastructure, and relationships and links. The last chapter of Part II evaluates the intellectual capital in the Polish and Slovak regions. The DEA methodology was used for the evaluation of the intellectual capital efficiency.

Part III of this book focuses on the evolution and dynamics of regional innovation systems. Knowledge production processes during the transition period from authoritarian socialism to market economy experienced the disintegration of the former inventory networks followed by only a slow recovery over the last 20 years. The authors deal with the evolutionary development of regional innovation systems in CEE countries by spatial evaluation of the regional networks of inventors in the Slovak regions. The innovation systems, whether national or regional, are underdeveloped and lacking the main substance—social capital and well-functioning linkages between the actors. In the following chapter, spatial dynamics of inventor activity in the Czech Republic, Hungary, Poland, and Slovakia between 1981 and 2010 is studied. The international and domestic collaboration patents are compared to explain the number of citations and technological profile. The collaboration between the assignee-inventors is analyzed at the town level.

Lastly, Part IV responds to the expected questions about the location factors for investment in the automotive industry in Central Europe. A qualitative survey focused on discussing the interaction between MNCs and the local environment and whether foreign direct investments have a capacity to stimulate a growth based on an endogenous innovation pattern. The role of knowledge spillovers on firms' productivity, demand, and successful implementation of product and process innovations is studied in the following chapter, looking for differences between the group of countries—Czech, Slovakia, Estonia, Lithuania, Romania, Croatia, Slovenia, and Hungary. The analysis is aimed at evaluating the influence of selected determinants of the knowledge economy on the selected output—turnover from innovated production. The last chapter of the book estimates the interregional knowledge and human capital spillovers within the triangle of three capitals—Vienna, Bratislava, and Budapest and their impact on total factor productivity. Despite the unique proximity of the three cities and support from EU cohesion policy, the transmission of knowledge in the territories is still rather limited.

The business climate, innovation systems, and knowledge spillover processes are still specific in the CEE countries, experiencing complex interactions of external and domestic knowledge and marked by the cultural differences between Western and Eastern Europe. This is highlighted by different historical trajectories as a sort of mental barrier of the former Iron Curtain. Therefore, one of the key questions is: what are the main differences between Western models of the mechanisms of knowledge generation and diffusion and their CEE derivatives, which demonstrate rather mixed results, unstable and fragile innovation systems, as well as incomprehensible environments and outcomes? Typically, innovation performance is increasing, but post-socialist development suffers from disintegration and a slow recovery for these formerly closed innovation networks as the CEE countries look for a new balance between international and domestic collaboration.

CEE countries deserve to be studied, but the knowledge and innovation mechanisms are not easy to understand. The authors believe that this book on regional innovation systems and knowledge spillover mechanisms will contribute to a better understanding of the current dynamics of the newer EU countries, exploring the roots, evolution, and external influences on current trends.

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Contents

Part I
Overview

The Effects of Cooperation and Knowledge Spillovers in Knowledge Environment

Viktor Prokop and Jan Stejskal

Abstract Knowledge is unequivocally one of the new sources of economic growth, though its use is not a new phenomenon from the economic perspective. The role of knowledge, along with its connection to innovation and economic performance, is a topic of interest for a growing number of researchers. Thus, many studies have been investigating not only the relationship between creating knowledge and innovation, but also the relationship between knowledge, creating innovation, and company performance—as well as economic growth. The collaboration plays in this process very important role. Participation in cooperation has thus become an important company tool, thanks to which the given participants are able to mutually support creation of knowledge, acquisition, transfer knowledge spillovers. The process of knowledge spillover is becoming increasingly important—primarily due to the potential it has for bringing value added to production processes. However, it is a process that is difficult to record and analyze; moreover, its results can be seen only over the long term. The goal of this theoretical overview chapter is to define spillover effects, describe their emergence and relationship to innovative activities, and subsequently depict their diverse influence as they operate in individual countries. The last section is devoted to the problem of measuring spillover effects, because it has not yet been possible to record and measure knowledge spillovers, and there is still the problem of which method to use when measuring them.

1 Knowledge in Globalized Economic System

1.1 From Traditional Resources to the Knowledge Economy

In recent years, the concept of the knowledge economy has been gaining in importance. This concept describes the knowledge that supplements and sometimes even

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entirely replaces the “original” production factors for ensuring increasing competitiveness and overall economic growth. In fact, it is apparent—and a number of international studies confirm this (e.g., Kim 2015; Snieška and Drakšaitė 2015; Magnier-Watanabe 2015; Verba 2016)—that there is currently a shift from traditional resources, such as work, land, and capital towards knowledge and its use, i.e., from hard factors (e.g., infrastructure) towards soft (intangible) factors such as local atmosphere, synergetic effects, human capital, and knowledge assets (Becattini 1990; Camagni 1991; Camagni and Capello 2009). It has been demonstrated that the most important of these are knowledge and the ability to learn. Heng et al. (2012) state that knowledge

- influences the economic growth of individual countries and regions,
- represents an important production factor, and
- causes differences in the productivity of countries and regions.

Today, the growth of a national economy is therefore much less dependent on quantities of natural resources, as was previously the case; rather, it is being increasingly influenced by intellectual capacity, the quality of human resources, and social and human capital, i.e., potential. Westlund (2006) stated that human capital is the individual-related resource (in the human nodes), while social capital is to be found in the links (relations) between individuals/actors and analysed that production and the exchange of knowledge in research, education and commercial R&D processes is promoted by the social capital. It refers to features of social organization, such as networks, norms, and trust, that facilitate coordination and cooperation for mutual benefit. Social capital plays an increasingly important role in the knowledge-based society and economy as it facilitates and speeds up economic actors’ acquisition of information and knowledge. In the following parts, we continue analysing issues that have been dealt with in the earlier Springer series Advances in Spatial Science (see Westlund 2006) with focus on the role of knowledge and its spillovers because individual economic actors are more frequently being forced to seek new resources—usually knowledge to help secure competitive advantage and sufficiently set them apart from the competition. As a result, the production of knowledge and information has been continuously growing, just as automobile or steel production saw growth in previous years (Stiglitz 1999). These changes have happened gradually alongside technological development, which started up half way through the twentieth century. The first visible impulse was the proliferation of personal computers, but the biggest boom happened with the mass use of the internet. Over time, developed countries have gradually become more dependent on the production and spread of knowledge (Powell and Snellman 2004) in connection with technological advancement. This has resulted in a shift from creating materially based prosperity to prosperity that is knowledge-based and better recognition of the role that knowledge and technology play within economic growth. Today, the individual economies of the OECD are strongly dependent on the production, distribution, and use of knowledge—more than in any previous time, because production/output and employment are expanding and growing most rapidly in technologically advanced sectors, such as computers, electronics, or aerospace technology (OECD 1996).

Smith (2000) states that knowledge alone is a more significant output than it has been in the past—both quantitatively and, to a degree, qualitatively; he lists a number of reasons for this:

- Knowledge is now becoming a production factor that is displacing capital and work (this statement relies primarily on the implicit idea that the accumulation of knowledge and its related technological advancement can be separated from the accumulation of capital);
- In comparison with natural resources, physical capital, and an unqualified labor force, the role of knowledge has acquired greater importance, and all the OECD economies are gradually becoming (at different paces) knowledge based;
- In a certain way, knowledge is a much more important product than it has been up to now—because it is possible to see an increase in new types of activities based on trade in knowledge products.

Thus, knowledge is unequivocally one of the new sources of economic growth, though its use is not a new phenomenon from the economic perspective (Snieška and Bruneckienė 2009). It was Schumpeter who, around the year 1911, came up with the idea of using knowledge and its combinations as the basis for innovative activities and business undertakings (Cooke and Leydesdorff 2006). This lead to a gradual increase in the importance of creating innovation as a key driver of regional growth, living standards, and international competitiveness (Acs et al. 2002). The role of knowledge, along with its connection to innovation and economic performance, is a topic of interest for a growing number of researchers. Thus, many studies have been investigating not only the relationship between creating knowledge and innovation (e.g., Shapira et al. 2006; Martín-de Castro 2015; Osoro et al. 2015) but also the relationship between knowledge, creating innovation, and company performance—as well as economic growth (e.g., Capello and Lenzi 2015; Rodríguez-Pose and Villarreal Peralta 2015; Aghion and Jaravel 2015; Fidel et al. 2015). It is clear that economic growth cannot be achieved in the same ways as it has been in the past, i.e., by employing an ever greater number of workers as a source of input or by increasing consumer demand (Pulic 1998; Chen et al. 2004). The historical development of economic theories that deal with sources of competitive advantage shows that economic entities must always seek further (new) ways to achieve their company strategy and cope with the pace of rapid change (Stejskal and Hajek 2015).

1.2 The Role of Knowledge in Economic Theory

Just as economic thinking has evolved over the years, theories and approaches have evolved concerning (long-term) economic growth (including regional growth) and the role of knowledge. In this way, the sources of competitiveness as well as of company and regional growth (and of national economies) have come to be generally acknowledged in the present day. Economists have been studying economic growth at the national (or regional) level for more than 200 years (Klenow and Rodriguez-Clare 1997), but it is only in the last 30 years that there has been a sharp increase in interest in this problem as well as in the role of soft factors (knowledge, local atmosphere, synergetic effects, etc.), which has subsequently led to the creation of a number of new theories. The reasons why they have been and are continuing to be developed are numerous. Some of these reasons are (Volejníková 2005)

- The polarization of wealth and poverty at the individual and country levels;
- A change in how individual sectors are represented within the national economy;
- Globalization;
- Innovations in banking and the financial markets; and
- Information technology, science, and research.

At the same time, the existence of these factors results in the fact that contemporary economic theory is not able to explain some of these problems, and if it can, it does so with difficulty or perhaps only incompletely.

Whereas the 1950s and 1960s, using Solow's neoclassic model, saw long-term economic growth as determined exogenously, i.e., by external factors (human capital and technology), the 1980s saw the emergence of a new theory, in which these factors were considered endogenous and were thus incorporated into the economic growth model. The reason why this occurred was because economic growth began to be increasingly influenced by previously unexplained and undefined exogenous input, which now began to increase in importance (Capello and Nijkamp 2010). One of the first and most significant theories is thought to be the new theory of (endogenous) growth, whose main proponents are Romer and Lucas. This theory presents knowledge, technology, human capital, and innovation as the key drivers of growth, where countries and regions can show convergence or divergence over the course of their economic development. One of the primary mechanisms causing convergence or divergence is increasing profits from knowledge, i.e., the accumulation of knowledge and external savings, primarily in the field of creating and disseminating knowledge (Blažek and Uhlíř 2011). Thus, the primary causes of differences are the varying quality of human resources and different technological and behavioral parameters.

Other theories of economic thinking developed during the last two decades of the twentieth century. The focus of institutional and neo-institutional economics, which even began to develop in the Czech Republic in the 1990s (Volejníková 2005; Blažek and Uhlíř 2011), has been very helpful when clarifying both the origin and development of economic differences between countries and regions and the mechanisms of evolutionary change in the economy, as well as for understanding an economy's dynamics. Institutional theories postulate the thesis that the traditional concept of economics includes problem areas that have not yet been given enough attention, which are nonetheless primary factors for understanding differing economic growth. These areas include (Blažek and Uhlíř 2011)

- Technology and technological innovation, where innovation and the learning pr cess are essentially a process of constant disruption of the market equilibrium;
- The concept of companies: Richard Nelson, one of the main representatives of Institutional economics, stated that economists have not yet attempted to understand the principles of how companies operate and their relationship to the competition, suppliers, or differences in the ways companies internally organize work; and
- Institutions, such as formal institutions (e.g., trade unions, pro-export organizations, etc.), and especially informal institutions (institutionalized practices, routine behavior, habits, etc.).

The topics listed above also inspired the development of the so-called institutionalized theories of regional development, which deal with all or only some of the selected areas. Blažek and Uhlíř (2011) have created a summary of the individual institutional theories of regional development (Table 1).

From the preceding text, it is clear that, over time, there has been a shift in the economic understanding of economic growth as well as a different understanding of knowledge and the role of human capital. In the last 20 years, analysis of the problem of using knowledge and human capital has increased to playing a central role in the discussion on the growth and success of nations, regions, and businesses. This is primarily because advanced societies have increasingly begun to orient themselves towards a knowledge economy (Capello and Nijkamp 2010).

1.3 The Definition and Features of the Knowledge Economy

It is rather difficult to find a unifying definition of the knowledge economy in contemporary literature. Each author adds their own perspective and significance to the concept. Brinkley (2006) has tried to find a unifying definition of the knowledge economy, and he presents the following definitions:

- It is an economy in which the creation and use of knowledge have a dominant role in creating prosperity. This type of economy is based on the most effective use of all types of knowledge within economic activities.
- The main idea of the knowledge economy is based on the description of new sources of competitive advantage (knowledge) that can be used by all companies, in all regions, and all sectors—from agriculture to biotechnology.
- Economic success is increasingly based on the effective use of immaterial assets such as knowledge, experience, and innovation potential. These assets are key elements for acquiring competitive advantage. The concept of the knowledge economy is then used to describe these emerging economic structures.
- The knowledge economy and society's knowledge represent a larger concept than merely paying more attention to research and development. It includes each aspect of the current economy, in which knowledge is the basis for value added—from high-tech industry and ICT to knowledge intensive sectors and even creative sectors, such as the media and architecture.

Table 1 An overview of regional development theories within institutional theory

Theory name	Theory basics	Main authors
The Theory of Flexible Specialization (Flexible Accumulation)	This theory deals with the decline of mass production; the main driver of interregional differences is differences in the cultural framework for organizing production as well as for company behavior. Examples of the causes of convergence (divergence) are considered to be external savings, economies of agglomeration, or team work. The main actors in this theory are small companies in less industrialized areas	Piore, Sabel, Scott
The Industrial District Theory	The basis for a region's prosperity is considered to be high-quality social, cultural, and institutional structures. The main mechanism causing convergence (divergence) is considered to be networking (network trust, cooperation, and management) as well as, for example, economies of scale and specialization, information sharing, and innovation. The main actors in this theory are networks of small companies and their supporting institutions	Brusco, Becattini, Bagnasco
The Theory of Learning Regions	This theory's main thesis is the statement that competitiveness is based on a better capacity for continuous learning and that sociocultural and institutional differences lead to interregional differences. Convergence (or divergence) is achieved primarily via the existence of positive feedback in the areas of learning, adopting new technologies and approaches, or information exchange (market and non-market) and the existence of technological infrastructure	Lundvall, Florida
The Triple Helix	In this theory, creating innovation, considered the driver of regional development, is determined by mutual cooperation and the emergence of synergetic ties between the relevant actors (companies, the public sector, academic institutions). The cause of interregional differences is the differing quality of relationships inside each of the triple helix elements (actors). The deliberate decisions of individuals and their groups and even chance phenomena are some of the main mechanisms of convergence (or divergence)	Etzkowitz, Leydesdorff
Clusters	In this theory, the quality of the surrounding environment, where the localization of individual activities is a strategic issue, is one of the causes of company success. The main reasons for interregional differences are considered to be company strategy, the	Porter

(continued)

Table 1 (continued)

Theory name	Theory basics	Main authors
	nature of competition between companies, the quality and price of inputs, market intensity, and the quality of interconnected and supporting sectors. Convergence (or divergence) occurs on account of economies of agglomeration determined by the emergence of a sufficient labor supply of qualified workers, establishing specialized infrastructure, and the emergence of specialized suppliers	
Regional Innovation Systems	These systems are formed from two subsystems: the first subsystem is focused on producing knowledge (research and development institutes) and the second subsystem (companies) subsequently use this knowledge. Here, targeted support of competitiveness and of company upgrading using an RIS fundamentally supplements existing spontaneous (or even random) synergetic effects. The things that primarily create interregional differences are the differing quality of research and development institutions, the various abilities of companies to create and absorb innovation, as well as the differing quality of these mutually interconnected subsystems. The main convergence (or divergence) mechanism is considered to be a varying degree of connectivity and trust between the actors within and between the two subsystems	Cooke
Global Commodity (Value) Chains, Global Production Network	The essence of this theory is the attempt to understand the factors, motives, and processes creating the form of the current global economy, where the possibilities and behavior of companies are influenced by their position and standing within these chains and networks, organized primarily by large supranational companies. The main cause of interregional differences is thus asymmetry in the power of the leading companies and suppliers. Convergence (or divergence) is influenced by, for example, upgrading (process—making the production or development process more effective; product—implementing/introducing new products or services; inter-sector—using skills acquired within a given chain or network for producing other goods; or function—implementing new activities with greater added value)	Hopkins, Wallerstein. Gereffi

Source: Adopted from Blažek and Uhlíř (2011)

Brinkley et al. (2009) later add that the term "knowledge economy" is used in a number of cases, but it is rarely defined; therefore, they have also come up with their own concept. It is a transformed economy, in which investment into assets based on knowledge (research and development, design, software, and human and organizational capital) dominates in comparison with investment into physical assets (machinery, equipment, buildings, and vehicles). The knowledge economy thus describes an industrial structure, work methods, and a basis for organizations' mutual competition that have gradually changed.

Hendarman and Tjakraatmadja (2012) suggest that the knowledge economy is an economy based on creating, evaluating, and trading in knowledge. Thus the knowledge economy means production and services based on activities that demand knowledge and contribute to the accelerated pace of technological and scientific advancement—as well as to their rapid obsolescence. Consequently, one of the key signs of the knowledge economy is greater dependency on intellectual capabilities than on physical inputs or natural resources, in combination with an attempt to integrate improvement into each phase of the production process—from the laboratory to research and development, from the factory through to communication with customers (Powell and Snellman 2004).

In the current information society, in which knowledge is one of the most important factors for achieving added value, there is a distinct shift in capabilities and their utilization (Mortazavi and Bahrami 2012). Therefore, the literature differentiates two terms, the knowledge economy and the knowledge-based economy, which are often incorrectly used as synonyms. The origins of the knowledge economy reach roughly back to the 1950s. Initially, the knowledge economy was focused primarily on the appropriate composition of a variously educated workforce, whereas the knowledge-based economy expands on the original term to include structural aspects of technological trajectories and regimes from the systems perspective. This perspective leads to discussion on international property rights as another form of capital, for example (Cooke and Leydesdorff 2006). More simply, it can be said that the knowledge economy is an economy producing products and services based on knowledge-intensive activities and contributing to both an accelerated pace of technical and scientific advancement as well as more rapid obsolescence. A key component of the knowledge economy is greater reliance on intellectual capability than on physical input or natural resources (Powell and Snellman 2004). On the other hand, an economy based on knowledge is an economy that is founded directly on the production, distribution, and use of knowledge and information (OECD 1996) and has four fundamental aspects, which are: (1) innovation, (2) education, (3) an economic and institutional regime, and (4) information infrastructure (Popovic et al. 2009). Knowledge-based (knowledge-driven) economy is therefore the economy (1) in which the generation and the exploitation of knowledge has come to play the predominant part in the creation of wealth and (2) which is about the more effective use and exploitation of all types of knowledge in all manner of activity (Peters 2001).

Brinkley (2006) adds a number of key features to the definition of the knowledge economy:

- The knowledge economy manages an increasing intensity of use of information and communication technology on the part of educated knowledge workers (these are workers with a high level of experience, which can be seen in their diploma or equivalent qualification; these workers perform tasks requiring expert thinking and comprehensive communication abilities, often with the help of computers; and they are often workers at top-level positions—managers, experts, or professionals).
- In the knowledge economy, there is a growing share of GDP devoted to intangible knowledge assets in comparison to physical capital.
- The knowledge economy is composed of innovating organizations using new technologies to introduce new innovations (e.g., process, product, or organizational).
- Companies in the knowledge economy reorganize work so that they can manipulate, store, and share information using knowledge management (knowledge management describes how an organization monitors, measures, shares, and uses intangible assets, such as an employee's ability to think and react quickly in a crisis. Some of the key steps in knowledge management are (i) the creation of a knowledge-sharing culture, (ii) a motivational policy for retaining employees, (iii) an alliance for acquiring knowledge, and (iv) a written concept for managing knowledge).
- The knowledge economy is present in all economic sectors—not only in knowledge-intensive ones.

This last point is tied into the Knowledge Economy Index Report (2014), which states that just as there is no one comprehensive definition of the knowledge economy, there are no precise sectors or activities singled out as belonging to it. In this study, the knowledge economy is defined as an economy composed of individuals, businesses, and sectors creating, developing, verifying, and commercializing new and emerging ideas, technologies, processes, and products that are then subsequently exported throughout the world. In the interest of trying to preserving competitive advantage, companies are always trying to remain at the forefront of their sector by (i) hiring highly qualified individuals, (ii) investing in research and development, (iii) implementing innovation, (iv) supporting creativity, (v) marketing, and (vi) seeking new markets. Therefore, the knowledge economy is an important element of all the advanced economies around the world, because it strengthens and contributes to increasing their global competitiveness, which results in economic growth. Some of the sectors belonging to the knowledge economy are

- Pharmaceuticals and biotechnology;
- Manufacturing medical equipment;
- Software and digital content;
- IT services;
- Telecommunications;
- Computational technology and advanced electronics;
- Creative content and digital media;
- Other technical services; and
- Aviation and other forms of transport.

From the above, it is clear that the knowledge economy penetrates across the individual sectors of a national economy, and knowledge inputs and outputs are a main source of competitive advantage for companies and regions that are dependent on their capacity for using knowledge potential—their own or foreign in combination with investment in research and development. It is clear, however, that not all economic entities are able to use the given sources to the same degree or as effectively. Linked to this is the fact that all types of knowledge are not the same nor can they be applied to all sectors. Therefore, three types of knowledge bases have been distinguished: analytic, synthetic, and symbolic.

1.4 Knowledge Bases and Knowledge Assets

The importance of knowledge and its influence on business performance and economic growth was clarified in the previous section. However, international studies (e.g., Fitjar and Rodríguez-Pose 2015; Arvanitis et al. 2015; Woo et al. 2015) warn of the fact that the influence and impact of knowledge are different in connection with the different sectors of a national economy.

In general, it can be stated that, thanks to globalization, innovation is the main driver of companies for achieving and maintaining competitive advantage. This statement is underscored by the fact that creating innovation is linked to a company's ability to absorb external information, knowledge, and technology (this fact is confirmed by a number of international authors, e.g., Negassi 2004; Segarra-Blasco and Arauzo-Carod 2008; Lichtenthaler 2011; Santos and Teixeira 2013).

However, Asheim and Coenen (2006) emphasize that innovative processes are becoming increasingly complicated. Namely, there is a wide spectrum of knowledge sources and inputs that companies and organizations are able to use. Generally, these are divided into three types of knowledge bases—analytic, synthetic, and symbolic. These knowledge bases incorporate various combinations of tacit and codified/explicit[1] knowledge, experience, competitive challenges, or implications for different sectors that can support companies' innovation activities (Asheim and Coenen 2005).

Initially, Asheim and Coenen (2005) differentiated only the first two knowledge bases—the analytic or scientific, and the synthetic. The symbolic knowledge base was defined a while later. The typology of individual knowledge bases is depicted in Table 2. The problem of knowledge bases has been dealt with most extensively by Asheim in his own work and in collaboration with other authors (e.g., Asheim and

[1]Tacit knowledge is knowledge that has never been recorded in explicit form and therefore cannot be easily transferred between individual entities; for the most part, this means experience and know-how. On the other hand, codified (explicit) knowledge is knowledge that can be recorded and can thus be easily interpreted and transferred—i.e., handbooks or instruction manuals (Neef et al. 1998).

Table 2 Typology of the different knowledge bases

	Analytical (scientifically based)	Synthetic (based on engineering)	Symbolic (artistically oriented)
Arguments for creating knowledge	The development of new findings on natural systems using the laws of nature (know-why)	The application or combination of existing knowledge in new ways; (know-how)	Creative, aesthetic creation of symbols, imagery, and aesthetic quality; (know-who)
Development and use of knowledge	Scientific findings and models, deduction	Resolving problems, custom manufacturing, induction	The creative process
Participating actors	Cooperation within and between research units	Interactive education with customers and suppliers	Experimentation in studios, project teams
Knowledge types	Strongly codified knowledge content, highly abstract, universal	Partially codified knowledge, strong tacit component, more specific context	The importance of interpretation, creativity, cultural knowledge; implications of strong contextual specificity
Output	Developing medicine	Mechanical engineering	Cultural production, design, brands
Professional groups	(i) Physicists, chemists, and related professionals; (ii) mathematicians and statisticians; (iii) professionals in the area of computational technology; (iv) university workers, the education of experts	(i) Architects, engineers, and related professionals; (ii) the physical and technical sciences; (iii) optical and electronic equipment; (v) ship and airplane inspectors and technicians; (vi) safety and quality inspectors	(i) Writers and creative artists

Source: Asheim and Hansen (2009), Asheim et al. (2011)

Coenen 2005, 2006; Asheim and Hansen 2009; Asheim et al. 2011). On the basis of their studies, it is possible to define the individual types of bases as follows.

The analytical knowledge base relates to the industrial environment, in which scientific findings and knowledge are most important and where knowledge creation is often based on cognitive and rational processes or on formal models (e.g., genetics, biotechnology, or information technology). Basic and applied research are relevant activities as is the systematic development of products and processes. Even though companies have their own R&D division, they still rely/are dependent on the research results of universities and other research organizations for their innovation processes. Cooperation, ties, and networks at the “university-industry” level, i.e., between universities and companies in industry, are important and more frequent than for other types of knowledge bases. Codified knowledge (for inputs and outputs) occurs more frequently in the analytical knowledge base than in the other types of knowledge bases. This is for a number of reasons:

- Knowledge inputs are often based on the evaluations of existing studies;

- Knowledge generation is based on applying scientific principles and methods;
- Knowledge processes are more formally organized (e.g., in R&D centers); and
- Outputs have the tendency to be documented in reports/final evaluations, in electronic documents, or via patenting. Knowledge is applied in the form of new products or processes and results in much more radical innovation than for the other types of knowledge.

The synthetic knowledge base relates to the industrial environment in which innovation emerges primarily by applying existing knowledge or by combining knowledge in new ways. In most cases, it occurs as a reaction to the need for resolving concrete problems that arise from interaction with clients and suppliers. The most frequent examples of this type of field are plant engineering, specialized advanced production of industrial machinery and equipment, and ship construction. In most cases, the products that arise are "one-shot" or produced in small series. In this type of knowledge base, research and development does not gain in importance. If it is used, it tends to be used in the form of applied research, though more often in the form of product or process development. The ties between universities and industrial companies are important, but more in the case of applied rather than basic research. Knowledge is not created as often by the deductive method or using abstraction, but rather using the inductive process of testing, experiments, computer simulation, or practical work. The knowledge that is contained in the relevant technical solutions or engineering work often tends to be codified. Tacit knowledge appears to be more important, because that knowledge emerges from experience gained at the workplace as well as practical tasks utilizing mutual interaction. Afterward, the innovation process is most frequently focused on how effective and reliable the new solutions are or how practical and user-friendly the products are from the customer's viewpoint. Overall, this results in innovation emerging in a somewhat cumulative way, with the prevailing idea being the modification of existing products and processes.

The symbolic knowledge base relates to the creation of products' aesthetic aspects—the creation of design, imagery, and symbols as well as to the economic use of such types of cultural artifacts. The increasing importance of this type of knowledge is seen in the dynamic development of cultural production, such as media (film production, publishing, and music), advertising, design, brands, and fashion. This production demands a personal take on innovation. A fundamental portion of the work is devoted to creating new thoughts, ideas, and imagery, while the actual physical process has been pushed into the background. Competition has thus shifted further away from products' utility value (tangible) to the visible value (intangible) of brands. Inputs thus tend to be aesthetic in nature rather than having cognitive quality. For this base, specialized characteristics and creativity are demanded over "mere" information processing; it is marked by a distinct level of tacit components.

Nonaka et al. (2000) state that so-called knowledge assets are another integral part of the successful process of creating and using knowledge in companies. These assets are defined as specific company resources necessary for creating a company's value added. Generally, knowledge assets are divided into four main groups:

- Experience knowledge assets—created with tacit knowledge that is spread using common experiences (e.g., the experience and know-how of individuals, care, trust, safety, energy, passion, or tension);
- Conceptual knowledge assets—created by explicit knowledge articulated through imagery, symbols, language (e.g., design, brand value, or product concepts);
- Routine knowledge assets—created by tacit knowledge that is routine and inserted to common actions and processes (know-how in daily operations, organizational routines, or organizational culture);
- Systemic knowledge assets—explicit knowledge that is systematizing and packaged (documents, specifications, manuals, databases, patents, and licenses).

Knowledge bases and assets, i.e., knowledge and its ability to be transformed (into innovation, for example) are becoming the core of individual regions' and countries' economic systems. They often try to support their generation, acquisition, and transfer both financially and non-financially. Disseminating knowledge has thus become one of the knowledge economy's key activities; this can happen in a number of ways, which are described in Sect. 1.5.

1.5 Creating and Disseminating Knowledge

In the present day, creating and disseminating knowledge are key activities that must be handled by most economic actors. Namely, there are many ways to create (new) and disseminate (new and existing) knowledge. Frenz and Ietto-Gillies (2009) present four sources of knowledge that can be used:

- Generating original knowledge,
- Purchasing knowledge,
- Internal company sources (transfer of knowledge within a single company), and
- Cooperation.

The latter, i.e., cooperation, has recently been becoming increasingly important (Miozzo et al. 2016; González-Benito et al. 2016). It can be said that, in the present day, cooperation is necessary for any given entity that wants to grow and compete on the market. It is clear that while non-cooperating businesses focus on their own sources and on developing key competences, knowledge is being updated at an ever more rapid pace, resulting in the obsolescence of technologies, which is linked to a necessary increase in investment and growing costs for knowledge creation. As a result of these factors, it is nearly impossible for a company to create and accumulate all the knowledge necessary for its survival and prosperity on its own. Participation in cooperation has thus become an important company tool, thanks to which the given participants are able to mutually support their knowledge and create new knowledge. Thus, companies bring both prior knowledge, primarily patents and know-how acquired before the given cooperation, to the collaboration as well as their current attempts at creating knowledge, which include financial capital and physical and human resources (Ding and Huang 2010).

Whereas explicit knowledge can be disseminated at the individual, company, or international level, tacit knowledge can only be acquired at the lowest, or individual, level. Transferring explicit knowledge can happen through the use of technologies, documents, products, and processes (at the company level)—or a multilateral agreement on the transfer of technologies, education, and professional training or the direct import and export of products (at the international level). On the other hand, the exchange of tacit knowledge at the individual level can be conducted by either deliberate transfer of knowledge or by unintentional spillover effects.[2] Fallah and Ibrahim (2004) list three levels of knowledge spillover effects:

- Individual (between people). Here, knowledge is unintentionally exchanged between people. Individuals have control over their tacit knowledge and can share it with whomever they wish or need to share it with. Most frequently, knowledge spillover effects happen as a result of unawareness or ignorance—or when the tacit knowledge is externalized for use. Though individuals can use patents or copyrighting to protect knowledge, it nonetheless starts spilling over to others once the tacit knowledge has become explicit. For example, sharing knowledge as a member of a cooperating team (within a single company, through cooperation between companies, or as a part of the customer-supplier relationship) is not considered a spillover, because, in this case, the given team was created specifically with the goal of transferring knowledge. However, unintentional sharing of knowledge that was not specified for the given group in the first place or even sharing the group's knowledge with people outside the group (outside the organization) is considered to be a knowledge spillover effect.
- Company (between companies). In this case, knowledge exchange occurs between companies—between neighboring companies (often located in close proximity) or as part of joint business endeavors by connected companies. Just as in the previous example, this process is called knowledge sharing or transfer if it the knowledge exchange is intentional. Any information that is not intentionally shared is then a spillover effect.
- Global (between countries). Knowledge spillover effects occur when there is unintentional knowledge sharing between individual countries. This sharing can happen both between neighboring countries as well as between countries that conduct trade with each other (e.g., an accompanying process during technology transfer).

There are other levels at which knowledge spillover effects between companies and other entities can occur; these are now coming into prominence:

[2]Spillover effects are the process of direct (and indirect) knowledge transfer from one party to the next—or also often to third parties—who are not directly involved in the given process; this is an example of a positive externality. The problem of spillover effects is covered in the second part of this chapter.

- *University-industry*. In this case, cooperation occurring between universities and companies increases in importance and is being investigated by an increasing number of researchers (e.g., Siegel et al. 2003; Ponds et al. 2010; Maietta 2015). Perkmann and Walsh (2007) list various ways this cooperation can happen (Table 3).
- *University-industry-government collaboration* (or the Triple Helix). Similar to cooperation with universities alone, this type of collaboration between universities, companies, and government is also increasing in significance and is being investigated by a number of international authors (e.g., Etzkowitz and Leydesdorff 2000; Leydesdorff 2012; Zhang et al. 2014; Petersen et al. 2016). In recent years, the original Triple Helix concept has been expanded to include a fourth component, human society as those who use innovations; this model is called the Quadruple Helix.

Other studies are also appearing that deal with the influence of cooperation and its resulting knowledge spillover effects. Specifically, this means the relationships between competitors, suppliers, and customers (e.g., Dai Bin and Hongwei 2011; Classen et al. 2012; Belderbos et al. 2014).

The options that are described are then also discussed extensively as they relate to practical application. Individual companies are forced to decide whether they will implement their own research and development either (i) alone, (ii) as part of a research alliance with other companies (universities or government laboratories), (iii) contractually through specific research and development projects, or (iv) by contracting researchers from other companies or research centers (Mueller 2006). Research and development activities offer a number of other possibilities in addition to generating innovation; they increase the ability to identify, adapt, and use externally created knowledge—resulting in the opportunity to utilize research and development activities at a higher level, greater absorption capacity, and a larger pool of

Table 3 The types of University-Industry Cooperation

Type of cooperation	Means of cooperation
Research partnership	Intercompany measures to intensify cooperation in research and development
Research services	Activities contracted by industrial clients that include contract research and consulting
Academic entrepreneurship	The development and commercial use of technologies created by academic inventors using firms claiming (partial) ownership
Informal interactions	Creating social relationships and networks—at conferences, for example
The commercialization of property rights	The conversion of university property rights into company IPR (e.g., patents)—using licenses, for example
The transfer of human resources	Via a multifunctional training mechanism (e.g., employee training in the industrial sector, industry-oriented postgraduate education, internships, etc.)
Scientific publication	Using codified scientific findings in industry

Source: Perkmann and Walsh (2007)

knowledge. The absorption capacity may become critical circumstance as for the final spillover effects because creation of spillover effects is depend considerably on the economic environment to which they are extended. Therefore, research specialization should be generally aligned with economic specialization. This is because of the fact that the close match between the regional knowledge base and the needs of industry is often not the case and the absorption capacity of local economy is hindered by number of factors (Gál and Ptaček 2011). These factors for example are (Varblane et al. 2010): discrepancies between the existing knowledge base and the needs of the economy, problems of cooperation between universities and businesses—lower innovation capability of enterprises on the one side and problems with the orientation of public sector research to the needs of the business.[3]

Even despite the clear advantages that cooperation and disseminating knowledge bring, there are many companies that do not participate in cooperation or are not able to fully use its advantages. Iammarino and McCann (2006) refer to two differing perspectives on knowledge spillover effects, i.e., knowledge inflows and knowledge outflows. Knowledge inflows are looked upon positively by companies. On the other hand, unplanned knowledge outflows can have either a positive or negative impact on the company. For a company, one of the main negative unintentional knowledge outflows is the escape of valuable intellectual capital and intangible assets. Conversely, a potentially positive effect of an unintentional leak of knowledge is seen in the nature of knowledge as a public good. This outflow would be important in a situation where it helped strengthen the local knowledge base, and the given territory thus became more attractive for other innovative companies, which would result in a greater knowledge inflow in the future. Therefore, this primarily depends on individual evaluation of how knowledge spillovers benefit individual companies, i.e., the relative significance of these two effects. At the moment, such considerations appear to be quite complicated, because there is no single universal method that would provide companies the opportunity to measure the size of knowledge inflows and outflows as well as the effects linked to them.

Moreover, certain companies are not able to entirely use the knowledge they have acquired (Mueller 2006). One of the possible reasons for this is the fact that many established companies are not willing to accept the risk linked to introducing new products and processes. These companies would rather focus on generating profit from their time-tested production program and are not interested in looking for or acting on new opportunities. For many companies, this is caused by management's aversion to risk. Many companies do not have the ambition of becoming leaders in innovation or participating in cooperation. Other problems include insufficient funding, excessive bureaucracy connected to implementing public projects, unprofessional assessment of grant applications for research projects, and a large time lag between producing and commercializing knowledge (this is a significant barrier for industry-university cooperation on account of their dichotomous goals).

[3]Despite long-standing industrial traditions (specifically within Central and Eastern Europe Countries).

Therefore, companies prefer to withdraw from many projects or wait until they are able to accomplish them with their own resources. If a company is not hindered for any of these reasons, there is another problem on the horizon: the availability of a sufficiently qualified work force. The availability of this type of labor is a problem encountered by an overwhelming majority of companies across sectors.[4]

In order to analyze cooperative ties with the goal of creating innovation, it proves to be necessary to conduct detailed analysis of knowledge flows and spillover effects—as well as their causes and effects. These ties serve to disseminate and use knowledge in networks, which to a large degree has a positive influence on overall company performance. De Faria et al. (2010) discovered causal/significant relationships between the flow of external information and knowledge and the decision to cooperate on research and development activities. Companies that value the general availability of the incoming knowledge spillover effects as an important input into their innovation processes are the most likely to be involved in cooperation agreements on research and development activities. Likewise, companies that are more effective in adopting the results of their innovation processes are more often involved in cooperation in research and development. From this, we can see that managing incoming knowledge spillover effects and their adoption have significant effects; companies that are more able to acquire/absorb knowledge from external sources and are also better prepared to protect their own knowledge are more often (with higher likeliness) involved in research and development cooperation. Some of the primary factors that later influence company decision making on cooperation are

- engagement in research and development,
- the qualification of human resources (in relationship to absorption capacity and the ability to optimize spillover effects),
- company size, and
- competitiveness.

Companies that subsequently decide to cooperate look for the most varied ways of creating the most favorable environment for cooperation and for using knowledge spillover effects. One way to support their emergence and the positive influence on company research, development, and innovation linked to them is by creating regional innovation systems or industrial clusters and their initiatives, which are typically spatial concentration and sector specialization (Tsai 2005). An obvious fact that has been stated by a number of international authors, e.g., Baptista and Swann (1998), is that company research and development does not occur in isolation. In other words, it is much more effective if it is supported by external resources (in each of its phases). Actually, the geographical proximity of these resources very often plays an important role—this is determined by knowledge's cumulative nature (knowledge generally spreads more easily over shorter distances). Therefore, faster

[4]This is confirmed by research results from "INKA—Innovation Capacity 2014," published by the Technology Agency of the Czech Republic in 2015.

growth, easier generation of new knowledge, and other innovative outputs will generally be recorded for companies with headquarters in a strongly innovative area. Another important determinant is regional policy, which helps create a favorable economic (business) environment for individual economic entities and significantly influences public financing systems in the present day. This has resulted in the emergence and increasing importance of functional regions, innovation systems, or supranational industrial clusters. However, judging the effectiveness of these steps is very difficult. Namely, there are no standardized methods for measuring the effects of implementing knowledge or its spillover effects (Kitson et al. 2004). Various studies argue about whether an economy's knowledge base is measurable or how to measure the output of the knowledge economy, which is necessary for various types of economic analysis (e.g., Leydesdorff et al. 2006; Shapira et al. 2006).

1.6 Measuring the Effects of Applied Knowledge

It has been mentioned that there is a problem with the extent to which spillover effects from applying knowledge are measurable. Researchers in this area are increasingly facing questions of how it is possible to measure knowledge and knowledge inputs and output—and whether they are measurable at all. On one hand, the possibility of measuring knowledge is rejected for a number of reasons, e.g., because measuring would be a very complicated process, primarily at the regional level (Chen and Huang 2009), or because economic entities are unable to provide suitable data. On the other hand, a number of authors are tying to create systems and procedures would make it possible to measure knowledge and its effects, primarily using composite indicators (Nelson 2009; Méndez and Moral 2011; Dubina et al. 2012; Leydesdorff and Zhou 2014).

The OECD (1996) states that one of its primary problems when measuring knowledge is the fact that knowledge is not a traditional economic input. In agreement with traditional production functions, the previous account has made it clear that economic growth occurs when traditional inputs are added (e.g., adding units of labor results in GDP growth by the amount that was dependent on actual work productivity). On the other hand, new knowledge influences economic performance by changing the traditional production schemes; this change then results in product or process changes/possibilities that were formerly unavailable. While new knowledge generally increases potential economic output, the quality and quantity of this impact is not known in advance (the change that has been brought about generally depends on a number of factors: economic competition, business, competition, etc.). Consequently, it is difficult to find a production function encompassing the relationship between inputs, knowledge, and the resulting outputs. Therefore, four main reasons are generally listed for why knowledge indicators cannot approximate the systematic comprehensiveness of traditional economic indicators. These are primarily the following:

- The absence of stable production schemes for transforming knowledge inputs into knowledge outputs,
- Inputs for creating knowledge are very difficult to map,
- There is lack of a systematic price system for knowledge, which would be used as the basis for aggregating findings that are essentially unique, and
- The creation of knowledge need not always mean an increase in the base of findings, and the obsolescence of specific knowledge in this base has not been precisely documented.

The World Bank has offered its own possible solution, which provides a spectrum of knowledge economy factors that are used for analyzing its development: the Knowledge Assessment Methodology (KAM). This is an interactive comparative tool to help individual countries identify the challenges and opportunities they face when changing over to a knowledge economy. KAM provides a specific basic evaluation for countries and regions and their level of readiness for the knowledge economy; the uniqueness and strength of this method are due to the fact that it represents a wide range of factors describing the knowledge economy (Chen and Dahlman 2005). This method is composed of 148 structural and qualitative variables making it possible to measure the performance of a total of 146 countries using individual areas of the knowledge economy (World Bank 2015). These areas are divided into four parts: (i) economic incentive and institutional regime, (ii) educated and qualified workers, (iii) an effective innovation system, and (iv) corresponding information infrastructure (Chen and Dahlman 2005). KAM's advantage lies in the fact that it is available in a total of six different forms: (i) a basic evaluative document, (ii) a personalized evaluative document, (iii) knowledge economy indexes, (iv) over-time comparison, (v) cross-country comparison, and (vi) a world map evaluating countries' readiness for the knowledge economy.

A number of contemporary international studies list patent creation as a potential tool for measuring knowledge outputs and competitiveness as well as being an important indicator (e.g., Lam and Wattanapruttipaisan 2005; Olivo et al. 2011). The number of patents was also used for analyzing the relationship between regional competitiveness, the emergence of spillover effects, and innovative company behavior (Audretsch et al. 2012). Patents are also part of the previously mentioned set of indicators used by the World Bank. Even the OECD attaches a significant role to patents in their method—for evaluating innovative activities, outputs, and economies' performance (OECD 2004). The number of patents is also used in a number of economic analyses; Nelson (2009) lists the reasons. It is because the number of patents is monitored by statistical offices, i.e., long-term statistics enabling international comparison thanks to harmonized procedures. They are often divided into categories and subcategories, they identify creators/developers (individuals and corporations), and they make it possible to observe public financing as well as, in certain specific cases, the emergence of a patent from first reference to registration. In their studies, Fontana et al. (2013) also confirm the significance of patents and their ability to measure the output of the innovation process. This works because patents are by definition connected to innovative activity; they are easily available; in this case, they make it possible to save time and effort when collecting data; they are available for a relatively long period of time; and they encompass essential and important information, e.g., the name and address of the inventor, the owner of the given innovation, a description of the innovation, and its relationship to previous innovations represented by patents.

On the other hand, there are studies that criticize this method of measurement primarily because not all innovations are patented. Naturally, how many innovative outputs are patented and how many of these outputs are not is only a matter of speculation. Fontana et al. (2013) put forth the opinion that there are three types of reasons why inventors decide not to patent their outputs:

- The innovations are not patentable—the inventor is convinced that it is not necessary to patent the given output;
- The innovation is patentable, but the creator assumes that the creative steps of their innovation process are not large enough for it to be suitable for a patent;
- The inventor decides not to patent their output, because they prefer keeping the given information secret.

Arundel (2001) conducted a study in which he determined that a large percentage of companies conducting research and development activities find secrecy to be a much more practical and effective method than patenting. Moreover, researchers must take a number of other risks into account when using patents. Van Zeebroeck et al. (2006) list the source of patent data as one of the risks that must be considered when conducting research. Specifically, it is clear that globally there are a whole range of patent statistics that can be used. These include the United States Patent and Trademark Office (USPTO), the Japan Patent Office (JPO), the European Patent Office (EPO), the Triadic Patent Families, the World Intellectual Property Office (WIPO), and national patent offices. The topicality of this problem can be seen in Svensson's study (2015), which states that the weakness of a number of patent databases is the fact that they are not able to determine which patents were used commercially, i.e., which patents were introduced in the market as innovations. Moreover, certain patents are introduced in the market only for competitive advantage so that companies can prevent the competition from using the given patent. In many cases, these patents do not encompass very much innovation. For certain inventions, it must be considered whether it may be more advantageous to use an alternative to patents, i.e., utility models.

Researchers have been investigating the ratio of patented to unpatented innovations for many years. For example, Moser (2012) conducted a study focused on innovation creation without patenting, in which she achieved the result that 89% of innovations from British exhibitions were not patented. In their study, Fontana et al. (2013) presented the results of Mansfield's research from 1986, which dealt with the question of how many patentable innovations are actually patented. This research was conducted on a random sample of large American companies from various sectors. The results of this research showed that roughly 34% of the patentable inventions were not patented in sectors in which patenting is not considered a very effective mechanism (electronic equipment, tools, office supplies, motor vehicles, etc.).

However, in sectors where patenting was considered practical and effective (the pharmaceutical, chemical, oil, machinery, metals, and metalworking industries), this percentage was lower—around 16% (Fontana et al. 2013). Further research was conducted by Arundel and Kabla (1998) and Arundel (2001). This research investigated the situation of companies in 19 industrial sectors and their tendency in percentages for making patent applications. The results showed that the average tendency towards patenting product innovations is 35.9% (this tendency ranges between 8.9% for the textile industry and 79.2% for the pharmaceutical industry). This tendency was somewhat lower for process innovation—roughly 24.8% (again ranging between 8.1% for the textile industry and 46.8% for the field of precision instruments). The given analyses also provided another interesting result—that this tendency for both types of innovation was >50% in only four sectors.

From the above, it can be seen that today knowledge (in combination with traditional production factors) is a key element for economic growth in most countries—despite the fact that there is still no unified, universally used method for measuring it. With the arrival of the knowledge and knowledge-based economies, the focus of individual analyses has shifted from technological change to a focus on innovation. Knowledge has thus officially become one of the most important strategic resources, and the learning process has become one of the most important processes in the present day (Tappeiner et al. 2008). Whereas the significance of knowledge in the new growth theory was connected to stimulating technological progress and the resulting growth in productivity, Romer and Lucas explained that economic growth occurs via the accumulation and spillover of technological knowledge (Mueller 2006). Blažek and Uhlíř (2011) created a framework for regional development theories, whose conclusion attempted to find a "miraculous formula" and practical guide for regional policy motivated by the attempt to create and strengthen regional competitiveness in the age of the knowledge economy. This framework includes a total of eight areas:

- Excellent research and a top-notch interface between research and the business world;
- Support for talent
- Company culture and the role of models;
- Smart money and qualified consulting;
- Contacts, networks, and clusters;
- Governance and a regulatory framework;
- A region's attractiveness and quality of living; and
- Access to transportation.

In the present day, another factor has also been increasing in importance—knowledge spillover effects. Knowledge spillovers are a complicated process influencing the economic system both at the microeconomic level (inside individual companies and their outputs) and at the macroeconomic level (e.g., by acting on gross domestic product).

2 Knowledge Spillover Inside the Economic Environment

Previously, the issue of the knowledge economy and the role of knowledge in contemporary globalized society were described, with the new (endogenous) growth theory being one of the first theories considering knowledge, technology, human capital, and innovation to be key drivers for growth. Proponents of this theory dealt with two basic problems: whether technological change is the result of conscious economic investment and the explicit decision making of many varied economic entities and whether the existence of significant externalities, knowledge spillover effects, and other sources of increasing profits can lead to constant (sustained) economic growth (Griliches 1991). The first question was dealt with by a number of important economists in the 1960s, such as Schultz, Griliches (1957), and Mansfield (1968). The second question, i.e., the problem of knowledge spillovers, has primarily become more significant in the past 20 years, when a number of studies showed that the positive effects of disseminating knowledge and implementing innovation are used not only by the solitary actors involved in these processes but also by third parties who are not directly integrated into the given activities. This occurs precisely because of the emergence of knowledge spillover effects, which mainly exert significant influence over companies' innovation processes and countries' economic development (Mueller 2006). The creation, flow, and capitalization of knowledge spillovers contribute greatly to the varying speeds of growth in different regions (Fritsch and Franke 2004)—within countries as well as in international comparison. The goal of this chapter is to define spillover effects, describe their emergence and relationship to innovative activities, and subsequently depict their diverse influence as they operate in individual countries. The last section is devoted to the problem of measuring spillover effects, because it has not yet been possible to record and measure knowledge spillovers, and there is still the problem of which method to use when measuring them.

2.1 The Emergence of Spillover Effects

In the previous section, the problem of knowledge and knowledge-based economies was described, including four basic terms that have been distinguished over time (OECD 1996; Fallah and Ibrahim 2004):

- Knowledge production, which is realized via research and development;
- Knowledge transmission, which is achieved via education and vocational training;
- Knowledge transfer, in which intentional knowledge exchange occurs between people or organizations; and
- Knowledge spillover, the unintentional transmission of knowledge.

The path of knowledge from its owner to the recipient of this knowledge is recorded by Fallah and Ibrahim (2004) in Fig. 1, as is the difference between knowledge transfer and knowledge spillover. From this, it is clear that the first step in transmitting knowledge from the owner to the recipient is a process called externalization, i.e., when knowledge is articulated and transformed into explicit knowledge. In the next step, the owner of the knowledge decides with whom to share the given knowledge (transfer). Knowledge transfer can also occur unintentionally (via spillover). Thus, a situation can occur within this process where an individual who owns knowledge cannot control its dissemination. It is generally true that the more knowledge is codified, the less opportunity its owner has to control who will obtain and use the knowledge in the end, because the knowledge transfer can be influenced by other entities as well. Naturally, this does not mean that spillover effects do not emerge from non-codified knowledge. However, this type of transfer is much more complicated.

It is therefore clear that the process of knowledge spillover is becoming increasingly important—primarily due to the potential it has for bringing value added to production processes. However, it is a process that is difficult to record and analyze;

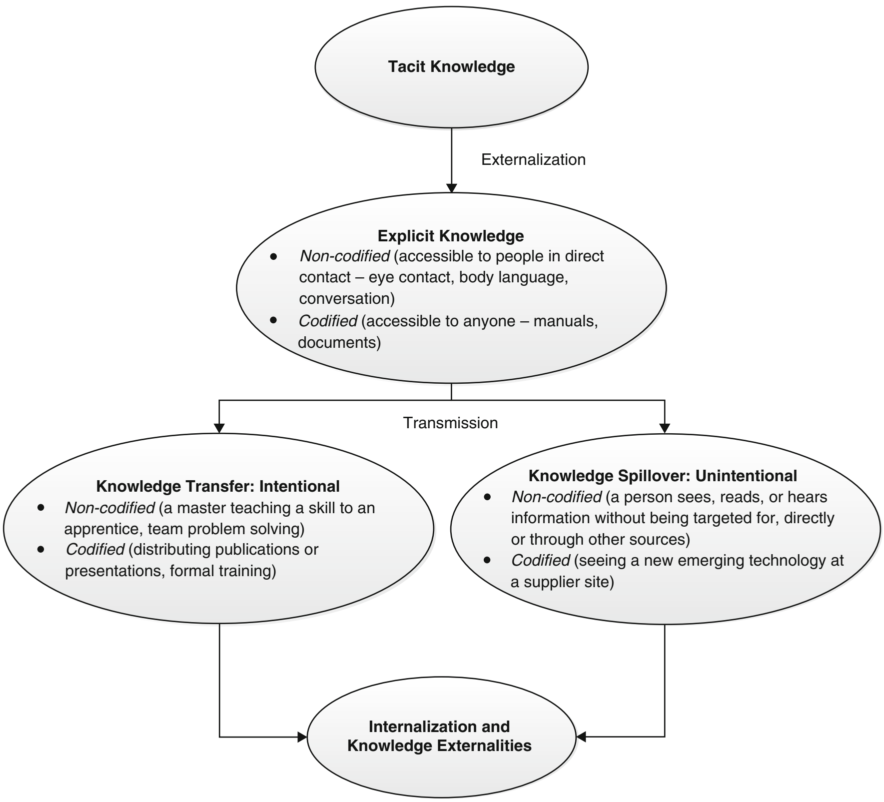

Fig. 1 Knowledge transfer versus spillover. Source: Adopted from Fallah and Ibrahim (2004)

moreover, its results can be seen only over the long term. Examples of this include student experience at professional workplaces or the process of preparing doctors for accreditation, with this type of learning very closely relating to the capacity (ability) of individual economic entities for absorbing knowledge. Companies' ability to absorb knowledge thus depends primarily on their employees' experience and professional training. For individuals, absorption capacity is influenced by their sagacious knowledge. Mueller (2006) describes a company's absorptive capacity as the ability to produce, identify, and use knowledge; this ability depends on existing knowledge stock and the entities' (employees in companies or researchers at universities or research institutes) absorptive capacity. Therefore, it is clear that when the same new information is obtained by two different entities, one of them can connect this information with previously obtained knowledge and learning and use it in an innovative way. Conversely, the other individual may not notice the emergence of this knowledge and put it to further use. Sagacious knowledge and the use of tacit knowledge thus influence the way knowledge is acquired and internalized.

2.2 Defining, Classifying, and Disseminating Spillover Effects

The issue of knowledge spillover and its resulting effects are perceived differently by many authors; in consequence, there is no one fixed definition. Gilbert et al. (2008) define knowledge spillover effects as the direct or indirect transfer of knowledge from one party to the next, i.e., from one economic entity to the next. This knowledge tends to be generated by companies engaging in innovative activity and is very valuable, because it provides knowledge and findings that are completely new to the company that embraces it (i.e., the company that uses these positive externalities). When there are technological effects from knowledge spillovers, companies are equipped with specific industrial knowledge that helps them know (i) what technological activities have been conducted by others, (ii) what activities are currently being conducted, and (iii) what level of success was achieved by companies as part of these activities. It is assumed that technological spillover effects help companies utilize the latest technology and compete on the most attractive markets.

Kesidou and Romijn (2008) state that knowledge spillover has been defined by economists as knowledge flows that emerge and provide an altogether spontaneous source of knowledge that does not require any type of compensation. The authors naturally add that, to a degree, knowledge spillover can also occur intentionally via the mutual interaction of the participating parties (companies, universities, development centers, etc.). The important feature of these effects (externalities) is the fact that they emerge outside the market and directly influence companies' production function—in contrast to financial externalities that exert indirect influence via price change.

Fallah and Ibrahim (2004) describe spillover effects as the unintentional transfer of knowledge across the boundary of what was intended; they see potential for knowledge exchange within every possible interaction. The authors differentiate between knowledge transfer, which encompasses knowledge exchange between select people or organizations, and spillover effects, which include any type of knowledge that is exchanged outside the boundaries of what was intended. The unintentional use of knowledge exchanged in this way is then called a knowledge externality.

Many authors use various approaches for distinguishing the types of spillover effects. Lee (2006) distinguishes between rent spillovers and knowledge spillovers. Typically, rent spillovers emerge exclusively within economic transactions, whereas real knowledge spillovers may not always emerge exclusively within economic transactions. Fischer et al. (2009) distinguish between different types of knowledge spillovers called pecuniary and non-pecuniary knowledge spillovers. The first type designates spillover effects embodied in traded capital or intermediate products and component services (so-called pecuniary externalities). The second type describes intangible spillovers (non-pecuniary externalities), which emerge because the production of knowledge is a public good and limits companies' ability to prevent other companies or individuals from investigating and acquiring this knowledge. Sun et al. (2015) define spatial spillover effects as the influence regional economic development has on (less developed) neighboring regions. De Jong and von Hippel (2009) describe intentional and voluntary spillovers, which primarily result when a company (the inventor) intentionally reveals their own innovative outputs because they believe that they will receive valuable feedback and suggestions for improvement from other economic entities.

Another way of categorizing spillover effects is into vertical and horizontal (De Faria et al. 2010). Vertical spillover is linked to the interaction between suppliers and customers and influences research and development activities more significantly. Horizontal spillover happens within interactions between universities, research institutes, and competitors. Cooperation with different types of partners is increasing in significance and, according to numerous international studies, positively influences innovative activities and overall company performance. Thus, the choice of partners is a key process for achieving a company's strategic objectives, primarily when creating innovation. De Faria et al. (2010) determined that it is always necessary to choose a suitable partner for cooperation in order to be successful when implementing various types of innovation. Whereas the key to success when implementing product innovation is to have customers and public sector institutions as the primary partners for cooperation, suppliers and universities positively influence the success of process innovations. Cooperation with suppliers and competitors distinctly influences the growth of work productivity, whereas cooperation with universities, research institutes, and competitors positively influences growth of sales from products and services that are new in the market per employee.

Cantù (2016) demonstrates that spillover effects can also emerge at specific economic levels (micro-, mezo-, and macro-) and at differing geographic distances (Fig. 2), where strong ties are created between the given entities at each of the levels.

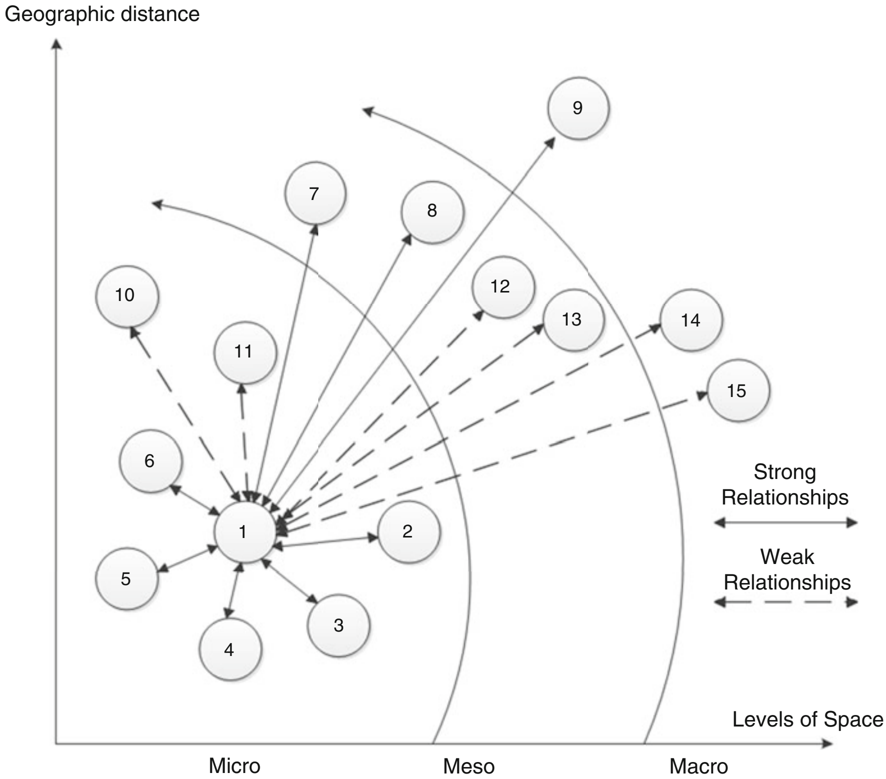

Fig. 2 Network spaces in place perspective. Legend: Numbered cells represent economic actors. Source: Adopted from Cantù (2016)

It is thus clear that when achieving strategic company objectives and creating innovation, knowledge spillovers are becoming more important: (i) at the individual economic levels and (ii) within cooperation between various partners. Nevertheless, innovative activities are currently perceived as one of the key elements helping individual economic entities achieve competitive advantage, create value added, and even achieve economic growth. Nonetheless, the process of implementing innovation is complicated on its own and encompasses many elements that need to be managed in order to apply the final innovation—within companies though primarily on the (often international) market. There have been a number of studies (Maidique and Zirger 1984; Martin and Horne 1993; Lengyel and Leydesdorff 2011; Scarbrough et al. 2015) proving that just as not all economies using knowledge are knowledge economies, not all companies that innovate are innovative companies reinforcing their competitive advantage or another strategic goal—rather, they are failing at their innovative activities. The following section consequently focuses on the significance of knowledge spillover effects in relationship to innovation activities.

2.3 The Growing Influence of Spillovers on Creating Innovation

The effect of spillovers in today's most advanced economies has become a key question for many scientists (e.g., Coe and Helpman 1995; Baicker 2005; Sun et al. 2015) investigating their influence on economic growth, company productivity, supply and demand, and innovation. Namely, innovation is a driver for both companies and entire economies, and it increases competitiveness and economic performance. Innovation policy is continuing to become more significant and is considered key in today's dynamic market environment (Tödtling and Trippl 2005; Seidler-de Alwis and Hartmann 2008).[5] Thus, the creation, dissemination, use, and especially spillover of knowledge are key processes that help companies with their innovative activities. For companies, creating innovation makes it possible for them subsequently to create value added, set themselves apart from the competition, and occupy a very strong position on the national or international market. Innovation thus appears at the forefront of political programs both in industrial fields as well as in regional policy; no driver of economic growth has gained as much attention as innovation—the basic driving force of economic growth, prosperity, and competitiveness (Matatkova and Stejskal 2012; Hudson and Minea 2013; Sleuwaegen and Boiardi 2014).

Innovation can take a number of forms (product, process, service, or marketing) and is a complicated process that is influenced by numerous determinants and factors (internal and external). According to Maier (1998), these are as follows:

- Market structure and potential (e.g., monopolistic or oligopolistic markets as well as markets that are changing from a monopolistic to a competitive structure);
- Factors directly influenced by managerial decision making (such as price setting and advertising, product quality as influenced by the quality of the production process, technical know-how incorporated into a product via research and development, etc.); and
- Other aspects of the innovation diffusion process (e.g., spillover effects).

Here, the interaction between innovation activity's various determinants (internal and external), company creativity, learning, and innovation are bi-directional, synergetic, and lead to creating spillovers (Huber 1998; Stejskal and Hajek 2015). As described above, not every economic entity is always able to use their innovation potential and transform it into a successful innovation that can be put on the market. The individual actors within innovative processes encounter a whole range of barriers and limitations. Hadjimanolis (1999) has divided these barriers into internal and external (Table 4).

[5]This is the same in the Czech Republic, where the Operational Programme Enterprise and Innovation for Competitiveness is an important tool for supporting Czech entrepreneurs using EU funds from the EU's Programme 2014–2020. Its goal is to achieve a competitive and sustainable economy based on knowledge and innovation.

Table 4 Innovation barriers

Internal innovation barriers	External innovation barriers
Supply (difficulty when obtaining technological information, raw materials, or financing)	Resource related (insufficient internal resources, expert technical knowledge, managerial time)
Demand (customer needs and their perception of the risk of innovation, or national/international market limitations)	System related (accounting and database systems)
Environmental (government regulations or anti-trust and other political measures)	Related to human nature (top management's attitude towards risk and risk-taking or employee resistance to innovations)

Source: Compilation according to Hadjimanolis (1999)

One of the initial problems faced by a specific innovating entity is the fact that many innovative plans fail in their beginning phase, and only a small percentage of the initial innovations are realized. The problem of implementing innovation has been dealt with by Maier (1998), who stated that innovation (or constantly updating and improving company products and activities) is of key importance for company survival in a competitive environment, where questions (and problems) concerning innovation processes are currently becoming more complicated and dynamic. Thus, the innovation management of individual enterprises must have an ever more rapid reaction to the most varied of needs (primarily the market's), and technically complicated products must be developed at an increasingly rapid pace. Likewise, individual financial resources must be utilized and distributed among research and development projects in the most effective way possible—in order to achieve economically successful results, i.e., a quick and easily commercialized innovation. In most cases, new products are introduced in global markets and thus face strong international competition. Therefore, companies—primarily their innovation management—must first comprehensively understand the innovation process and manage its individual phases (Maier 1998):

- Developing a new product (invention),
- Implementing a new product or process (innovation), and
- Disseminating innovation (diffusion).

The first phase, developing a new product, is a very dynamic and complicated process; nonetheless, the processes of implementing and disseminating the innovation are just as important, if not more so. The importance of a company managing these phases properly is depicted in Fig. 3, which expresses a hierarchical process for innovative activities and their associated costs.

Here, Maier (1998) demonstrates that even though roughly 40% of all research projects are successful from the technical perspective, only 22% have a chance of being economically successful and a remaining 18% have been terminated because they do not have the potential to be successful in a market environment. Therefore,

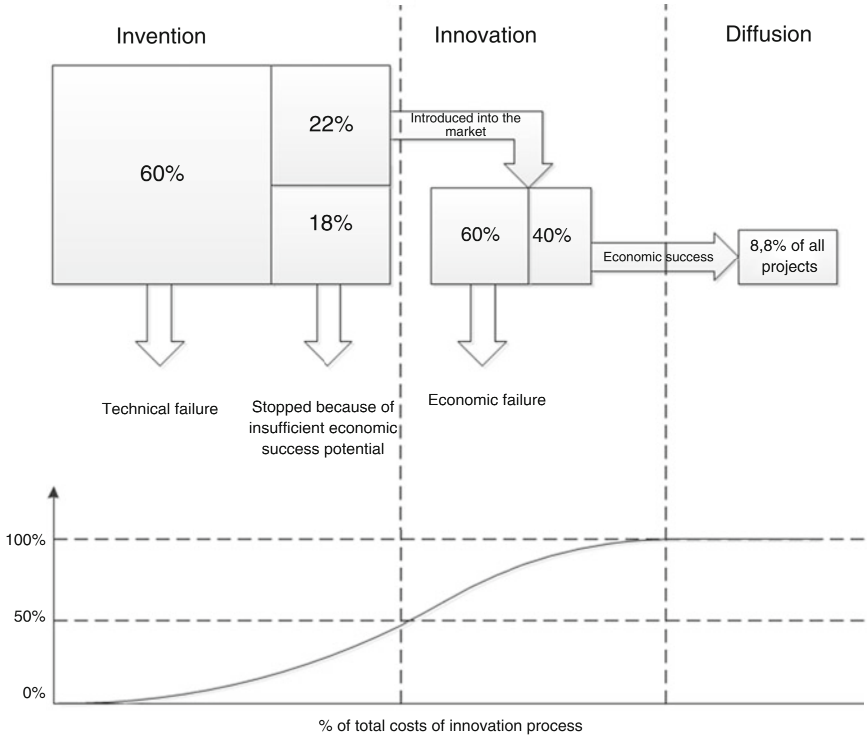

Fig. 3 Cascading outcome of innovation activity. Source: Adopted from Maier (1998)

roughly 22% of research projects are introduced in the market though only 40% of those are truly successful. On the other hand, more than 50% of all the costs for innovation are invested in the second and third phases of the innovation process, which underscores the importance of these phases.

Thus, the approach to innovations and their successful implementation has undergone a number of changes over time with the use of the most varied innovation models; the first innovation models were created as early as the 1950s and 1960s. Kotsemir and Meissner (2013) recorded seven phases for the development of approaches to innovation models, which are listed in Table 5.

However, the problem that most of the proposed models face are systemic deficiencies and failure (Tödtling and Trippl 2005; Hudec 2007; Blažek et al. 2014) leading to low levels of research and innovative activity (primarily at the regional level):

- Organizationally thin regional innovation systems, in which certain of the basic elements are missing or poorly developed—not enough innovative companies or other key institutions and organizations and a low level of clustering;

Table 5 The development of innovation models from a historical perspective

Developmental phase	Period	Authors of the main ideas	Innovation model	The model's fundamentals?
1	ca. 1950–1960	–	Technology push	Focused on linear processes
2	ca. 1960–1975	Myers and Marquis (1969)	Market (need) pull	Research and development based on customer needs
3	ca. 1975–1985	Mowery and Rosenberg (1979)/ Rothwell and Zegveld (1985)	The coupling model/the interactive model	The interaction of different functions/interaction with research institutes and the market
4	ca. 1985–1990	Kline and Rosenberg (1986)	The integrated model	The simultaneous process of feedback, the so-called chain-linked model
5	ca. 1990–1999	Rothwell (1992)	The networking model	Systems integration and networking
6	ca. 2000–2009	Chesbrough (2003)	Open innovation	Innovative cooperation
7	ca. 2010–	–	Open innovation	Focused on individuals and overall conditions that lead to being innovative

Source: Kotsemir and Meissner (2013)

- Locked-in regional innovation systems, which typically have above-average anchoring and above-average specialization on traditional, declining sectors with outdated technology;
- Fragmented regional innovation systems, which suffer from insufficient networks and knowledge exchange between system participants, resulting in insufficient collective learning and systemic innovation activities.

From the above, it is apparent that the innovation process is complex and that there has not yet been a suitable proposal for a single model of innovation. Individual economic entities are therefore faced with the decision of which approach and which determinants to use as part of their innovation process. Moulaert and Sekia (2003) created the territorial innovation model, which includes international authors' approaches to innovation models and which demonstrates that the given models have common elements despite the diversity of approaches (see below). Some of the models mentioned are the innovative milieu, industrial districts, regional innovation systems, local production systems, and learning regions; all of these models are based on the concept of local production systems.

Individual theories and approaches dealing with the problem of creating innovation are depicted in Fig. 4. The individual models demonstrate a noticeable shift in the

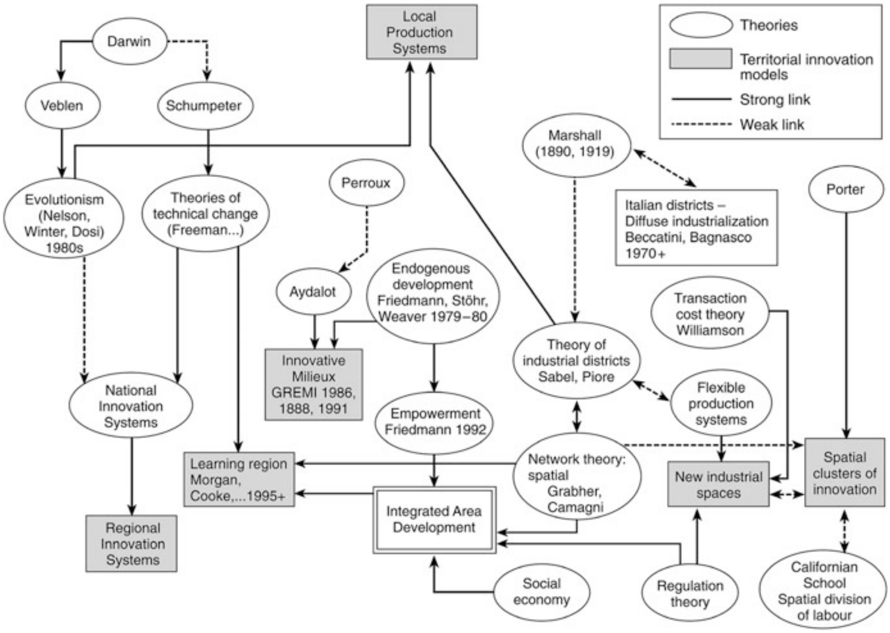

Fig. 4 Territorial innovation models. Source: Moulaert and Sekia (2003)

authors' approaches and opinions; these models' common elements are companies, knowledge, and public institutions (or the government) as well as the assumption of cooperation by individual entities and creating a favorable innovation environment in which public authorities have their role and tasks (even if often only marginal). The individual approaches agree on the following common determinants:

- Networking—suppliers and producers, subcontractors, etc. (Hansen 1992);
- Cooperation (Abramovsky et al. 2009);
- An innovative milieu (Moulaert and Sekia 2003);
- Knowledge (primarily tacit), the ability to learn, and creativity (Cassiman and Veugelers 2002); and
- Knowledge transfer and spillover effects.

These determinants of the innovative environment can then be found within cooperative chains or knowledge networks (e.g., the triple helix) and are able to effect them. It is thus clear that innovation and its creation, dissemination, and application in a market environment are linked to and influenced by knowledge and knowledge spillover effects, i.e., the static transfer of knowledge based on informal (non-business) relations within the innovation process of knowledge exchange (Table 6).

Table 6 The types of knowledge exchange in the innovation process

	Static (knowledge transfer)	Dynamic (collective learning)
Formal/traded relation	Market relations	Cooperation/formal networks
Informal/untraded relation	Knowledge externalities and spillovers	Milieu informal networks

Source: Cooke (2007)

It is clear that knowledge spillovers function differently in individual sectors or countries (or regions) and that individual economic entities achieve different results from implementing innovation. These differences and their causes are described in the next section of this paper.

2.4 Measuring Spillovers

In recent years, there have been a number of attempts at measuring knowledge flows and their related knowledge spillovers—both at the microeconomic and the macroeconomic levels (Fischer et al. 2009). However, the impacts of spillovers are usually identified in terms of quality whereas their scope and intensity is often only estimated because merely part of them can be duly assessed. The following effects have been successively investigated:

- Between individual companies (e.g., Mairesse and Sassenou 1991; Los and Verspagen 2000);
- Between the individual sectors of a national economy (e.g., Scherer 1994; Branstetter 2001); and
- Between individual countries (e.g., Park 1995).

The entire process of spillover effect emergence is naturally influenced by a number of factors; therefore, it is difficult to find one universal method for measurement. For this reason, it is possible to encounter various studies investigating different factors and their influence on spillover creation, the resulting innovation creation, improving company performance, and economic growth. Examples of some of the most frequently investigated factors are:

- Cooperation with diverse partners—universities, companies, customers, suppliers, or competitors (López et al. 2014),
- Providing public funding from national and/or European funds (Rodríguez-Pose and Di Cataldo 2014), and
- Investment into research and development (Hall et al. 2013).

Here, the relationships between the various determinants are mutual and synergetic and therefore cannot be investigated separately (Huber 1998). Researchers thus face a number of problems and risks (primarily the choice of data and the selection of variables) when they conduct individual measurements. The factors listed above are the ones most commonly selected to be input (independent) variables. The choice of suitable output (dependent) variables is more difficult. Nieto and Quevedo (2005) created an overview of studies that focuses on analyses that measured spillover effects between the years 1984 and 1999.

From Table 7, it is clear that over the course of recent years, the approaches to measuring spillover effects have changed and the authors have come to differing results both depending on the choice of factors as well as depending on the selected sample of companies, sectors, or even countries to be investigated.

Currently, it is also possible to encounter other studies that try to depict emerging spillover effects (Table 8), but once again different samples are used in most cases—companies, sectors, and countries. From the given conclusions, it is complicated to deduce a unified evaluative method, precisely identify spillover effects, and propose suitable recommendations for the creators of public policy. Therefore, it is necessary to conduct initial macroeconomic analysis at the level of individual countries and subsequent microeconomic analysis across the individual industries of the national economy.

Likewise, the analyses of spillover effects often disagree on how to create a suitable methods for measuring them. Cai and Hanley (2012) described quantitative evaluative methods using three approaches:

- Composite (innovation) indicators. These have been adopted by a number of institutions for evaluating innovation capacity at the national level (e.g., when evaluating a country's competitiveness, as conducted by the World Economic Forum). Systems of these indicators may include indicators such as input, output, the management of innovation and innovative activities, institutional measures, etc. Nonetheless, this method ignores the effectiveness of innovation systems, because input and output indicators are treated in the same way—this can result in economies with high innovative inputs and low innovative outputs achieving the same or even a higher number of points than economies with low innovative inputs and high innovative outputs.
- The econometric modeling approach. This is often used to analyze factors influencing national innovation capacity. This approach includes the steps of theoretical analysis through to mathematical modeling and econometric testing. In this case, the factor analysis is supported not just by econometric theory but also by empirical data and reliable results. Nonetheless, in econometric tests, one indicator is chosen to be the explained (dependent) variable, for example the number of patents, which naturally may not always completely explain innovation capacity or describe spillover effects. The results presented can then result in distortion.
- Data envelopment analysis (DEA) is an approach that is focused on analyzing the input-output efficiency of the independent decision making units under investigation—companies or even countries. The advantage of this method is the option of selecting more indicators to represent inputs and outputs. DEA analysis then depicts the ability and efficiency of individual decision making units when translating/transferring innovative inputs into outputs.

Table 7 An overview of spillover analyses from 1984–1999

Author	Sample investigated	Dependent variable	Independent variable	Results
Spence (1984)	Theoretical study	Net company profits	Production costs dependent on accumulated stock of technological findings and knowledge (the related company expenditure on R&D and on externally acquired knowledge—spillover effects)	Companies in an environment with pronounced spillovers have very weak motivation to invest in research and development
Jaffe (1986, 1988, 1989)	500 American companies in the manufacturing industry with expenditure on R&D and at least 10 patents created between 1969–1979	Patents granted, profits, the company's market value, gross company earnings	Investment into R&D, the knowledge base, technological possibilities, capital, market share	Spillover effects are significant for explaining variance in the dependent variables
Bernstein (1988)	Companies from the following sectors: food, paper, metals, machinery, aviation, electrical products, and chemicals in Canada for 1978 and 1981	Industry costs and production structure	Spillovers between and within sectors, outputs, factor prices	Spillovers result in lowering production costs in sectors, and they change production structure (they modify the percentages of individual factors)
Bernstein and Nadiri (1988)	American companies in the high-tech industries: chemicals, non-electrical machinery, electrical products, transportation, and scientific instruments between 1958 and 1981	Variable costs	Output, physical capital, the work force, company R&D capital, the R&D capital of other sectors	Variable costs decrease as a result of spillovers. Work and demand for materials are reduced as a reaction to spillovers
Levin and Reiss (1988)	The business units of American manufacturing companies	R&D expenditure, market concentration level	Spillover effects	The existence of significant differences in the degree of spillover generation between sectors and their productivity

(continued)

Table 7 (continued)

Author	Sample investigated	Dependent variable	Independent variable	Results
Bernstein (1989)	Companies from 9 Canadian sectors between 1963 and 1983	Production costs	Company output, factor prices, company R&D capital, the R&D capital of other sectors	All the investigated sectors were influenced differently by spillovers from R&D activity. The effect of external R&D factors on company costs depends on the specific source of the spillovers
Bernstein and Nadiri (1989)	48 American companies from the following industries: chemicals, oil, machinery, and tools	Company output	Physical capital, variable factors, company R&D capital, spillovers	The costs of companies profiting from spillovers decrease as a result of knowledge dissemination. This results in a change in demand for factors such as the reaction to the emergence of spillovers
Jaffe (1989)	29 American states (the individual states were the units for analysis)	The number of patents acquired by companies in the given states in the given technological fields over the given time period	State R&D investment in the given sectors and technological fields, R&D investment by universities in the given sectors and technological fields	Knowledge spillover from universities is relevant for establishing the number of patents acquired by companies. The geographic proximity of companies and universities working in the given technological field increases spillover effects
Henderson and Cockburn (1996)	Ten large pharmaceutical companies	The number of significant patents acquired by companies ("significant" means registered in at least two of the three main economic zones—	R&D expenditure of each investment program, the size of the overall R&D efforts expended by the company, the presence of economies of scale, the	Spillovers are significant for explaining company research results

(continued)

Table 7 (continued)

Author	Sample investigated	Dependent variable	Independent variable	Results
		Japan, USA, and Europe)	level of dispersion of technological interests, stock of prior knowledge, spillover effects	
Nadiri and Mamuneas (1994), Mamuneas and Nadiri (1996)	12 American companies in the manufacturing industry	Industry cost structure, productivity	The prices of variable factors, the amount of outputs, infrastructure financed by the govt., R&D financed by the govt., the prices of traditional factors, share capital financed by the given sector, capital stock financed by the state and developed in the given sector, capital stock financed by the state and developed in other institutions such as universities or independent laboratories	R&D capital significantly influences company productivity; it results in a decrease in costs and the growth of productivity; it also influences demand for factors; R&D financed by the govt. and developed within a given sector influences cost savings more than R&D financed by the govt. but developed outside the given industry; R&D financed by the govt. results in lowering costs while simultaneously lowering private investment into research; tax incentives stimulate investment into research and development
Mamuneas (1999)	American companies from six industries (chemicals, metals, non-electrical machinery, electrical appliances, transport, scientific instruments)	Overall sector output	Variable factors, physical capital, R&D capital, investment into physical R&D capital, R&D capital financed by the govt.	The emergence of positive effects connected to public investments into R&D

Source: Compilation according to Nieto and Quevedo (2005)

Table 8 An overview of select spillover analyses

Author	Analysis
Belderbos et al. (2004)	An analysis of the impact of cooperation with diverse partners (competitors, suppliers, customers, universities, and research institutes) in the area of research and development on company performance (work productivity and innovation productivity). Overall, 2056 innovative companies in the Netherlands were analyzed across the sectors of the national economy
Fischer et al. (2009)	An analysis of the influence of knowledge capital stocks on the overall productivity of factors on a sample of 203 regions from 15 European countries
De Faria et al. (2010)	An analysis of the significance of the influence of cooperation between companies on their innovation activity for a sample of 766 Portuguese companies from the processing industry and select service sectors
Chyi et al. (2012)	An analysis of the influence of internal and external spillovers on the performance of 92 Taiwanese companies in high-tech clusters
Block et al. (2013)	The causes of different outputs of innovative companies in the processing industry in 21 European companies were analyzed using findings from knowledge spillover theory
Isaksson et al. (2016)	An analysis of knowledge spillovers in supply chain networks, i.e., an analysis of the influence of customer innovation on supplier innovation. Overall, 203 American supply companies were analyzed

Source: Author's own work

From the description of these methods, it can be seen that data envelopment analysis is the model most suitable at the macroeconomic level that is used for this type of measurement in practice (e.g., Chang et al. 2016; Wanke and Barros 2016; Rakhshan et al. 2016). At the microeconomic level, the choice of methods for measurement is greater.

3 Conclusions

The main problem of modelling the knowledge spill-over effects of is that it is not possible to measure them accurately (Kaiser 2002). As stated in Krugman (1991): "*. . . knowledge flows are invisible, they leave no trace that would be measurable*." Therefore, researchers analyzing the knowledge spill-over effects have to rely on more or less accurate proxies. These variables are based on similarity or technological distances between firms, sectors, or regions. For example, firms engaged in similar research areas have similar educational structure of employees or patents in the same classes of patents are considered similar in technological space. The problem lies in the choice of proxies. Five fundamental groups of proxies (degree of patents' sharing, the share of researchers, geographical distance, technological distance rates, and the risk of imitation of innovations), which were used in many previous and above mentioned studies, can be analyzed. These studies are based on the hypothesis that the size of the knowledge spill-over effects depends on the intensity of information exchange between firms.

The importance of spill-over effect in economies is highlighted also in the context of regional and local development (Hajek and Stejskal 2010). Regional innovation systems (RISs) are currently applied in most of the regions and cities of the developed EU countries (Tödtling and Trippl 2005). The knowledge based networks among the firms (private subject), public administration (public sector), and knowledge institutions are crucial substances of the RISs (the elements of RIS are described by P. Cooke´s studies). It seems that there are the same elements in RISs as in industrial clusters (Stejskal 2011). Among the industrial clusters and RISs (both supported from public finance, see e.g. Oughton et al. 2002), there must exist connections and relations supporting the goals of both firms and public bodies (the goals of regional and local development). Although the RISs are increasingly used in practice, there is still a lack the methodology to measure their effectiveness at both regional and local levels.

Even though the cities and regions are increasingly regarded as important levels of economic policy, there have been very few attempts so far to investigate the impact of knowledge on local- and region-level economic development (Fischer et al. 2009). Therefore, the key role of knowledge spill-over effects and knowledge networks in contemporary regional and local development requires the design of new approaches to their modelling. The proposed monography has the ambition to make novel solution for better knowledge and spill-over effects management, which will ultimately increase their effectiveness.

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Part II
Evaluation and Assessment of Regional Innovation Systems

Assessing the Absorptive Capacity of Regional Innovation Systems: A Case Study of Lithuanian Regions

Vita Juknevičienė, Jurgita Mikolaitytė, and Diana Šaparnienė

Abstract Absorptive capacity is considered a main precondition for regional innovativeness. However, each region is unique, and analyzing its innovativeness requires an appropriate methodology. Within scientific discussion on the concept of the "region", most of the scientific research analyzing absorptive capacity tends to be conducted for large or highly developed regions. Small countries (such as Lithuania) are considered indivisible regional units; therefore, there is still a lack of research to provide specific tools that could be adapted to assess regional absorptive capacity in a small country. Taking this into consideration, this chapter's objective is to present a methodology for assessing RIS absorptive capacity that has been adapted to the context of regions in a small country (Lithuania). Its goals are as follows: (1) to explain the concept of absorptive capacity in the context of a RIS; (2) to provide the theoretical background for assessing absorptive capacity; (3) to present a methodology for assessing absorptive capacity in a small country (Lithuania); and (4) to explain the main results of the research, which was conducted for RIS in Lithuania using the methodology presented here. The scientific research methods used were an analysis of scientific literature, statistical analysis, and the SAW multiple criteria method. The research revealed that regions in a small country differ in their various indicators of absorptive capacity. Using the appropriate tool for assessment can also be a tool for identifying a region's strong and weak points as well as for promoting or interfering with the absorption of external knowledge.

1 Introduction

Modern society's welfare and the challenges it encounters require new ways of thinking and acting. It has been claimed that developed countries and regions will be built on diversity and variety (Matatkova and Stejskal 2013) and that innovation currently accounts for more than half of growth (Horibe 2016). Radical (absolutely

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new item, solutions) as well as incremental (improved, changed, developed items, solutions) innovations play crucial role in development process, both are important in this context. Therefore, new products, processes, and social initiatives (innovations in the broad sense of the word) are considered the quickest path to socioeconomic development and achieving competitive advantage. Innovation should not be an a single phenomenon nor should it occur in isolation; it must be a systematic process, made possible by the relevant participants and interconnected by various links (relationships, agreements, regulations, collaboration, networking, etc.), i.e. supported by an innovation system. Participants in the innovation system (individuals or groups, innovators or followers) should possess the appropriate abilities for operating, maintaining, and developing themselves as well as the system overall.

It has been stated that absorptive capacity increases the speed, frequency, and magnitude of innovation, i.e., that it helps to identify, evaluate, absorb, and diffuse new knowledge. This knowledge can be applied to the process of creating and exploiting innovation, it is useful for promoting innovative activity, and it contributes to generating competitive advantage (Lane et al. 2002; Mahroum et al. 2008; Abreu et al. 2009). Hence, absorptive capacity is considered the main precondition for a region's innovativeness. Participants in a regional innovation system (RIS) and their abilities are the main focal point for stimulating activities (knowledge access, anchoring, and diffusion), which leads to better understanding and breakthroughs. Developing regions (characterized by low industrialization and income levels, being averse to change and innovation, and having limited innovative capacity) especially should consider their innovation policy's main goal to be enhancing the absorptive capacity of existing regional participants (Moutinho 2016; Brown 2016). Innovative activities (those leading to innovations) are supported by two main capacities: absorptive capacity (the ability to attract good ideas or information from elsewhere) and development capacity (the ability to exploit absorbed knowledge to create and develop new products or services; Mahroum and Alsaleh 2012). First of all, specific types of knowledge (explicit and implicit) are needed to create or exploit an innovation. Here is where absorptive capacity plays a crucial role. Building a successful regional innovation system requires methods, means, and techniques to assess the existing situation of innovativeness and to identify options for solving the region's problems.

The way the concept of a "region" is perceived is related to how it is referred to as a unit for analysis (from a functional area to an administrative unit—macro-, micro-, meso-, sub-national, etc.; Dubois et al. 2009). Due to ongoing scientific discussion and debate devoted to the concept of the region and its features, the majority of scientific research analyzing absorptive capacity levels focuses on large or highly developed regions (macroregions). Small countries (such as Lithuania) are considered to be indivisible regional units; therefore, there is still a lack of research to provide specific tools that can be adapted for assessing the absorptive capacity of a small country's regions. However, Sleuwaegen and Boiardi (2014) emphasize that every region (even sub-national ones) has specific assets, unique capabilities, and industrial policies that make it different from other regions. Regions differ in the nature of their institutional structure as well. Therefore, regions should look for the best tools and ways to maximize their potential, which is connected to a region's capabilities for absorbing external knowledge as a main prerequisite for its development. Thus, because each region is unique, analyzing its innovativeness (knowledge absorption) requires an appropriate methodology for assessing the current situation and identifying possibilities for development. This research was based on the "regional" approach, where sub-national territorial entities (in Lithuanian case—counties) can be defined as regions (Bucar 1995; Freeman 2002; González-Pernía et al. 2012; Mineikaitė 2013) and presented as an important basis for a country's overall economic development and innovativeness. A regional innovation system (RIS) in this research is perceived as a network of cooperation among different institutions (public and private formal organization, situated in a sub-national territorial entity) based on organizational and institutional arrangements, relationships and contacts, contributing to knowledge access, anchoring and diffusion processes (Jucevičius et al. 2017).

The goal of this overview of theoretical and empirical research findings on absorptive capacity and literature on innovation is to develop a methodology for assessing an RIS's absorptive capacity in order to better understand the assessment of absorptive capacity for the regions of a small country (i.e., Lithuania). The goals are as follows: (1) to examine the concept of absorptive capacity in the context of a regional innovation system; (2) to describe the theoretical framework for assessing absorptive capacity; (3) to present a methodology for assessing absorptive capacity in a small country (Lithuania); and (4) to explain the main results of the research—conducted for Lithuanian regional innovation systems using the methodology presented here. The methods used for this scientific research were an analysis of the literature, statistical analysis, and the multiple criteria SAW method. The research on assessing the absorptive capacity of Lithuanian regional innovation systems included sub-national regions, i.e., Lithuania's counties (in accordance with the NUTS classification), on account of its being a small country.

2 The Concept of Absorptive Capacity in Regional Innovation Systems

Scientists and researchers in various areas (management, economics, sociology, politics, etc.) who analyze issues of knowledge management and innovation, economic development, and policy analysis have been investigating the preconditions that lead to innovativeness. Consequently, the concept of absorptive capacity and its importance for innovation systems have become a subject of research. Despite the fact that the regional dimension of absorptive capacity has been being analyzed more frequently in various studies (Narula 2004; Döring and Schnellenbach 2004; Uotila et al. 2006; Fu 2008; Mahroum and Poirson 2008; Thulin 2009; Abreu et al. 2009; Bergman and Usai 2009; Halkier et al. 2010; Kallio et al. 2010; Autant-Bernard et al. 2013; van Hemert and Iske 2015; Moutinho 2016; etc.), the systematic concept of absorptive capacity in regional innovation systems is still the primary subject of scientific debate.

Absorptive capacity, the ability to attract and absorb external innovative ideas, is primarily important because it enhances the prosperity, operational efficiency, and effectiveness of organizations or regions. Three main components that can help describe absorptive capacity better and more comprehensively can be identified based on the study conducted by Mahroum et al. (2008) on the use of the concept of absorptive capacity: the capacity to access knowledge and innovation through global networks; the capacity to anchor external knowledge from people and organizations; and the capacity to diffuse innovation and knowledge. All these components are necessary for making the knowledge absorption process possible and for maintaining it.

The first component of absorptive capacity, access to knowledge (information, human knowledge, intelligent goods, etc.), promotes the creativity of individuals and organizations. The regional capacity for accessing external knowledge depends on economic, social, and institutional factors. Economic activity—public and private investments into infrastructure, foreign trade, foreign investment, investment into knowledge, incorporation with multinational companies, etc.—is particularly important for developing regions because of the supply of resources for the process. Social factors (such as collaboration, international relations, the local innovation culture, confidence levels, and even social cohesion) play a decisive role in gaining access to external knowledge. The regional capacity for accessing global knowledge depends on clustering—the number of specialized, knowledge-intensive companies established in the region; appropriately equipped universities; technical, research, and knowledge centers; as well as other institutions that generate intellectual knowledge, manage knowledge flows, and accelerate learning and knowledge transfer.

The capacity to understand the accessed knowledge, to find the necessary knowledge, to identify its value, and to apply it to a particular activity is known as knowledge anchoring, the second component of absorptive capacity (Halkier et al. 2010). Knowledge can be anchored from the external as well as the internal environment by individuals, organizations, or specific participants in the RIS. Anchoring activities can be enhanced by interpersonal and organizational relations as well as by participation in local and global clusters and networks.

The last component of absorptive capacity (the capacity for diffusing knowledge) occurs when RIS participants transmit and transfer previously absorbed knowledge. New knowledge complements old knowledge at the individual, organizational, and regional levels. Providing the necessary resources, abilities, and motivation to do this is essential for this process (Zhuang et al. 2011). The result of knowledge diffusion is the creation of value added by improved, innovative activities.

Despite the emergence of global networks, knowledge (especially tacit) is transferred better among organizations that are situated in one geographical area. A regional innovation system should be thought of as a collaborating network of different public and private institutions (the system's static element) that is based on organizational and institutional agreements, relations, and links (the system's dynamic element); contributes to generating (initiating and creating), exploiting (importing and implementing new technologies and knowledge), and diffusing knowledge; and promotes regional innovativeness and competitiveness. The majority of innovative activities remains concentrated in regions, because they have a certain combination of elements—"institutional thickness," which consists of "a strong organizational infrastructure, high levels of interaction, a culture of collective representation, and shared norms and values which serve to constitute the social identity of a particular locality" (Chaminade 2011). Moreover, an institutionally thick RIS is usually found in more urban regions and has greater innovative capacities, saturation of support organizations, and high level of agglomeration when compared to a thin RIS.

Continuous absorption is dependent on the existence of RIS participants (institutions) as the primary source of necessary knowledge. It is possible for these participants to be specific industry organizations, groups of companies from several industries, universities and research institutions (Abreu et al. 2009), formal and informal educational institutions, institutions for public policy and public administration (responsible for all the country's regions—i.e., a national innovation system (NIS) with the purpose of ensuring RIS viability), and business and innovation support institutions (providing support to innovation system participants). All these types of institutions (even if they differ in scale, intensity, speed, and strength) are important for building a successful regional innovation system. Therefore, the Triple Helix model (Etzkowitz and Leydesdorff 2000; Etzkowitz 2007; Leydesdorff 2012)—which distinguishes the three main institutional groups of universities, industry, and the government—is most often used as the theoretical background for analyzing RIS institutional structure. The authors of this chapter would like to emphasize that there are other interpretations of this model; however, the authors have identified four main groups of RIS participants in compliance with the research logic—academic (universities and colleges), business (the manufacturing and service sectors), government (regional and national), and other organizations (business and innovation support organizations). All these institutions (with their particular functions, roles, and connections) are important for maintaining and reinforcing a RIS. One of their tasks is to empower and develop absorptive capacity.

Absorptive capacity is characterized by a dynamic dimension—it is able to change and develop. Developing absorptive capacity is a task not for one particular institution, but rather for the system as a whole. This is the reason why the development process needs to use its full available knowledge potential and create appropriate conditions for generating and implementing innovative ideas. According to Strube (2011), absorptive capacity is not only affected by regional innovation policy and its instruments, but it also affects knowledge absorption in neighboring regions. Consequently, internal regional capacity as well as the level of absorptive capacity in adjacent areas is important for the situation and development of regional innovativeness.

Moreover, the development of absorptive capacity requires the proper economic, social, cultural, and institutional environment within the RIS and the joint activities of all RIS participants (institutions). In the end, absorption and its development depends on the activity of institutions "swinging and spinning" in the triple helix as well as on the factors of the wider environment and the activities of its actors. In this way,

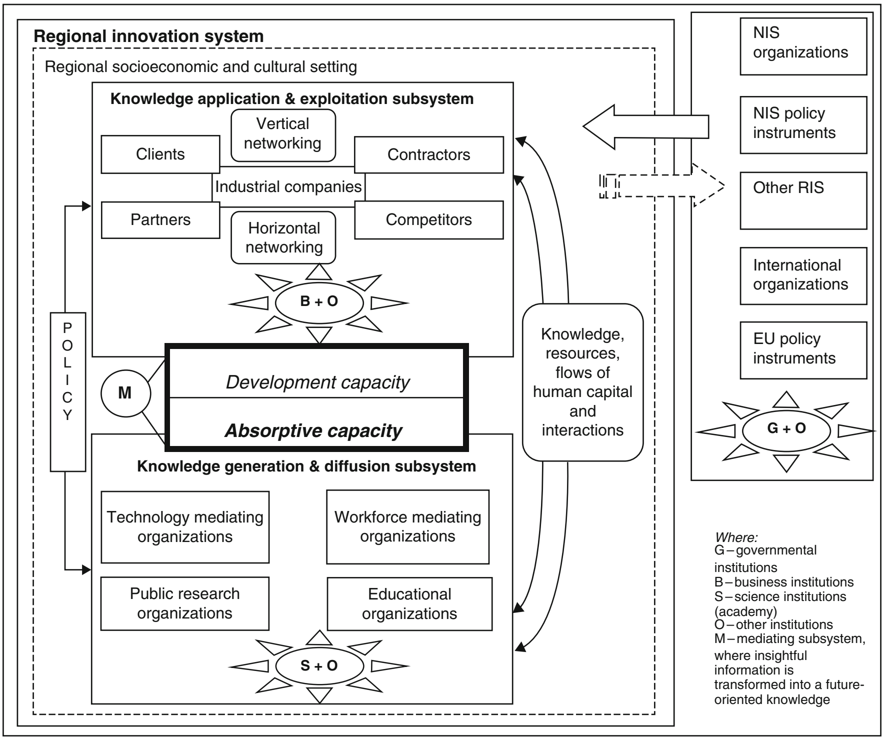

Fig. 1 Absorptive capacity in a regional innovation system. Source: Adapted from Uotila et al. (2006)

absorptive capacity becomes an important part of the mediating subsystem—one of the three subsystems of the regional innovation system (see Fig. 1).

The first subsystem is that of knowledge application and exploitation. Here, business institutions are the most active participants. They are in contact with other market participants (partners, clients, competitors, and contractors) and enable permanent vertical and horizontal networking. They can even adopt the best practices (via training, consultations, etc.) of the other institutions (such as clusters, associated institutions, and innovation support institutions) playing a role in this subsystem. First, this subsystem must possess development capacity in order to adapt the existing or acquired knowledge.

The second subsystem is that of knowledge generation and diffusion. This subsystem mostly embraces academia (educational and scientific institutions as well as public research institutions). However, interactions between academia and business institutions stimulate effective knowledge diffusion. Other institutions play the same role here, acting as intermediates between science and research institutions and organizations as well as being a resource for employees and technology. In a certain sense, the knowledge generation and diffusion subsystem stimulates access to knowledge, human resources, and technology. Absorptive capacity is particularly important for this subsystem because of the nature of its activities.

The operation of both subsystems would be harmed if they did not have both absorptive and development capacities (albeit different). This explains why these capacities comprise the third subsystem—the one for mediation. This subsystem helps transform information into knowledge; it is focused on future technologies and new ideas. The mediation subsystem is supported by the RIS's existing knowledge, resources, flows of human capital, and interactions (the circulation of people, knowledge, and production is mentioned in the Triple Helix model as well), which maintain the absorptive capacity and ensure that interaction continues. This particular interaction requires favorable RIS conditions, which are determined by the regional socioeconomic and cultural setting, i.e., the existing regional institutions and individuals working in them must be ready and motivated to implement these innovative activities, based on their economic resources. In order to strengthen the impact of this interaction on the region, the actions of government institutions must be implemented in the region (via political decisions that affect businesses, academia, and other institutions) as well as external stimulus.

The institutions that create external stimulus operate outside the region. These are international organizations, the national innovation system's institutions, and other regional innovation systems. At this point, the role of government institutions is distinguished by the effects on the RIS shown by policy and its instruments. The biggest contribution to regional innovation development is made by policy instruments, determined by a "top-down" policy. The National Innovation Policy is formed by the national innovation system and equipped with programs and funding. International organizations' programs and funding (e.g., those of the European Union, which is especially significant for its member countries) can be considered examples of such instruments. A regional innovation system is always associated with a large institutional system. The RIS may belong to it or maintain a stable relationship with it (via collaboration, programming, funding, or other activities).

Furthermore, there are other institutions at the national, international, or even local level that operate together with the government institutions. They may become important on account of collaboration activities: in order to ensure better access to additional resources for the RIS, to assist in knowledge anchoring, and to facilitate more effective knowledge diffusion between regions. Hence, only a region with the proper level of absorptive capacity can gain a favorable position within a national innovation system. Therefore, researchers have tried to design appropriate tools for determining absorptive capacity levels—for measuring and evaluating absorptive capacity.

3 The Background for the Absorptive Capacity Assessment Methodology

Assessment is considered to be the collection of evidence related to a particular research subject. This process makes it possible for researchers to measure the subject and its components in a specific field in order to determine the trend of its development, identify its strong and weak points, and even provide useful information for future improvement. In this study, assessing absorptive capacity is considered to be the collection of evidence (statistical data) on knowledge absorption (excluding the components of knowledge access, anchoring, and diffusion) in a small country's regional innovation system; the analysis of how it changes over time; a general review; and the identification of weak points for future development. This type of assessment and its results can be useful for all RIS participants. It can be especially important for policy makers and institutions supporting innovation to help with making reasonable decisions on implementing innovation policy, issues of continuation, and making changes via various tools for accelerating (or even decelerating) particular activities of RIS participants. Consequently, the assessment methodology must be valid and applicable in a regional context.

Studies that have been conducted in the field of analyzing regional absorptive capacity are based on quantitative research rather than on qualitative. Mahroum et al. (2008) conducted a statistical analysis of a system of parameters for the absorptive capacity of UK regions (the regions are compared according to calculated parameters). Fu (2008) focused on the statistical analysis of regional data for analyzing the relationship between absorptive capacity, regional innovation capacity, and foreign direct investment in China. Abreu et al. (2009) conducted comparative statistical analysis of regional innovation indicators and used the method of a case study for analyzing interfaces between regional innovativeness and absorptive capacity in the UK. A case study (using the qualitative Delphi method) was conducted for the Lahti region (Finland) by Uotila et al. (2006). The same region's case was previously analyzed using a statistical approach by Kallio et al. (2010). Castillo et al. (2012) have been studying Latin America as a region; they conducted statistical analysis and used the time series method (although the subject of their study was the affect of foreign direct investment and trade on knowledge spillovers). Time series analysis and statistical analysis were used by Onyeiwu (2011) for identifying how absorptive capacity and innovations are important for Africa's development (as a region). Moutinho (2016) applied statistical methods as well as artificial neural network modeling to the study of RIS structure (using a research sample of 158 regions in 18 EU countries) to identify how 'hidden' mediating variables (including absorptive capacity) may influence the overall effect of government R&D investment on economic and employment growth.

The analysis of studies on absorptive capacity assessment in innovation systems revealed a trend towards quantitative research. These studies are based on the fact that this phenomenon is able to be measured using quantitative scales and that the data is easy to collect, manage, and analyze by statistical methods. Such methods make it possible to examine a limited sample, and there is high probability that the results can be generalized for the whole population (Bitinas 2006; Juozaitienė et al. 2011). However, it was necessary to move away from research that provided data on absorptive capacity only at the organizational level (an organization-wide data and measurement system may be limited and not able to achieve the desired results). This research was based on those insights and studies that allowed absorptive capacity to be evaluated on a territorial (regional) basis. Since the term "region" by itself describes not only sub-national entities (e.g., Lithuania's counties) but also whole countries (e.g., Lithuania), this study has used previous studies of both levels (regional and national). Unfortunately, as was mentioned previously, there is still little research focused on the absorptive capacity of regional or national innovation systems and their assessment (moreover, most of them analyze developed countries or regions), in comparison to research conducted in the area of evaluating innovation activities.

Various techniques offered by INSEAD, WIPO (the World Innovation Index), and the OECD (but only for countries belonging to the organization) are used for identifying the level of innovativeness. However, it must be emphasized that the data presented highlight country competitiveness, and the regional aspect is revealed only on the basis of large countries (macro- and mesoregions; Kirstukas et al. 2013; The Global Innovation Index 2012. . . 2013; Main Science and Technology Indicators 2014). Although the element of knowledge absorption can be identified in those techniques, the data is presented at the national and international levels. In these cases, the national data are of a comparative nature, but it is difficult to identify regional disparities within a small country using these techniques.

The Innovation Union Scoreboard is one of the most important sources for assessing regional innovation. It gives a comparative evaluation of research and innovative performance in European Union countries and also highlights the strengths and weaknesses of research and innovation systems. This study is supplemented by the Regional Innovation Scoreboard every 2 years. Both types of studies outline their methods of measurement, which are more focused on three types of indicators—enablers, firm activities, and outputs (the total number of indicators that have been distinguished is 25, but only 12 of these are available at the regional level; Innovation Union Scoreboard 2013 2013; Hollanders and Tarantela 2011; Hollanders et al. 2012). Unfortunately, Lithuania (a small country) is considered and evaluated as a single region in both types of these studies; moreover, some of the indicators are not calculated at all because of the inaccessibility of certain data. Regrettably, both studies do not identify absorptive capacity as a separate research subject; rather, it is integrated into the concept of innovative activities. Therefore, the set of indicators that it is possible to apply to both assessing knowledge access, anchoring, and diffusion as well as to distinguishing their specifics requires adaptation to the regional level.

The INNO-Policy TrendChart reports are another important source for analyzing innovative performance. They describe and analyze the main trends of innovation policy at national and regional levels across Europe and provide information about programs not only at the international but also at the country level (including Lithuania). However, they essentially describe the change of priorities in innovation policy and review methods for supporting, managing, and modeling innovation (Iszák and Griniene 2012; Kriaučionienė 2008). This source is relevant to the aspect of the preconditions for developing absorptive capacity—political decisions (innovation policy and R&D), activities to promote supporting innovation, and collaboration networks (cross-sector partnerships, clusters, etc.; Iszák et al. 2013). However, the indicators needed to assess absorptive capacity are not identified here.

The organization NESTA (the National Endowment for Science, Technology, and the Arts), operating in the UK, also publishes important publications for supporting innovation. One such publication is the study on assessing absorptive capacity in regional innovation systems conducted by Mahroum et al. (2008). This study presents a set of 26 indicators for assessing absorptive and development capacities in the United Kingdom's regions. All indicators are connected to the capacity components (knowledge access, anchoring, diffusion, creation, and exploitation); therefore, it is possible to apply certain principles from this study to research in a small country. It is possible to criticize this study due to the inaccessibility of some data—the part provided includes only the taxed activity reports of international organizations (not all research institutions have access to them); the data for Lithuania is listed as that of a single region in these reports. Moreover, the given set of indicators is more appropriate for analyzing large, developed regions or countries. This does not comply with the needs of research for a small country.

Another study presenting a set of indicators for assessing absorptive capacity at the national level is the study by Mahroum and Alsaleh (2012). They proposed indicators according to the three components of absorptive capacity and, additionally, classified them as input or output. It is claimed that the factors of input and output are important, because they can affect attracting and naturalizing external resources of knowledge, such as foreign direct investment, a migrating qualified labor force, etc. This study was relevant to the research, but it was not possible to follow it too closely for the situation of a small country's regions, because of the level of application and the absence of certain data (some of this is not accessible or even calculated for Lithuania's regions).

Another study was conducted by a group of Lithuanian scientists, Jucevičius et al. (2011). This study was initiated as a research project to identify criteria for evaluating absorptive capacity and to verify an assessment methodology. This unique study provided a system of evaluation criteria for assessing innovative (absorptive and development) capacities at the national and sector levels. Again, this study cannot be taken as an authoritative methodological basis for an analysis of regional absorptive capacity in a small country, because it distinguishes the criteria for evaluation but does not give a particular set of indicators (each criteria can be interpreted or expressed by a number of indicators). Moreover, the given criteria do not emphasize the disparities between regions; therefore, they must be adapted to the particular context of the study.

In summary, the authors of the quantitative research, seeking to ensure its validity, have created a set of indicators for assessing regional absorptive capacity in the context of the small country of Lithuania (Juknevičienė 2015), substantiating the choice of indicators on the intersections between the studies mentioned here (links, coincidences, similarities), the possibilities for adapting the indicators to context of the regions to be analyzed, and the limitations of the statistical regional data in databases.

4 The Methodology for Assessing Absorptive Capacity in the Context of a Small Country (Lithuania)

In the classification systems used by international organizations, smaller countries are considered to be indivisible regional units.[1] However, as was mentioned earlier, the proportion of value added (as well as absorptive capacity) that is created differs not only for institutions but also for economic sectors or regions. Consequently, even the results of studies conducted for particular fields show important differences. Even in a small country, every region is characterized by social, economic, institutional, and cultural specifics; therefore, assessing absorptive capacity in a small country's regional innovation system requires specific methods and tools.

Lithuania is a European country, the southernmost of Europe's Baltic States, and it borders Poland, Latvia, Belarus, and Russia (the Kaliningrad region). Lithuania meets the criteria for being a small country [the area covers 65.3 thousand km^2, the population is 2.872 million people, and GDP was EUR 7.2 billion in 2015 (fifth from last among EU members)]. It was only added to the group of advanced economies by the International Monetary Fund (IMF) in 2015 (World Economic Outlook 2015). One horizontal priority that is outlined in Lithuania's National Progress Strategy, Lithuania 2030, is equal, sustainable development focused on reducing the disparities between the Lithuanian regions (Lithuania's Progress Strategy 2012). However, considerable national and European funds have been allocated—and regional policy has been implemented—to promote sustainable development across the country and reduce the currently existing social and economic disparities between regions (Puidokas and Daukaitė 2013). In this light, research on the absorptive capacity in Lithuania's regional innovation systems is even more relevant and significant.

All data in the reports on innovation that have been calculated for Lithuania consider it to be a single EU region. Due to objectives of this research, the sample should include smaller regions, than a country (Lithuania). Historically (from the sixteenth century till 2010) Lithuanian territory was divided to administrative units—counties. Now (in 2017) counties still exist as territorial units (but not administrative ones anymore). But this division is still important in Lithuania for the measurement of economic and social regional development. In 2017 there are 10 counties—the country's territorial sub-national regions—and they can be analyzed as NUTSIII regions.[2] Besides, in agreement with a number of Lithuanian researchers (Daugirdas and Mačiulytė 2006; Bruneckienė and Krušinskas 2011; Bruneckienė and Kilijonienė 2011), a county can be considered a regional innovation system (as a region—the system of institutions, situated in the territory, together with its internal

[1]NUTS are a common classification of territorial units for EU regional statistics. Lithuania is classified as a NUTSII region. All information concerned with innovations is collected at the country level without distinguishing regional indicators.

[2]Regions classified as NUTSIII have a population of 150,000–800,000 inhabitants, and their area must range within 10–83.5 thousand km^2. All ten of Lithuania's counties are classified as NUTSIII regions (Commission Regulation... 2014).

and external links). This approach was taken as a starting point, and it made it possible to collect the targeted data and to clearly identify and separate statistics. Due to the research objective of revealing the regional dimension of absorptive capacity, two regions (from ten counties) were selected as a sample. Abreu et al. (2009) and Uotila et al. (2006) proved that it is possible for success in innovation to be the basis for a case study (the analysis of a particular region). In order to avoid distortions in the regional analysis (by using entirely dissimilar regions), it was decided to analyze two regions that have social, economical, and infrastructural similarities but distinct differences in their innovative activities. Twenty-two criteria—reflecting geographical, social (demographic), economical, institutional, and infrastructural regional specifics (4, 4, 6, 6, and 2, respectively)—were identified and applied in order to determine the two region sample (Juknevičienė 2015). In accordance with the method of criteria selection,[3] two Lithuanian regions were selected: one region that has been successfully conducting innovative activities, and the other that has been conducting them with inadequate success (the Kaunas and Šiauliai regions of Lithuania, respectively). These are regions that have been looking to achieve economic growth, competitive advantage, and the development of their absorptive capacity in different ways.

As was mentioned above, the authors verified a set of indicators (the initial list for assessment consisted of 52 indicators) for assessing absorptive capacity in a regional innovation system (see Table 1). Even with high data allowances for publication and calculation at the regional level, this was based on findings, insights, and proposed sets of indicators from the previously mentioned studies and adapted to the context of Lithuania. All the regional innovation system indicators are presented according to the theoretical components of absorptive capacity: knowledge access (c_1–c_{18}), anchoring (n_1–n_{25}), and diffusion (d_1–d_9). The identification of the indicators' numerical estimates and their analysis revealed the existing states of absorptive capacity in the regional innovation systems and the way they changed over the selected time period in the small country of Lithuania.[4]

Over the course of the research (it was conducted first in 2014 and then again in 2016), the authors sought to include a time period of no $<$10 years (2004–2013). Unfortunately, it was only possible to obtain some of the statistical data[5] beginning

[3]The method of criteria selection is used to verify and identify the sample in the population by selecting units according to a set of criteria that has been determined by the authors. This method is useful when the population is quite big and researchers wish to compare results.

[4]There were assumptions concerning the regional dimension that were made in order to formulate certain indicators (to calculate their numerical estimates). However, it is possible to discard these assumptions and to calculate more accurately in the case of access to more detailed information sources that can provide detailed statistics for the small country's regions.

[5]All statistical data for the paper was acquired from two institutions—Statistics Lithuania (a government institution that collects, analyzes, and publishes statistical data and reports on the country's industrial, commercial, financial, social, etc. activities and the environment) and the State Patent Bureau of the Republic of Lithuania (a government institution that implements the legalization and state protection of industrial property (inventions, designs, brands, typography, etc.) and the functions of the central industrial property office within the EU and the European Patent Organization). For the first source, databases and direct communication with the institution's staff were used to get the necessary statistics. For the second, official monthly bulletins were analyzed.

Table 1 The set of indicators for assessing absorptive capacity in a Lithuanian RIS

	Indicator (unit of measurement)	Symbol
Knowledge A*c*cess	Households with internet access in the region (thousands of units)	c_1
	People using the internet daily in the region, aged 16–74 years (thousands of units)	c_2
	Number of enterprises using e-networks for purchases and orders in the region (units)	c_3
	Number of enterprises using e-networks for sales in the region (units)	c_4
	Currently active subscribers to public mobile telephone connections in the region (thousands of units)	c_5
	Length of the local roads (km)	c_6
	Number of planes that took off and landed in an international airport in the region (units)	c_7
	Number of passengers that arrived and departed from an international airport in the region (thousands of units)	c_8
	Number of service enterprises in the region (units)	c_9
	Number of organizations engaged in educational activities in the region (units)	c_{10}
	Number of organizations engaged in vocational, scientific, and technical activities (excluding R&D) in the region (units)	c_{11}
	Number of organizations engaged in financial and insurance activities in the region (units)	c_{12}
	Number of universities in the region (units)	c_{13}
	Number of colleges in the region (units)	c_{14}
	Industrial confidence indicator (%)	c_{15}
	Service sector business confidence indicator (%)	c_{16}
	The Regional Gross Domestic Product's share of National GDP (%)	c_{17}
	The Regional Industrial Value Added's share of Gross Value Added (%)	c_{18}
Knowledge A*n*choring	Number of specialists that graduated from regional universities (units)	n_1
	Number of specialists that graduated from regional colleges (units)	n_2
	Number of specialists that graduated from regional vocational schools (units)	n_3
	Percentage of citizens aged 25–64 with secondary education (ISCED 3–4) in the region (%)	n_4
	Percentage of citizens aged 25–64 having secondary education or greater (ISCED 3–6) in the region (%)	n_5
	Percentage of citizens aged 25–64 having higher education or greater (ISCED 5–6) in the region (%)	n_6
	Net migration within the region (units)	n_7
	Net international migration of the region (units)	n_8
	Labor force (aged 15–64) participation rate (%)	n_9
	Percentage of employees involved in R&D in the region's higher education and governmental sectors within the overall labor force (%)	n_{10}

(continued)

Table 1 (continued)

	Indicator (unit of measurement)	Symbol
	Percentage of employees employed in the region's service sector within the overall labor force (%)	n_{11}
	Percentage of employees employed in the region's manufacturing sector within the overall labor force (%)	n_{12}
	Expenditure on vocational training by the region's SMEs (EUR mil.)	n_{13}
	Expenditure on vocational training by the region's enterprises (EUR mil.)	n_{14}
	State and municipal budgets for students of the region's higher education institutions (universities and colleges) (EUR mil.)	n_{15}
	State and municipal budgets for students of the region's vocational schools (EUR mil.)	n_{16}
	The percentage municipal budgets provided for education in the region (%)	n_{17}
	Foreign direct investment per capita in the region (EUR)	n_{18}
	Foreign direct investment in vocation, scientific, and technical activities as a percentage of total FDI (%)	n_{19}
	Ratio of regional R&D expenditure in the higher education and governmental sectors to the region's GDP (%)	n_{20}
	Expenditure on internal R&D by regional enterprises that introduced technological innovations (EUR mil.)	n_{21}
	Expenditure on external R&D by regional enterprises that introduced technological innovations (EUR mil.)	n_{22}
	Expenditure on the acquisition of facilities and equipment by regional companies that introduced technological innovations (EUR mil.)	n_{23}
	Expenditure on the acquisition of external knowledge by regional companies that introduced technological innovations (EUR mil.)	n_{24}
	Capital investment per capita in the region (EUR)	n_{25}
Knowledge Diffusion	The number of specialists aged 25–34 having graduated from regional universities as a percentage of the regional population (%)	d_1
	Number of applications for patents in the region (units)	d_2
	Number of patents issued in the region (units)	d_3
	Number of designs registered in the region (units)	d_4
	Number of enterprises that introduced innovations in the region per 1000 residents (units)	d_5
	Number of SMEs that introduced innovations in the region per 1000 residents (units)	d_6
	Regional value added at production costs (EUR mil.)	d_7
	Value added per employee involved in vocational, scientific and technical activities in the region at production costs (EUR mil.)	d_8
	National origin export as a percentage of regional GDP (%)	d_9

Source: Authors' own work

in 2005–2006 (when the collection began), and there is no data yet for 2013. In order to give an accurate depiction of the current situation of absorptive capacity, the time period of 2005–2012 (8 years) was selected for the analysis.

In addition, when the authors encountered limited data in their research, they used a polynomial trend function to calculate estimates for the missing indicators (in the very beginning or end of the period analyzed).[6] Research revealed dynamic change for particular factors affecting the general situation of regional absorptive capacity by analyzing statistical regional data (using the methods of grouping, systemizing, analysis and interpretation, and graphic visualization). This chapter provides just part of the research results, but most of the statistical data presented confirms the disparities existing between the regions. The sample is made of two unequal regions (carrying out innovative activities with success and with inadequate success), and the statistical analysis provided the opportunity to supply evidence of those differences and to identify the strong and weak points of knowledge absorption.

In order to determine the trend for the way absorptive capacity changes in a regional innovation system, the multiple criteria Simple Additive Weighting (SAW) method was used initially. This method made it possible to analyze and identify the directionality of absorptive capacity in the particular regions selected in the sample. It was possible to use the SAW method in this research for several reasons:

- It takes into account criteria that is difficult to measure or even immeasurable;
- It is easy to use when all indicators are maximized (even minimized indicators are easy to transform into maximized ones); and
- It reflects the essence of the multiple criteria methods—it helps combine primary factors of a very different nature (indicator values and weights) into a single generalized value (Podvezko 2011; Žvirblis and Zinkevičiūtė 2008) that plays a crucial role in this study's logic and methodological approach.

For calculating using the SAW method, Sj (SAW method criteria) is the sum of the values of the weighted indicators (Ginevičius and Podvezko 2008a, b; Kareivaitė 2012):

$$S_j = \sum_{i=1}^{m} w_i \tilde{r}_{ij} \qquad (1)$$

where w_i is the weight of the i-th indicator and $\tilde{r}_{ij}$ is the number of the measured values (the normalized value of the indicator).

Before normalization, it must be clear whether all indicators are maximizing (an increasing rate represents a good situation), because all indicators must be maximizing when calculating using the SAW method. In many cases, the indicator's

[6]A polynomial trend function is a suitable tool for calculating missing estimates when numerical data with some fluctuations has been provided. Missing estimates are calculated (predicted) according to the value of the statistical data series' coefficient of determination (R^2). The prediction is more targeted when R^2 is closer the value of 1 ($R^2 > 0.65$ for this calculation and predicting the missing estimates in this paper).

minimum estimate cannot be less than or equal to 0. When this happens in the table of estimates, there is a step that must be taken before normalization. According to Kareivaitė (2012), the estimate must be recalculated (moved) using the formula:

$$r'_{ij} = r_{ij} + \left|\min_{j} r_{ij}\right| + 1 \tag{2}$$

where: r_{ij} is the value of the i-th indicator, and r'_{ij} is the moved value of the i-th indicator for the j-th object.

According to the ideas of the authors that have been mentioned, "classic" normalization is performed by using the SAW method:

$$\tilde{r}_{ij} = \frac{r_{ij}}{\sum_{j=1}^{n} r_{ij}}, \quad \text{when} \quad \sum_{j=1}^{n} \tilde{r}_{ij} = 1 \tag{3}$$

According to the statistical data, a decision matrix must be constructed. The next step in normalization is the *normalized matrix*. The authors of this study have assumed that the indicators for all three components of absorptive capacity (knowledge access, anchoring, and diffusion) have equal significance and equal weights (theoretical analysis showed their interface and integrity). Assessing the indicator weights leads to the next step—formulating the *normalized weighted matrix* (the highest value of the Sj criteria indicates the best situation; Ginevičius and Podvezko 2008a, b; Podvezko 2011; Kareivaitė 2012; Jukněvičienė 2015). In this way, it reflects the state of the region's absorptive capacity and how it changes over the analysis period (the trend is depicted graphically).

The inaccessibility of certain data determined the basic list of indicators (36 indicators) for assessing absorptive capacity from 2008 to 2012. Only the indicators with all estimates (obtained for the entire time period or calculated using the polynomial trend function) were included in the basic list for calculating using the SAW method (some of the indicators needed to be eliminated; see Table 2).

After calculating the data for the basic list of indicators, it was necessary to present the results of the modified list of indicators. Thus, it was possible for the total number of indicators calculated for this modified list to differ from year to year. This depended on the existence of statistical data—all the indicators from the primary list of indicators were included in the calculations for the particular year if the data was available to the public (see Table 2). It was possible to identify changes in the estimates and dispersion by comparing the basic and modified results of the SAW method.

In summary, this empirical research (the analysis of statistical data and the use of the SAW method) allows researchers the chance to assess the actual situation in the particular regions of Lithuania and to see the dynamic change of social, economic, and institutional factors. The SAW method (comparing the basic and modified results for RIS absorptive capacity) identified differences in the actual situation and demonstrated how certain indicators impacted the final results (the state of absorptive capacity). It also helped to identify the trend for absorptive capacity's development.

Table 2 Variations in the set of indicators for assessing RIS absorptive capacity

The AC concept component	Knowledge access	Knowledge anchoring	Knowledge diffusion	Total
The set of indicators for the component (The primary list)	18 (c_1–c_{18})	25 (n_1–n_{25})	9 (d_1–d_9)	52
Indicators eliminated due to requirements for complete data (The SAW method)	5 (c_3, c_4, c_9, c_{10}, c_{11})	9 (n_{11}, n_{12}, n_{13}, n_{14}, n_{19}, n_{21}, n_{22}, n_{23}, n_{24})	2 (d_5, d_6)	16
The set of indicators for the component (The basic list)	13 (c_1, c_2, c_5, c_6, c_7, c_8, c_{12}, c_{13}, c_{14}, c_{15}, c_{16}, c_{17}, c_{18})	16 (n_1, n_2, n_3, n_4, n_5, n_6, n_7, n_8, n_9, n_{10}, n_{15}, n_{16}, n_{17}, n_{18}, n_{20}, n_{25})	7 (d_1, d_2, d_3, d_4, d_7, d_8, d_9)	36
The set of indicators for each year (The modified list)				
2005	13 (c_1–c_2, c_5–c_8, c_{12}–c_{18})	17 (n_1–n_{10}, n_{13}, n_{15}–n_{18}, n_{20}, n_{25})	7 (d_1–d_4, d_7–d_9)	37
2006	13 (c_1–c_2, c_5–c_8, c_{12}–c_{18})	16 (n_1–n_{10}, n_{15}–n_{18}, n_{20}, n_{25})	7 (d_1–d_4, d_7–d_9)	36
2007	13 (c_1–c_2, c_5–c_8, c_{12}–c_{18})	16 (n_1–n_{10}, n_{15}–n_{18}, n_{20}, n_{25})	7 (d_1–d_4, d_7–d_9)	36
2008	15 (c_1–c_8, c_{12}–c_{18})	19 (n_1–n_{12}, n_{15}–n_{20}, n_{25})	9 (d_1–d_9)	43
2009	18 (c_1–c_{18})	19 (n_1–n_{12}, n_{15}–n_{20}, n_{25})	9 (d_1–d_9)	46
2010	18 (c_1–c_{18})	25 (n_1–n_{25})	9 (d_1–d_9)	52
2011	18 (c_1–c_{18})	19 (n_1–n_{12}, n_{15}–n_{20}, n_{25})	9 (d_1–d_9)	46
2012	18 (c_1–c_{18})	19 (n_1–n_{12}, n_{15}–n_{20}, n_{25})	9 (d_1–d_9)	46

Source: Authors' own work

5 Absorptive Capacity in the Lithuanian Regions

The processes of accessing, anchoring, and diffusing knowledge do not occur on their own. They are affected by various social, economic, institutional, and even infrastructural factors at the regional and national levels. As mentioned earlier, the process of knowledge absorption needs maintenance. RIS participants can exploit the existing environment to enhance knowledge absorption—or, conversely, to present it as a reason to explain their failures. Consequently, the authors have presented data on dynamic change during the analysis period, trying to identify positive and negative issues concerning the development of absorptive capacity in the Kaunas and Šiauliai regions in the small country of Lithuania.

5.1 The Dynamics of Factors Affecting Absorptive Capacity in the Kaunas and Šiauliai Regions (2005–2012)

The capacity for knowledge access can be promoted by a relatively intelligent society with knowledge management skills (first, at the level of the individual) and an appropriate amount of communication infrastructure, which creates the preconditions for knowledge flows and the ability to acquire knowledge at the right time. The knowledge access analysis uses certain indicators (c_1, c_2, c_5 and c_8), which are identified as indicators representing the RIS's infrastructural (communication) environment (see Fig. 2).

A growing need for internet access was observed in both regions. The usage of ICT (internet and mobile connection) shows a high, stable trend in the Kaunas region. The sharp jump of passengers using the services of regional airports in the Kaunas region in 2010–2012 can be explained by the increase in international emigration from the Kaunas region (more than 29,000 residents of the Kaunas region left for foreign countries between 2010 and 2012). The airport's modernization could also have influenced this indicator. Internet and mobile connection usage in the Šiauliai region, which has a smaller population (the Kaunas region had 599,600 residents and the Šiauliai region had 295,800 in 2002), is relatively similar. The issue of low usage of the Šiauliai international airport is explained by its more industrial specialization and its being used in part by the military.

The institutional environment is also significant for knowledge access (c_9, c_{10}, c_{11}, c_{12}, c_{13}, and c_{14}). Institutional differences between the two regions can be seen (see Fig. 3).

Despite the fact that the number of universities and colleges in both regions remained relatively stable during the entire period analyzed (the Kaunas region had

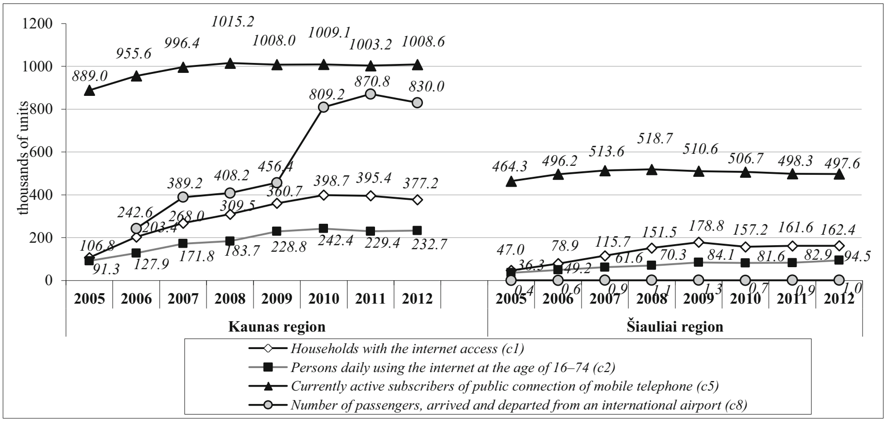

Fig. 2 The dynamics of infrastructural (communication) indicators for knowledge access in the Lithuanian regions for 2005–2012. Source: Authors' own work, according to Statistics Lithuania

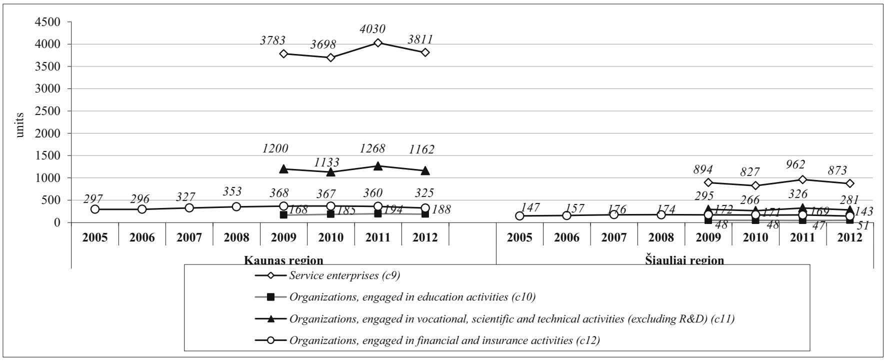

Fig. 3 The dynamics of institutional indicators for knowledge access in the Lithuanian regions for 2005–2012. Source: Authors' own work, according to Statistics Lithuania

5 universities—the number decreased by 2 after 2005—and 6 colleges, while the Šiauliai region had 1 university and 2 colleges—the number decreased by 1), the number of their other organizations differs. The number of service enterprises in the Kaunas region is 4.3 times higher than in the Šiauliai region (each year as of 2009). The number of nearly all types of organizations (except colleges and vocational, scientific, and technical organizations in the Kaunas region as well as universities and colleges in the Šiauliai region) decreased in both regions in 2012—to 6.24 and 10.35%, respectively. This change is mostly explained by the higher number of enterprises affected by economic difficulties due to a decrease in production demand, a more cautious attitude towards prospects for the Lithuanian economy on the part of businesses, and a decrease in society's confidence in the manufacturing and service sectors.

A tendency towards growth and a return to pre-crisis levels can be identified for knowledge access in both regions. The creation of favorable infrastructure for communication and institutions made a positive impact. However, the economic situation (the financial crisis, a decrease in the number of organizations, the amount of FDI and GDP, and an increase in emigration) noticeably harmed both RISes (especially in the less successful Šiauliai region).

A group of social indicators has been included that shows the preconditions for knowledge anchoring. The authors have presented some of these. Knowledge anchoring requires highly qualified human resources. Not only does this human capital need to be developed in regions, but it also needs to be maintained.

Qualified staff is able to acquire, understand, and anchor external knowledge. Education (though it must be at least secondary education) allows individuals to develop their own absorptive capacity. The structure of the population according to educational level (n_4 and n_6) makes it possible to review the readiness of regional human resources for anchoring knowledge. However, it is not enough to have qualified specialists in a region. To create value added from knowledge absorption,

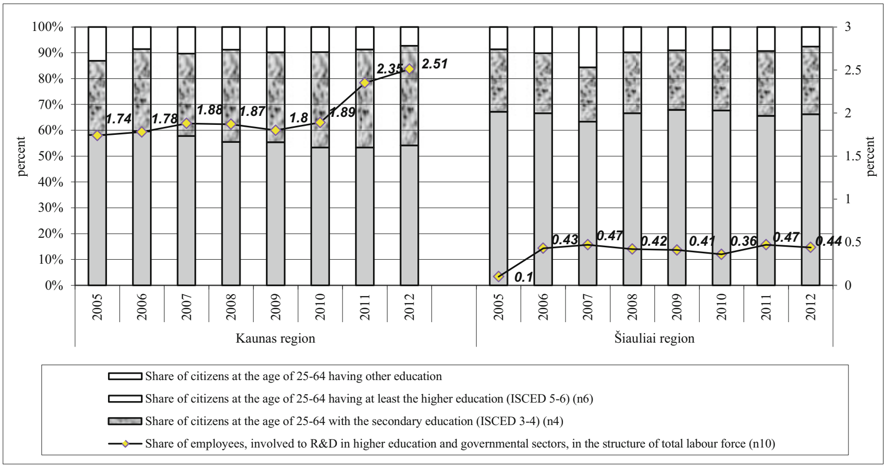

Fig. 4 The dynamics of the social indicators for knowledge anchoring in the Lithuanian regions for 2005–2012. Source: Authors' own work, according to Statistics Lithuania

these specialists must take job positions, which requires the exploitation of this capacity. The most promising activity for developing knowledge absorption is R&D (n_{10}).

Additionally, it should be mentioned that the number of university graduates (n_1) is declining in contrast to the number of graduates of colleges (n_2) and vocational schools (n_3); this is a new national trend, affected by the changing requirements of the labor market and national education policy objectives. Comparing the number of specialists that have graduated from universities, colleges, and vocational schools in the two regions, the Kaunas region surpasses the Šiauliai region 3.8, 2.7, and 2.2 times, respectively, during the period of 2005–2012. A similar regional tendency (a decline in the population aged 25–64 with higher education) was recorded within educational levels (see Fig. 4).

In the Kaunas region, there is a larger percentage of workers with a higher education diploma (bachelor's, master's, or doctoral degree); compared to the Šiauliai region, Kaunas exceeds this indicator by as much as 47% in 2012. However, this discrepancy can be explained by the difference in the number of higher education institutions in the region (the Kaunas region has 11 and the Šiauliai region has 3). Moreover, most students choose bigger cities (Vilnius and Kaunas) for their studies, because of better career opportunities for specialists, higher salaries, higher standards of living, or even because of the academic and scientific institutions' prestige. Furthermore, businesses and other organizations in the Kaunas region are more prepared to employ such specialists and will even provide them the opportunity to work on R&D activities (this is demonstrated by the level of the n_{10} indicator in the regions analyzed, which is 5.7 times higher for Kaunas than Šiauliai; see Fig. 4).

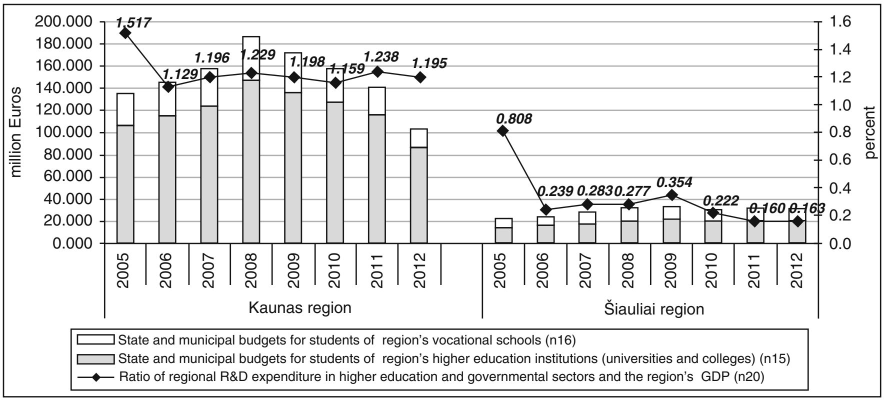

Fig. 5 The dynamics of the socioeconomic indicators of knowledge anchoring in the Lithuanian regions for 2005–2012. Source: Authors' own work, according to Statistics Lithuania

Consequently, the involvement of human resources in R&D activities can be identified as a field that deserves having significant efforts invested in its development.

As has been mentioned, a regional innovation system (and its participants) must create a favorable environment in order to preserve the region's most qualified specialists. Sometimes, it is not possible for businesses (especially SMEs) to help the system as a whole (they are more interested in organizational preservation). Therefore, state and municipal authorities provide support and funding for developing qualified human resources in regions (n_{15}, n_{16}, and n_{20}; see Fig. 5).

There is a very noticeable discrepancy between state (national) and municipal (local) investments for training specialists. This corresponds to national-level political policy (that complies with the position of employers) to stop funding the training of so many specialists with university education and to pay more attention on non-university higher education institutions—i.e., colleges as well as vocational schools with a greater focus on cooperation with the business sector. Despite this, funds from the state have been declining very rapidly (especially in the Kaunas region)—even for vocational schools. Therefore, academic institutions have been forced to look for other funding, acquiring it from national or even international programs and projects that provide research services for partners from the business sector. On one hand, this situation can be seen as a changing political attitude towards the system of science. On the other hand, it can be accepted as a challenge for developing knowledge anchoring and specialist competencies.

It should be mentioned that the Šiauliai region has very low expenditures on R&D activities (n_{20}), which proves that the RIS participants do not have enough capacity for investments in innovation; this complicates an academic institutions' situation when trying to obtain funds from regional sources. The Šiauliai region's potential for R&D activities could be enhanced by FDI (n_{19}) as a vital source for this region, which is lagging behind. However, the Šiauliai region's growth in FDI between 2009 and 2012 was not as fast as that of the Kaunas region (42% and 56%, respectively), and the level of FDI per capita was 4 times lower. FDI acquisition in the Kaunas region has been fostered by efforts of the region's center, the city of Kaunas; these funds were raised by joint venture and foreign capital companies, operating in such fields as manufacturing, real estate, wholesale and retail trade, financial intermediation activities, etc. This occurred because stronger market and RIS participants were looking for international partners and innovative solutions.

In general, it was possible to see non-significant recovery in the field of knowledge anchoring for both regions during the last 3 years of the period. However, this was negatively influenced by changes in workforce structure and the scale of emigration. This is a long-term challenge. Not only local and regional but also national government institutions are still trying to find solutions for these two problems even in 2016.

Knowledge diffusion can be described by several indicators. It is best represented by the number of intellectual property items (d_2, d_3 and d_4), the number of innovative RIS participants (d_5), and the value added that has been created (d_7 and d_8) as the output of intellectual activities and knowledge exploitation in an RIS.

There is a clear gap between the Kaunas and Šiauliai regions (Kaunas is the leader; see Fig. 6). The number of patent applications, patents issued, and registered designs do not exceed 5 in the Šiauliai region during the entire period analyzed, which means that the products developed by its RIS participants were not sufficiently original or the patent was refused on account of patenting procedures.

Registering intellectual property is a time-consuming, demanding effort and an expensive process; therefore, not all inventions or ideas are patented or registered. It is impossible to depict the trend for intellectual property registration, because the situation is strongly dependent on various factors, where the most important role is played by creativity. However, it is possible to identify a national trend: academic and research institutions (universities, institutes) have been providing an increasing share of patent applications. Such institutions evaluate the prospects for the patenting system; they undertake managerial activities for creating intellectual property as well as for commercializing it. This output can be enhanced by a high concentration of

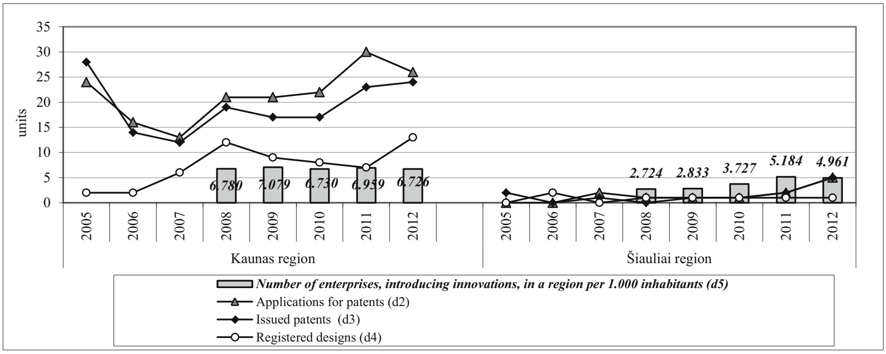

Fig. 6 The dynamics of the institutional indicators of knowledge diffusion in the Lithuanian regions for 2005–2012. Source: Authors' own work, according to Statistics Lithuania

innovative companies in the region in question (d_5). The number of innovative companies per 1000 residents is used to compare the two regions. Accordingly, the Šiauliai region has fewer innovative companies, but the number is growing (the change is 45.0% up from 2005), whereas the Kaunas region shows an indistinct decreasing trend. Again, Šiauliai is losing innovative companies at a lesser rate than Kaunas. In both cases, the number of innovative companies is declining—and not just because they have been suffering the loss of a great number of residents to emigration.

Other factors that reflect the state of knowledge diffusion are connected to value added (see Fig. 7). It is important to ensure that the level of value added that is created will grow not only at the regional, but also at the individual level.

When analyzing the change of value added per employee for 2009–2012, it was observed that this indicator increased for both regions—by an average of 1.36 EUR in the Kaunas region and 0.09 EUR in the Šiauliai region. According to the data, a direct correlation exists between individually created and regional value added (the same constant tendency can be noticed starting in 2009). However, this correlation does not exist for the Šiauliai region. On the contrary, value added per employee decreased even though the regional value added had a tendency to grow during 2010–2012.

It was only in 2012 that both indicators reached their pre-crisis levels in the Kaunas region. Unfortunately, the Šiauliai region is still behind its 2005 level. This may be related to that fact that the lowest level of labor productivity for recent years has been recorded in fields such as agriculture, forestry, and fisheries, and the concentration of such companies is rather large. The concentration of human resources in activities with low productivity does not promote knowledge diffusion—nor does it promote knowledge access or anchoring.

In summary, it can be emphasized that the process of knowledge absorption has been more sluggish for the Šiauliai region. This directly correlates with and affects

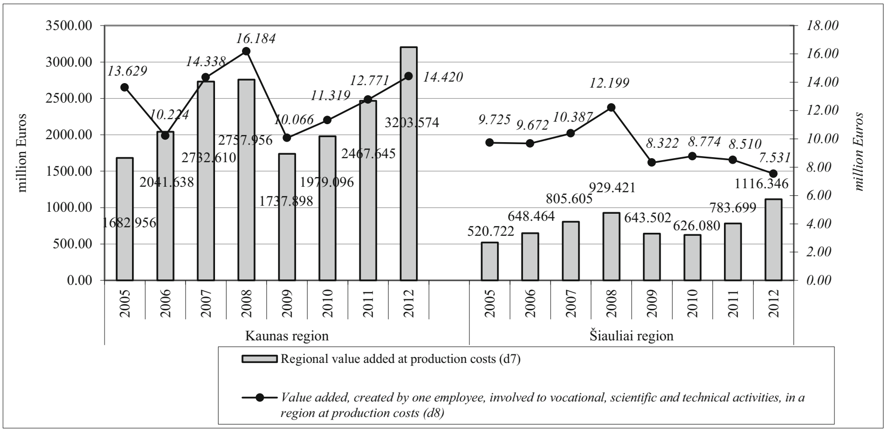

Fig. 7 The dynamics of the economic indicators of knowledge diffusion in the Lithuanian regions for 2005–2012. Source: Authors' own work, according to Statistics Lithuania

living standards, the region's societal welfare, and the speed and amount of regional development. At the same time, a general overview of the region for the entire period analyzed can be described only after seeing the results of the SAW method.

5.2 *The General State of Absorptive Capacity in the Kaunas and Šiauliai Regions (2005–2012): The Results of the SAW Method and Its Interpretation*

All 52 indicators analyzed were maximizing (their increase indicates the improvement of a situation within a regional innovation system). The necessary matrices were formulated for both the Kaunas and Šiauliai regions (decision, normalized, and weighted normalized matrices) to get a view of the state of absorptive capacity during the time period. In order to determine the differences in a situation, basic as well modified calculations were made (modified matrices included a different set of indicators, depending on the data provided). Following the requirement for the indicator's minimum estimate (not less than or equal to 0), recalculation (movement) of the particular indicators was made (c_{15}, c_{16}, n_7, and n_8 for the Kaunas region and c_{15}, c_{16}, n_7, n_8, d_2, d_3, and d_4 for the Šiauliai region). The first calculations for this study were made in 2014 and the second in 2016. The final results of these two studies differ because of certain changes in the estimates, which were connected to the mentioned movement and change in the national currency (the national currency was the Litas in 2014, now it is the Euro; therefore, some indicators were recalculated and the estimates declined by 3.4528, the Euro exchange rate).

Basic and modified indicator sums (obtained in normalized weighted matrices using the SAW method) made it possible to assign a ranking for each year of the period analyzed, 2005–2012 (see Table 3). Their numerical estimates were evaluated according to the SAW method's requirements: the higher value for Sj, the better the situation (1 indicates the best situation and 8 the worst). An overview of the results obtained is depicted in the graph, which shows the rankings (see Fig. 8).

It was observed that—irrespective of the type of calculation used, basic or modified—the worst state knowledge absorption in the Kaunas region occurred during 2005–2006 and 2008–2009. The year 2008 was nearly the peak of knowledge access, anchoring, and diffusion before the worldwide economic crisis. The Kaunas RIS had several higher education institutions; employees were more involved in intellectual activities (such as R&D, financial, vocational, etc.) in the region. Due to stable economic growth (2005–2008), RIS participants more actively used financial resources for development (human and material capital) and invested more into R&D activities and introducing new technologies and innovations. From 2009–2010, there was a sharp decline in all the region's areas caused by the financial crisis. It is not surprising that this also decelerated the process of knowledge absorption. This means that the indicators from the basic list are more connected to financial resources, whereas the modified list of indicators tends to represent

Table 3 The results of the SAW method for the Lithuanian Regions analyzed

Period	2005	2006	2007	2008	2009	2010	2011	2012
The Kaunas Region								
The sum for each year (basic)	0.10952	0.11653	0.12757	0.13657	0.11695	0.11970	0.13373	0.13942
Basic S_j	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
Rank	8	7	4	2	6	5	3	1
The sum for each year (modified)	0.11142	0.12112	0.12831	0.13249	0.11912	0.11197	0.12990	0.14568
Modified S_j	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
Rank	8	5	4	2	6	7	3	1
The Šiauliai Region								
The sum for each year (basic)	0.11245	0.12215	0.12797	0.13283	0.11946	0.11231	0.12955	0.14327
Basic S_j	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
Rank	7	5	4	2	6	8	3	1
The sum for each year (modified)	0.11662	0.12112	0.12831	0.14272	0.13817	0.22828	0.15055	0.16122
Modified S_j	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
Rank	8	7	6	4	5	1	3	2

Source: Authors' own work

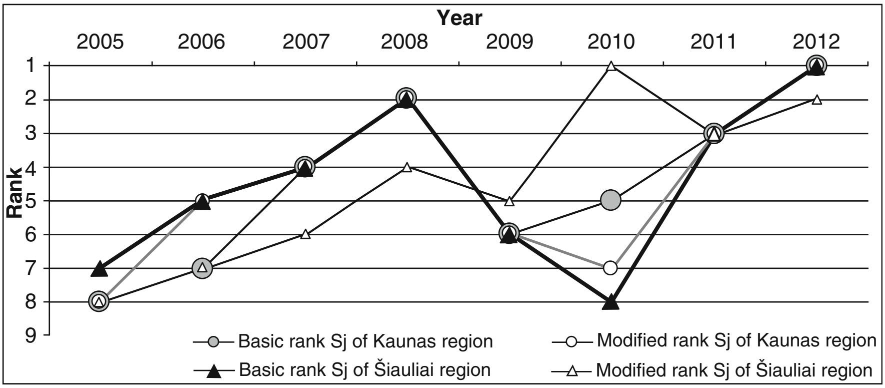

Fig. 8 The ranks of regions, obtained by SAW method. Source: Authors' own work

activities linked to development (innovative activities requiring qualified human resources who are able to operate flexibly in a changing environment).

The period of 2011–2012 was a period that showed the consistent recovery of knowledge absorption. It can be observed that 2010's modified rank is similar to that of 2005–2006, when the basic ranking was becoming more stable after the crisis. Again, this can be explained due to the composition of the two lists of indicators and specific data's effect on the analysis: one institution (Statistics Lithuania) calculated and publicized certain knowledge anchoring data (n_{13}–n_{14} and n_{21}–n_{24}) only for 2010. This means that the real state of an RIS's absorptive capacity in a small country can be assessed comprehensively and correctly only by using the entire set of 52 indicators—especially when they are concerned with innovative activities. A very serious situation at the national and regional levels in 2010 is clearly revealed by declining levels of GDP, FDI, and value added that was created; vastly increased emigration of qualified employees from the region; and the transfer of resources that normally would have been used for investment and training to repairing the damage caused by the crisis (or even survival in the market). These factors significantly affected the Kaunas region and its innovative activities (mostly reflected by the modified list of indicators). And yet both rankings confirmed the trend of absorptive capacity's development over last 3 years of the period analyzed.

A slightly different situation can be seen for the Šiauliai region. Even though the state of absorptive capacity indicates a stable developmental tendency in 2005–2008, the financial crisis marked the beginning of regional depression in the Šiauliai region for the period of 2009–2010. The previously mentioned deteriorating factors do impact the situation in the Šiauliai region—it is in last place for basic sums and rankings. Signs of recovery can be seen just after 2011. On the other hand, its modified sum and ranking in 2010 is the highest one during this period, which confirms the effect of certain indicators (concerned with innovative activities) on the assessment of the state of absorptive capacity. This can be explained two different ways. First, it could be assumed that the RIS's previous innovation performance was not very active, but the interface with the financial crisis pushed some participants to look for new ways of thinking and acting (supporting the development of absorptive capacity). The other explanation is based on the composition of the modified list of indicators. Even when the sum of the indicators' values includes more elements (52 indicators were included only for 2010 when calculating the modified normalized weighted matrix), the input of these indicators is significant (they do not reduce but rather increase the amount assigned to a single indicator).

The state of absorptive capacity in the Kaunas and Šiauliai regions shows an improving trend, since both (basic and modified) results show positive change in the last year (the trend of development). It is possible that this positive change will remain for a longer period of time, due to the recovering economic situation in Lithuania's national innovation system and a changing innovation culture in society.

On the other hand, this perception of positive changes is based on the formal approach—statistical analysis. It is very difficult to assess the extent of influence of financial and support activities initiated by the government and other institutions at the national and regional levels. These are able to transfer missing knowledge or make financial contributions to an RIS or its participants. The results of such activities are only able to be seen over the long term—even then, it is difficult to identify and statistically evaluate them because of the acquisition of many explicit and even tacit forms of knowledge. Therefore, scientific discussion on this issue remains the subject of future research.

However, positive change (the trend of development) can be influenced by RIS participants making political and institutional steps to improve the situation: developing innovative activities; promoting the processes of knowledge access, anchoring, and diffusion; paying more attention to infrastructure and communication development projects; implementing programs; supporting and maintaining innovative initiatives; and supporting staff mobility for developing and implementing absorptive capacity at the personal and organizational levels.

6 Summary and Conclusions

The concept of a regional innovation system's absorptive capacity is mostly based on general insights into this phenomenon based on its components of knowledge access, anchoring, and diffusion. However, the regional approach to this concept requires emphasizing the RIS's institutional structure. There are some variations on the institutional approach, but the most general approach is the Triple Helix Model. It explains the branches of an RIS (academia, business, government, and the institutions providing support) and the mechanisms connecting the components and mobilizing the efforts of RIS participants towards the same goal—enhancing a system's innovativeness by developing its absorptive capacity.

Due to theoretical and practical differences (different concepts of a "region" and it features as well as existing territorial, infrastructural, social, economic, and even institutional inequalities between regions/countries), it is very difficult to find a commonly accepted and general methodological approach for assessing RIS absorptive capacity. Each region requires extensive analysis (theoretical as well as methodological) for preparing an appropriate tool to assess absorptive capacity. However, the methodology presented here is an effective tool for properly assessing absorptive capacity in Lithuania's regional innovation systems. It reflects all three components of the theoretical concept of absorptive capacity (knowledge access, anchoring, and diffusion) and proposes a specific list of statistical indicators adapted for the context of a small country that in part has no data on innovations at the regional level. This list becomes applicable and measurable only because the multiple criteria SAW method has been used.

The empirical research using this methodology revealed that regions (even in a small country like Lithuania) differ in their various indicators of absorptive capacity, which leads to innovation. An appropriate tool (methods) for assessment provides not only statistical data for innovation policy makers and administrators, but it can also be used to identify the region's strong and weak activities promoting or interfering with the absorption of external knowledge, which is necessary to create and exploit innovations.

The results of this quantitative research confirm that the capacity to absorb knowledge is in a recovering state for the two Lithuanian regional innovation systems that were studied. The Kaunas region's lower level of knowledge access was influenced by continuously declining funding—necessary for education—and a low rate of confidence in manufacturing and the service sectors. Knowledge anchoring was reduced by large scale emigration and too few employees involved in R&D activities—even though the Kaunas region produces many highly educated professionals. Knowledge diffusion could be encouraged by innovative start-ups being established in the Kaunas region. Knowledge access in the Šiauliai region was negatively affected by the low institutional concentration (especially service companies). A small proportion of specialists with the highest level of education, who would be more engaged in R&D, could positively affect knowledge anchoring in the Šiauliai region. This could create a move towards a greater number of intellectual property items as well as more innovative companies creating more value added in the region.

This scientific and methodological approach could become the methodological basis for future studies in other small countries with comparable institutional framework and similarly limited access to data.

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Regional Innovation Systems Analysis and Evaluation: The Case of the Czech Republic

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Abstract Regional innovation systems (RIS) have become a very important regional policy instrument. This instrument is based on linkages among the region's institutions from the public and private sector. These linkages are very important because they provide an environment for the innovation process, which is the primary goal of the RIS. In this paper, we have defined and described the main characteristics common to every RIS. Knowledge of these characteristics allows us to create a new method to make it possible to analyze individual RISes. The goal of this chapter is to present a new method for evaluating RISes. The method must by easily applied in order for it to be used practically to map the development of the individual innovative systems in a region. The method is based on evaluating both qualitative and quantitative indicators and on applying WSA methods. The paper presents the application of this method on individual regions in the Czech Republic (NUTS3).

1 Introduction

Many regional policy instruments integrate elements operating on the principles of triple helix, especially: networking, industrial clusters, cluster initiatives, learning regions, innovation systems at the national and regional level and others. These systemic tools often incorporate other designated instruments. Thus, supporting their formation and their effective use should be able to produce a significant positive synergistic effect.

According to many studies related to innovation systems (for an overview of these studies see Tödtling and Trippl 2005), regions (defined as smaller than a national

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region and larger than a local unit) are considered to be the key to innovation systems working effectively for the following reasons (Cooke et al. 2000):

- First: regions differ according to their industrial specialization and their innovation performance (Howells 1999; Breschi 2000; Paci and Usai 2000).
- Second: knowledge spillover effects play the key role in the innovation process and are usually geographically bounded (Audretsch and Feldman 1996; Bottazzi and Peri 2003; Asheim and Coenen 2005; Stejskal and Hajek 2015).
- Third: the growing importance of "tacit" knowledge has been indicated (Polanyi 1966; Howells 2002; Gertler 2003; Matatkova and Stejskal 2013) for a successful innovation process. The latter is often influenced by interventions due to political representation or by public administration institutions. However, interventions due to political representation are more often seen at the regional or local level.

The regions are the most suitable area (space) for innovation. Next, it is necessary to define the framework and instruments that enhance the innovation process (Cooke et al. 1997; Morgan 2007; Sternberg and Arndt 2001; Antonioli et al. 2014). The original paradigm for national innovation systems was thereby temporarily[1] refuted and attention was transferred to the concept of the regional innovation system (RIS), which was introduced in the 1990s.

There are many scholars who analyzed the regional innovation systems and of course define it (for the overview see Cooke 2006). Majority of them is in line with Cooke's definition (Cooke 2006):

> RIS are useful for studying economic and innovative performance; they are also functional tools to enhance the innovation processes of firms. They do this by knitting together knowledge flows and the systems on which they rely, building trust and confidence in institutional reliability; and above all, they do it by generating institutional self-knowledge and a certain kind of collective dissatisfaction with the status quo. RIS comprise a set of institutions, both public and private, which produce pervasive and systemic effects that encourage firms in the region to adopt common norms, expectations, values, attitudes and practices, where a culture of innovation is nurtured and knowledge-transfer processes are enhanced (Matatkova and Stejskal 2011b).

Asheim and Coenen (2005; in Stejskal and Matatkova 2011b) divide the RIS this way:

- territorially embedded regional innovation systems,
- regionally networked innovation system,
- regionalized national innovation system.

Territorially embedded regional innovation systems are similar to grassroots RIS by Cooke (2006), the best examples of this type are networks of small and medium enterprises (SMEs) in industrial districts. These systems provide bottom-up,

[1]That it was temporary refers to the fact that, in the past 15 years, certain researchers have pointed to the significance of national innovation systems, even proposing the creation of national systems by using regional ones (e.g., Chung 2002; Guan and Chen 2012; Borrás and Edquist 2013; Lyasnikov et al. 2014) to the significance of national innovation systems, even proposing the creation of national systems by using regional ones (e.g., Chung 2002; Guan and Chen 2012; Borrás and Edquist 2013; Lyasnikov et al. 2014).

network-based support through, for example, technology centers, innovation networks, or centers for real service providing market research etc. (Storper and Scott 1995 in Asheim and Coenen 2005).

Regionally networked innovation system means that firms and organizations are also embedded in a specific region and characterized by localized, interactive learning. This type is very similar to network RIS by Cooke. We can say that a networked innovation system is a result of policy intervention to increase innovation capacity and collaboration.

Regionalized national innovation system is different from the two systems above in two main points. First, parts of industry and the institutional infrastructure are more functionally integrated into national or international innovation systems. Second, the collaboration between organizations within this type of RIS conforms more closely to the linear model, as the co-operation primarily involves specific projects to develop more radical innovations-based on formal analytical-scientific knowledge. Cooke named this type of RIS system dirigiste RIS. The concrete example of this system could be technopoles or science parks. For more information see Asheim and Coenen (2005b).

Braczyk et al. (1998), Asheim and Coenen (2005), Cooke (2006) divide the RIS according to the size of the region's incorporated companies, their financing methods or the territorial limits of the regional innovation system. It is also possible to divide regional innovation systems according to the degree of their infrastructure development within the region:

- RIS with hard elements but without any soft infrastructure elements,
- RIS with highly developed hard and highly undeveloped soft infrastructure,
- RIS with highly developed hard and partially developed soft infrastructure,
- RIS with highly developed hard and highly developed soft infrastructure,
- RIS with a developed network for knowledge diffusion.

Many other authors tried to create own divisions of RISes. There are two scholars many times mentioned in references (Braczyk et al. 1998; Asheim and Coenen 2005b). The first division is according to Braczyk (in Cooke 2006). He says that there are three types of RIS emerged (Matatkova and Stejskal 2011a):

- localist,
- interactive,
- globalized.

The localist type has few major public innovation or R&D resources, but may have smaller private ones. There will be high degree of associativeness among entrepreneurs and between them and local or regional policymakers.

The mix of public and private research institutes and laboratories in the interactive RIS is balanced, reflecting the presence of larger firms with regional headquarters and a regional government keen to promote the innovation base of the economy.

The innovation system in globalized RIS is dominated by global corporations, often supported by clustered supply chains of rather dependent small and medium-sized enterprises (SMEs). The research reach is largely internal and private in nature rather than public, although a more public innovation structure aimed at helping SMEs may have developed.

The second division is provided by Cooke (2004 in Cooke 2005) and it is based on the government dimension. There are three forms of RIS again:

- grassroots,
- network,
- dirigiste.

Grassroots is where the innovation system is generated and organized locally, at town or district level. Financial support and research competences are diffused locally, with a very low amount of supra-local or national coordination. Local development agencies and local institutional actors play a predominant role.

A network RIS is more likely to occur when the institutional support encompasses local, regional, federal and supranational levels, and funding is often guided by agreements among banks, government agencies and firms. The research competence is likely to be mixed, with both pure and applied, blue-skies and near-market activities geared to the needs of large and small firms.

A dirigiste system is animated mainly from outside and above the region itself. Innovation often occurs as a product of central government policies. Funding is centrally determined, with decentralized units located in the region and with research competences often linked to the needs of larger, state-owned firms in or beyond the region.

2 Characteristics of RIS

There are many definitions of the RIS. Cooke (2002) describes the RIS as the wide infrastructure that helps in the innovation creation processes realized in interactions among many entities. Hudec (2007) states that RIS (from systematic point of view) is defined as the system that stimulates the innovation abilities of firms in a region and aims at the economic and social development and the level of the competitiveness.

Stejskal and Matatkova (2011b) offer that we should try to imagine RIS as a framework which includes, according to Cooke (2002), two sub-systems:

- the knowledge application and exploitation sub-system,
- the knowledge generation and diffusion sub-system.

The first is principally concerned with firms while the second is mainly concerned with public organizations like universities, research institutes, technology transfer agencies, and regional and local governance bodies responsible for innovation support practices and policies. In reality, there may be some overlaps since firms conduct knowledge creation activities, especially where they have formalized R&D laboratories, and universities and public or private research institutes conduct knowledge application activities.

Cooke et al. (2000), Cooke and Memedovic (2003) in Tödtling and Trippl (2005) add to above mentioned subsystems another one. The third dimension is the regional policy because policy actors at this level can play a powerful role in shaping regional innovation processes, provided that that there is sufficient regional autonomy to formulate and implement innovation policies. Tödtling and Trippl (2005) further add that in the ideal case, there are intensive interactive relationships within and between these subsystems facilitating and continuous flow or exchange of knowledge, resources and human capital. On the other hand, there are several types of RIS problems and failures such as deficits with respect to organizations and institutions and lack of relations within and between subsystems (Matatkova and Stejskal 2011b).

Therefore, the RISs encompass (as already showed above) the institutions from both the private and public sector. These institutions we can call "basic components" of every RIS. Due to these necessary parts of the network we can determine whether there is some RIS in selected regions. The RIS existence and the evaluation (level of development) was discussed by many economists, i. e. Cooke et al. (1997), Cooke (2001), Doloreux (2002), Andersson and Karlsson (2004), Doloreux and Parto (2005). On the basis of their work we can define the basic components of the RIS, which we can summarize into three fundamental groups: (a) the core of the RIS, (b) auxiliary and complementary organizations and (c) infrastructure, institutions and technical support.

According to the above mentioned, the regional innovation system is composed of three fundamental layers:

(a) entrepreneurs,
(b) supporting organizations,
(c) environment and infrastructure.

In layer (a) companies, businesses and firms that are localized in the region are included. They should be focused on the creating of innovation, i.e. those who produce the market innovations, produce the patents, or spend public and private funds for research, development and subsequent development of innovations. In the layer (b) supporting organizations layer we include those organizations which helps and support the firms included in the first layer and provide complementary support services to them. The supporting organizations are primarily providers of knowledge, cooperating organizations for subcontracting, institutions for collaboration (they are the central part of industrial clusters and manage the cluster activities; Stejskal and Hajek 2012).

The layer (c) "environment and infrastructure" consists of three sub-layers (separate sub-system):

(a) Institutions making up the innovation environment (or ecosystem)

- Institutions forming the legal framework for business, preparing the strategic documents that support innovative business activities, innovation absorption, creativity, and development of innovation in firms;

- Facilitators providing facilitation of the entities in RIS. These organizations are established to support the industrial clusters or business networks births,
- Institutions and organizations that make up the convention, customs and usage in the ethics in business. They are often higher education providers (universities), often also entrepreneurial esprit chambers. These organizations support the social capital.

(b) Incentives and initiatives

- Public incentives to innovation creation and development or infrastructure suitable for innovations financially,
- Private incentives that have decided to financially support the ideas of firms that do not have sufficient investments or capital. we can include venture capital or business angels in this group.

(c) Hard and soft infrastructure

- Fixed infrastructure (industrial zones, technological parks, scientific research parks, innovation and high-tech centers, etc.),
- The infrastructure necessary for high-technology use (technological centers, testing and research centers or other scientific research centers and laboratories),
- Knowledge infrastructure (high schools, universities, and other knowledge organizations that allow horizontal or vertical transfer of knowledge between knowledge producer and firms recipients).

In all the layers we can find private organizations (firms), followed by public institutions (mostly regional governments or their representatives—regional development agencies) and other supporting public (often private or NGO) agencies, which are necessary components of a favorable innovation environment. Collaborating ties among the entities in the RIS are often referred to as triple (sometimes quadruple) helix (Leydesdoff and Etzkowitz 1996).

Every RIS should have, for example industrial clusters, the specialization (be focused on productions of something special). All authors cited above regard the RIS as a general system that is fixed into the socioeconomic environment of the region and integrated in the system that involves entities from the various sectors. We cannot completely agree with the general view of the RIS. We believe that the RIS should focus on some range of industries and this focus should be reflected by regional (public) policy, which is one of the RIS's subsystems. It will increase the efficiency of public policy and also the efficiency of financing because it cannot be assumed that the rule "all-does not fit-to all" will always be applicable.

The important components of each RIS are special activities resulting from geographical proximity, trust and willingness to cooperate. We cannot miss also the communication links between subjects of the RIS. These components determine the efficiency and quality of results arising from RIS existence in region.

3 Methods for RIS Analysis

There is no one shot method to be used universally for analysis and evaluation of the regional innovation system. Numerous authors have employed various methodologies when it comes to regional innovation system assessment. This piece of writing will take a critical review of some of the various methods that have been used to analyze the regional innovation system.

3.1 Participatory Evaluation

This method for assessing the regional innovation system is quite new and has not been widely accepted if we assess how credible it is (Diez and Esteban 2000). This method actively calls for allowing actors that are involved in the regional innovation system the chance to share their views and ideas when it comes to knowing how the regional dynamics of knowledge flow and innovation. The Participatory evaluation method is seen as an inner approach that does not rely on external factors or actors. This method is built on the premise that, regions are composed of numerous actors and stakeholders who are constantly interacting in the so when we want to get a clear understanding of how the system is working we need to involve all the active participants during the evaluation process. The active participation of the entities will ensure that outcomes achieved by the evaluation will be effective because it helps the regional actors in the process to perform the current evaluation and therefore come out with their results that can change the assessment into new ways of doing things.

The evaluation process is an important component of the learning process and this allows us to get a clear understanding based on the perspective of all the participants. It is precisely the very participants in the policy of economic development who contribute to understanding and learning about the processes of change underlying the program and to the development of a new awareness regarding the policy under evaluation (Diez 2001). Evaluation ceases to be an exercise of assessment where the predominant perspective comes from only one angle, that of the objectives of the policy designer as the only criteria for evaluation, and becomes an exercise stimulating the appearance of a learning process (Kuhlmann 1998).

We can summarize that the knowledge creation and transfer takes place inside and outside of the region (there is a so-called regional migration of knowledge). This knowledge "movement" helps to motivate the public organizations (regional governments, NGOs, agencies) to support these knowledge-based activities (described for example Finne et al. 1995; Diez 2001). This is the example of so-called participative development (if the funds are used and shared, we can called it participatory budgeting). The spill-over effects are learning during the co-operation and practice, and at the same time there is a significant cultivation of public policy that re-emphasizes the importance of knowledge as a production factor.

3.2 Interdisciplinary Methodology/Network Analysis

The interdisciplinary methodology has been described as the "appropriate tool" that can be used to evaluate network capital in the regional innovation system (Krätke 2002). Social network analysis is the mapping and measuring of relationships and flows between people, groups, organizations, computers or other information/knowledge processing entities (Krebs 2002). Social network or network analysis centers on the arrangement of relationships among actors and assess how resources are exchange among the various actors (Scott 1991; Wasserman and Faust 1994). The RIS is composed of numerous interactions among the various social entities and this result in the creation of network capital. So to evaluate the how this social network thrives, the interdisciplinary methodology can be used. Social Network Analysis has therefore proven to be useful because it enables the visualization of how people are connected, thereby enabling users of this methodology to find out how best people and institutions interact to share knowledge in the RIS. This methodology is built on the belief that social network are very important for the collaborating entities (Wassermann and Faust 1994) and society as a whole because of the end product that leads to transformation of the entities and society as a whole.

This analytical tool can be used to identify the vital properties of the RIS (Wassermann and Faust 1994; Jansen 1999). For a better and comprehensive understanding of networks and the participants involved, one needs to evaluate where the network is taking place (its location) and composition of actors that make up the network. These procedures provide us with a better understanding into the various roles and categories in a network—who constitute the connectors, where are the clusters and their makeup, who forms the center of the network, and who is on the periphery. This methodology can be relied upon in RIS when we endeavor to assess the rate at which knowledge and information flow across functional and institutional borders as in triple helix. It can also be useful when we want to find out who knows who (social relationships) and who might know what (expertise) in groups where individuals play key roles. One advantage of using this methodology in RIS is that, it provides it helps us to understand and simplifies the complex nature of interorganizational networks. It allows for comparative analysis by first of all mapping the already established network and its properties.

This methodology is able to generate data about network by using surveys. Since the network consists of industries and institutions, surveys will be able to determine the networked relationship by questioning the various actors involved. If the network structure is known, then an evaluation of its properties can follow to establish the extent of how they are interconnected and what role does the various actors play in the network can also be known. Haythornthwaite (1996) used the network analysis to study how information is exchanges in social networks and concluded that, the network analysis helped to create awareness of already established information exchange paths, and that information sources can act on information opportunities and alter information directions to improve the delivery of information services.

The overview of the case studies is presented in Table 1.

Table 1 Overview of interdisciplinary methodology/network analysis studies

Authors	Study regions	Objectives	Results
Fritsch and Kauffeld-Monz (2010)	16 German regional innovation networks	To analyze information and knowledge transfer	Strong ties are more beneficial for the exchange of knowledge and information than weak ties; broker positions tend to be associated with social returns rather than with private benefits.
Love and Roper (2001)	UK, Germany and Irish	To assess the location and network effects on innovation success	Inter-firm linkages do not affect the success of innovative activities, intra-group links have positive effect
Haythornthwaite (1996)	General	To study how information is exchanges in social networks	That information sources can act on information opportunities and alter information directions to improve the delivery of information services
Fritsch (2001)	3 German regions	To examine the co-operative relationships of manufacturing firms	Spatial proximity is obviously of particular importance for horizontal co-operation and for relationships to publicly funded research institutions
Ter Wal and Boschma (2009)	General	To shed light on the untapped potential of social network analysis techniques in economic geography To describe how these challenges can be met through the application of network analysis techniques, using primary (survey) and secondary (patent) data	Network analysis has a huge potential to enrich the literature on clusters, regional innovation systems and knowledge spillovers The choice between these two types of data has strong implications for the type of research questions that can be dealt with in economic geography, such as the feasibility of dynamic network analysis
Leydesdorff and Fritsch (2006)	Germany	Measuring the knowledge base of regional innovation systems in Germany	The configuration of medium-tech manufacturing can be considered a better indicator of the knowledge-based economy than that of high-tech manufacturing
Lee et al. (2010)	Korea Republic	Assess the effect of firm size on the effectiveness of innovation	Networking as one effective way to facilitate open innovation among SMEs

Source: Own

3.3 Cluster Analysis

Over the past two decades cluster analysis technique has been usage has increased (Everitt 1979; Gower 1967). Cluster Analysis also known as taxonomy analysis or segmentation analysis based on the techniques ability to produce classification (Everitt 1979). “Cluster analysis groups data objects based only on information found in the data that describes the objects and their relationships. The goal is that the objects within a group be similar (or related) to one another and different from (or unrelated to) the objects in other groups. The greater the similarity (or homogeneity) within a group and the greater the difference between groups the better or more distinct the clustering” (Nowak et al. 2008). According to (Romesburg 2004), cluster analysis refers to combinations of mathematical models that can be utilized to group objects that are similar into the same group. All objects have their attributes which might not be the same, but when has many objects, there is bound to be different attributes, so these can be arrange to for a cluster. Cluster analysis is the best and widely used research method when it is necessary to examine the similarity of the objects.

In the RIS, clusters analysis strongly focuses on the all the linkages and interactions that exist among various actors and people that results in the efficient creation of innovation, new products and services (Roelandt and Den Hertog 1999). The cluster in reference here is not assumed to be the same as happens in other forms of interaction they are very similar and linked in the value chain. Clusters can either be horizontal or vertical (cross-sectorial) network that consist of industries that are not the same but complementary firms that have a specific specialization that can result in the creation of innovation (Morgan 1997). The cluster analysis approach differs from other conventional research approaches because it takes into account collaborations and knowledge flow within the network (Rouvinen and Ylä-Antilla 1999). Comparatively, the conventional research approaches have focuses on networks that have homogenous firms producing same products, but the cluster have proven to be a reliable alternative because, it offers a different view in the RIS in the sense that, it places premium on the interaction-based theories of innovation which many authors now called “triple helix” (see Leydesdorff 2012; Vaivode 2015). This dynamic nature of the cluster analysis has made it a reliable alternative to the other traditional research approaches (Roelandt and Den Hertog 1999). Another reason that has made cluster analysis so important is its focus on vertical relationship and interdependence of actors who may not necessarily be similar firms or institutions (Roelandt and Den Hertog 1999).

Many studies have used cluster analysis methodology (Punj and Stewart 1983; Ketchen and Shook 1996; Feser and Luger 2003; Beuther and Sutherland 2007). The cluster analysis was used by Fesser and Bergman (2000) to study 23 national industry cluster template and the results proved that template clusters are useful to discover gaps and knowledge about extended product chains and therefore represents a useful first step in the detailed examinations of local cluster patterns. Arthur (1994) also used the cluster analysis to study the effects of Human resource system on manufacturing performance and turn over and concluded that “human resource

Table 2 Overview of cluster analyses

Authors	Study regions	Objectives	Results
Feser and Bergman (2000)	23 US manufacturing clusters	Using templates as an illustrative analysis of the manufacturing sector in a single US state	Template clusters help detect gaps and specializations in extended product chains and therefore constitute a useful first step in more comprehensive examinations of local cluster patterns
Almeida and Kogut (1999)	2 regions, Route 128 and Silicon Valley	investigate the relationship between the mobility of major patent holders and the localization of technological knowledge through the analysis of patent citations of important semiconductor innovations	Knowledge localization was found only in some specific regions (for example, Silicon Valley), the degree of localization varies regionally Mobility within inter-company cooperation enhances knowledge transfer (which is affected within regional labor networks)
Kronthaler (2005)	2 German regions (East Germany and West Germany)	Analyses the economic capability of East German regions compared with West German regions	Weak evidence that the economic capability of East German regions can be compared with West Germany. Development barriers have been observed: lower technological progress, low industrial activity and poor quality of transport networks
Baptista and Swann (1998)	248 manufacturing firms in the UK	To analyse whether firms located in strong industrial clusters or regions are more likely to innovate than firms outside these regions	A firm is considerably more likely to innovate if own-sector employment in its home region is strong; Congestion effects outweigh any benefits that may come from diversification within clusters
Sternberg and Arndt (2001)	11 European regions based on data from the European Regional Innovation Survey (ERIS)	To assess the absolute as well as the relative impact on innovation behavior of firm-specific (i.e. internal) factors on the one hand and region-specific characteristics on the other	Firm-specific determinants of innovation are more important than either region-specific or external factors; high-tech regions dominated by a small number of

(continued)

Table 2 (continued)

Authors	Study regions	Objectives	Results
			very large firms the innovation behavior of the smaller firms is more strongly influenced by regional factors than by factors internal to the firm
Poledníková (2014)	The Visegrad Four (the Czech Republic, Hungary, Poland and Slovakia)	To evaluate regional disparities in the case of the Visegrad Four (V4) countries in the year 2010	NUTS 2 regions with capital cities (Praha, Bratislavský kraj, Mazowieckie and Közép-Magyarország) still occupy the dominant positions in comparison with other regions in the V4; Significant disparities between clusters are visible, especially regarding the economic and innovative performance and territorial cohesion
Dümmler and Thierstein (2002)	Zurich (EMRZ)	Identification of the major manufacturing and service industries that are located within the EMRZ	The EMRZ can be regarded as a meta-cluster of several specialized economic clusters with regard to high-tech and high-services industries

Source: Own

system moderated the relationship between turnover and manufacturing performance”.

The overview of the case studies is presented in Table 2.

3.4 Data Envelopment Analysis

Data envelopment analysis or DEA for short has increasingly become a famous management tool since the method first came into practice (Charnes et al. 1978). Many studies have been done in relation to DEA (see Banker et al. 1984; Dyson and Thanassaoulis 1988; Seiford and Thrall 1990; Anderson and Peterson 1993; Banker 1993). According to Boussofiane et al. (1991), “DEA is a linear programming based techniques used for measuring the relative performance of organizational units where the presence of multiple inputs and outputs makes comparison difficult." The mathematical component of the DEA make it a useful tool that can be used to control and assess past activities and also useful for future planning. They have proved to be very vital for "ex post" evaluation of efficiency in management circles (Banker et al. 1984).

The DEA can also be employed to assess the performance of activities carried out by organization using output and input data (Lertworasirikul et al. 2003). In the knowledge based economies, universities produce knowledge using inputs in the form of labour (tutors), computers etc. to create output (knowledge). When one is given output and input data, it becomes easy to establish how the organization will perform using the DEA technique. They have become "powerful tools" that is used to measure efficiency and have since then been used to evaluate the efficiency of educational and research institutions in terms of their knowledge production functions (Lertworasirikul et al. 2003). The DEA is in the sense that it helps to characterize efficiency and inefficiency of decision making units (Zhu 2001).

To measure organization efficiency has been a source of worry for many years because there was no clear cut formula that provided the solution (Farrell 1957). As a mathematical model, it is not faced with deficiencies, (Andersen and Petersen 1993) have concluded that the DEA methodology has been very successful in determining the relative efficiency in decision making units but the method does not allow us to rank how efficient these units are. In addition Kao and Liu (2000) have also described the use of DEA to measure efficiency as very difficult because of its (DEA) use of complex economic and behavioral entities. This becomes more difficult when multiple outputs and inputs need to be aggregated in isolation to determine efficiency.

In a study to evaluate the comparative efficiency of ten Chinese third-party logistics providers 3PLs, Zhou et al. (2008) used the DEA approach and concluded that there was a decline in efficiency of Chinese 3PLs and this coincided with a steep decline in transportation activities as a result of the outbreak of the deadly SARS virus. The study also found out that technical expertise and sales opportunities directly correlate with operational efficiency of 3PLs at the same time, there was no direct correlation between the size of 3PLs and their performance. Abbott and Doucouliagos (2003) also used the DEA model to evaluate the efficiency of Australian universities. Their result proved that irrespective of the blend of input and outputs, Australian universities recorded high levels of efficiency relatively when compared one by one. In a study to measure the performance of 500 manufacturing firms in Turkey Düzakın and Düzakın (2007) used the DEA methodology and came out with the conclusion that during 2003 nine firms efficiently performed in Turkey, and out of these nine firms ranked among themselves. Furthermore, each of the firms in the analysis was ranked within each industry, and the results were that 65 firms were efficient among the industries.

The overview of the case studies is presented in Table 3.

Table 3 Overview of inputs and outputs in data envelopment analyses

Authors	Inputs	Outputs
Guan and Liu (2003)	**Impact of institutions** Innovation efficiency	**Decreasing returns to scale** Innovation capacity
Kutvonen (2007)	**Public funding** Public expenditure per capita **Education** Percentage of population with higher education **Research capacity** Total R&D personnel in the region, percentage of active population **Collaborative clusters** Number of identified potential clusters **Competent workforce supply** Participation of adults aged 25–64 in education and training (%) **Political support** Percentage of public funding used for regional Chen and Guan (2012)	**Regional competitiveness** Regional GDP per inhabitant growth rate, PPS **Socioeconomic wellbeing** Regional GDP per inhabitant, **Regional attractiveness** Private and public investment in region per capita **New knowledge** Applied patents to the European Patent Office per million inhabitants **Business growth** Regional employment growth rate (%) **Regional growth** Average annual growth rate of population (%)
Chen and Guan (2012)	**Technical development** Technological commercialization	**Regional growth** Improved performance of regional innovation systems
Fu (2008)	**FDI**	Positive absorptive capacity Regional economic growth Knowledge-based development
Guan et al. (2006)	Technological innovation capability	Competitiveness
Zhong et al. (2011)	**R&D activities** R&D expenditure R&D personnel	Number of patent applications Sales revenue of new products Profit of primary business
Liu and Lu (2010)	Funds Advanced human resources Basic human resources, and project time	License fee and royalty License fee/royalty Production investment
Zabala-Iturriagagoitia et al. (2007)	Innovation system performance	The higher the technological level of a region, the greater the need for system coordination

Source: Own
The bold means the title of the "group" of indicators

3.5 *Case Studies*

The case study methodology can also be used to evaluate the regional innovation system. The case study approach has been defined by many scholars (see below). Robson (2002) defines the case study as "a strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within its real life context using multiple sources of evidence". The case study as an approach can be adopted for a study based on the research questions and the objectives the researcher wants to achieve. The case studies are pertinent when the research being undertaken addresses either a descriptive question or an explanatory question (Shavelson and Towne 2002). The case study therefore seeks to provide a rich description and detailed explanation of the reason behind a complex phenomenon, and why they have happened or remained as they are.

The case study is a more appropriate methodology for evaluating the RIS because it provides more detailed information comparatively to the other methods. This information gathered from individual cases can be compared to find out why the differences exist. It also allows researchers to collect data from multiple methods such as surveys, interviews, and observations among others that can be validated through triangulation. The required data for the case study are likely to come from diverse and not a singular source of evidence (Denscombe 2003; Yin 2003).

Case study research assumes that scholars need to study the conditions and factors what appear in similar case studies to understand them more closely. The major limitation of case study approach is that it does not allow for generalization since findings are unique to the particular case as against the other cases. It however provides in-depth information and enough bases for improvement in the case under study.

Huggins et al. (2011) used the case study in their study on small firm-University Knowledge Networks using evidence from the United Kingdom and the US. They used this methodology to study 16 Small and Medium Scale enterprises (SMEs) from the UK and US (8 SMEs in the UK, and 8 SMEs in the US). They used the firm level case study to compare these firms and generated data from semi-structured interviews with Chief Executive Officers of these companies. Their study found out that, the bulk of firms were <10 years old, but their global customer base indicated that they were innovative firms as they have started exporting their products contributing to the regional economies supporting the empirical evidence that innovative firms are very important in economic development (Siegel et al. 2003).

The overview of the case studies is presented in Table 4.

3.6 Regression Models

Regression analysis is a quantitative research technique used research or studies that involve modeling and examining several variables, where the relationship consists of a dependent variable and independent variables (Mosteller and Tukey 1977). The regression analysis is mainly used to get a detailed understand of the relationship that exist between a dependent variable and an independent variables (Ai and Norton 2003). Regression analysis allows researchers to identification and classification of relationships among multiple components (Schneider et al. 2010). This technique has become a key to economic statistics and it's mainly used to achieve several

Table 4 Overview of case studies

Authors	Inputs	Outputs
Asheim and Isaksen (2002)	Place-specific local World-class knowledge	Strengthen competitiveness
Fritsch and Schwirten (1999)	Enterprise-university cooperation Public research institutions	Absorbing knowledge beyond the region Spatial proximity important
Asheim and Coenen (2005)	Knowledge base	Regional level innovation policy embedded in networks of actors
Acs et al. (2002)	Patents	Regional production of new knowledge
Koschatzky and Sternberg (2000)	Regional innovation potential	Network-building and regional innovation system
Doloreux and Parto (2004)	Regional innovation systems	Territorial dimension Role of institution
Love and Roper (2001)	1700 UK plants, 1300 German plants and 500 Republic of Ireland businesses	The effectiveness of R&D, knowledge transfer and network activities significantly influence the outputs of knowledge activities (confirmed in the UK, Germany). However, the results depend strongly on local conditions
Fischer et al. (2001)	Cooperation with government agencies	Innovation service/information service/ supervision service departments
Cooke et al. (2000)	Cooperation with intermediary institutions	Technology intermediaries, venture capital organizations, industrial associations
Romijn and Albaladejo (2002)	Innovation performance	Annual turnover of new products, products innovation index

Source: Own

objectives like predicting, forecasting, and finding the effect of one causal variable on another (Sykes 1993).

Regression analysis is preferred among statisticians because it allows users to make assumptions and it easily solves problems that are very complicated of because this method is very flexible (Oliver 2014). There are many types of regression techniques. The basic ones include linear regression, nonlinear regression, and the least squares method. According to Schneider et al. (2010), the linear regression is used to evaluate the linear relationship between a dependent variable and other independent variables.

3.7 Comparative Studies

Many authors believe that the RIS are specific entities that should be analyzed and evaluated individually. The findings should be compared with similar (and also foreign) regions. The researchers seek for the similarities (hits) or differences, and the analysis of the causes and consequences. The overview of the most important studies that dealt with RIS is given in the Table 5 below.

The overview of the case studies is presented in Table 5.

3.8 Qualitative Content Analysis

Qualitative content analysis has been defined as "a research method for the subjective interpretation of the content of text data through the systematic classification process of coding and identifying Themis or patterns" (Hsieh and Shannon 2005). Zhang et al. (2005) claim that "these three definitions illustrate that qualitative content analysis emphasizes an integrated view of speech/texts and their specific contexts. Qualitative content analysis goes beyond merely counting words or extracting objective content from texts to examine meanings, themes and patterns that may be manifest or latent in a particular text. It allows researchers to understand social reality in a subjective but scientific manner." There are some international studies what used the qualitative content analysis.

The overview of the case studies is presented in Table 6.

The practice shows that RIS analysis is not a simple process. Many studies have not been mentioned at all in this part of the publication, because they were too focused on specifics of individual regions and often cannot be generalized as the widely applicable methodology. Many of these studies tried to apply a combination of qualitative and quantitative approaches.

4 Application of the WSA Method for Regional Innovation Systems in Selected Regions of the Czech Republic[2]

Regional innovation systems are suitable and often used tool of regional policy also in the Czech Republic. The importance of these systems is even more emphasized after joining the EU. The significant decentralization of the regional policy was realized after 2004 and the emergence of RISs is good example of this trend (the same trend was noted in Western countries in past). The regional innovation strategies were created in all Czech regions (NUTS 3), i.e. documents in which the strategy how to create and promote RISs are contained. However, the emergence of regional strategies was left in the hands of the regional governments. This caused that the quality of strategies in different regions is different. It determines that the

[2]Methodological approach published in Nekolova, K., Rouag, A., & Stejskal, J. (2015). The Use of the Weighted Sum Method to Determine the Level of Development in Regional Innovation Systems – Using Czech Regions as Examples. *Ekonomický časopis*, 63(03), 239–258.

Table 5 Overview of comparative studies

Authors	Study regions	Objectives	Main results/lessons
Doloreux and Parto (2005)	11 Regions in the EU: Eastern and Central Europe (Baden-Württemberg, Wallonia, Brabant, Tampere, Centro, Féjer, Lower Silesia, Basque country, Friuli, Styria, Wales)	Explore theoretically key organization and institutional dimensions that provide a regional innovation system	Highly detailed info re different regions in terms of innovation performance potential for strong and weak regions
Sternberg (2000)	11 European regions (Vienna, Stockholm, Barcelona, Alsace, Baden, Lower Saxony, Gironde, S. Holland, Saxony, Slovenia, S. Wales)	Study the qualitative and quantitative determinants for innovation potential of any region and the innovative linkages and networks between different players	Innovation activities and business innovation process can be viewed as a network process in which business and interaction with other partners play a significant part
Asheim et al. (2003)	13 Nordic regions (Oslo, Stockholm, Helsinki, Gothenburg, Malmö/Lund, Aalborg, Stavanger, Linköping, Jyväskyla, Horten, Jaeren, Salling, Icelandic regions)	Explore the existence of similarities and differences between regional clusters of SMEs in different regions in the Nordic countries	Social networks are a major determinant of Nordic clusters. They help to gain social capital and trust. SMEs draw on available knowledge bases and innovate through science-driven R&D (e.g. in biotech). SMEs want to collaborate with global actors and acquire knowledge from them. SMEs now often collaborate with regional partners. (Doloreux and Parto 2005)
OECD (2001)	10 European regional clusters: ICT regional clusters in Finland, Ireland, Denmark, Spain, Flanders, and Netherlands; mature regional clusters: agro-food cluster (Norway) and construction cluster (Denmark, Netherlands, Switzerland)	Question the relevance of regional clusters in innovation policy	Regional clusters in every country/region have unique cluster blends; regional clusters are variation and selection environments that are inherently different; regional clusters may transcend geographical levels
Isaksen and Karlsen (2010)	2 regional industries in Norway (STI (marine biotechnology in Tromsø) and DUI (oil and gas equipment suppliers in Agder)	Analyse innovation and cooperation with universities in two regional industries in Norway	Universities play plays different roles in these two regional industries; The University of Tromsø is the main organization behind the development of the marine biotechnology industry in Tromsø and is an important knowledge node and source of biotechnology spin-offs

Source: Own

Table 6 Overview of qualitative content analyses

Authors	Study region	Objectives	Main results/lessons
Suorsa (2014)	93 scientific articles that use the RIS approach as their theoretical framework	Examine the concept of 'region' in research on regional innovation systems (RIS)	Regions and their boundaries are taken for granted in research; RIS research will gain new perspectives if the ontological basis is shifted to social constructivism
Shapira et al. (2006)	1800 Malaysian firms in 18 manufacturing and services industries	Assess the methodology and results of a project to develop sectoral knowledge content measures in Malaysia	Positive associations between technological innovation and at least one knowledge content variable are evident across all but four industries, although generally the results suggest that knowledge-based innovation is modest in Malaysia
Ceci and Iubatti (2012)	15 SMEs in the CISI consortium (Consorzio Italiano Subfornitura Impresa), operating in the automotive industry in Val di Sangro (Abruzzo, Italy)	Investigates the role played by personal relationships within networks	The coexistence of personal and professional relationships shapes a unique context that alters the usual dynamics of innovation diffusion; Honda Italia has a central role in professional activities

Source: Own

application in the coming years is not always good and efficient. The suitable conditions for the RIS emergence are created in all Czech regions; in some regions created RIS latently (clear evidences of RIS existence are missing).

In 2016, the national Czech government decided to create a central regional innovation strategy (RIS3) and in all regions there the regional innovation strategies were initiated. These new versions of regional RIS3 strategies are based on the national RIS3 strategy. The regional characteristics and specifics are taken into account by close cooperation (the national coordinators of RIS3 strategy collaborated with regional representatives). The RIS3 has to be the key conditionality for approving the operational programs and boosting the investments to the research, development, innovation and ICT (financed from EU Structural funds in programming period 2014–2020). After past experiences, we afraid that the strategies will lead to investment, but without noticeable positive effect (the goals of RIS3). Therefore, we need to develop methods that help to analyze the quality of the RIS, to support and to assess the regional innovation system development and level.

4.1 WSA Method Characteristics

The weighted sum method (WSM) is based on the principle of utility maximization (Fiala et al. 1997). This method has been simplified by using only a linear utility function. Calculations are then manageable without the use of specialized software. First, we created a normalized criteria matrix $R = (r_{ij})$ whose elements are obtained from the criteria matrix $Y = (y_{ij})$ using the transformation rule, (1):

$$r_{ij} = \frac{y_{ij} - D_j}{H_j - D_j}, r \in 0; 1, \forall i = 1, \ldots, pj = 1, \ldots, k \tag{1}$$

where r_{ij} is the normalized value for the i-th alternative and j-th criterion, D_j is the basal value, the lowest possible value an alternative acquires in the j-th criterion, H_j is the ideal value, the best possible value an alternative acquires in the j-th criterion.

Obviously, $r_{ij} = 0$ for the basal alternative, and $r_{ij} = 1$ for the ideal alternative (Chyna et al. 2012). When using the additive form of multi-criteria utility functions, the utility of the option ai is then expressed by (2):

$$u(a_i) = \sum_{j=1}^{k} v_j r_{ij}, \forall i = 1, \ldots, p \tag{2}$$

where v_j is the corresponding element from the weight vector, r_{ij} is the normalized value gained from (1).

Obviously, the alternative with the highest utility value is considered as a compromise. In addition, the WSM makes it possible to arrange all the alternatives with respect to their utility values (Chyna et al. 2012).

The option that reaches the maximum utility value is selected as being the best, or the results can allow the variants to be classified according to their decreasing utility values.

As seen in Eq. (2), the vector of criteria weights must be determined for calculating utility. In the context of this analysis, we use the Fuller's triangle method. The determination of weights is based on a pairwise comparison between criteria (Subrt et al. 2011). Because of the pairwise comparison, the number of comparisons is equal to:

$$N = \binom{k}{2} = \frac{k(k-1)}{2} \tag{3}$$

Each comparison may be performed inside Fuller's triangle. Criteria are numbered as serial numbers 1, 2,. . ., k. Users then work with the triangular diagram; the double lines formed by serial numbers are arranged in pairs so that each pair of criteria appears exactly once. The user indicates (by encirclement) which criterion is more important for comparing each pair. We mark the number of encirclements of i-th criterion as n_i. The weight of the i-th criterion is then calculated as:

$$v_i = \frac{n_i}{N}; i = 1, 2, \ldots, k \tag{4}$$

The main advantage of this method is the simplicity of the information required from users. If it is necessary to exclude zero weight, the number of encirclements may be increased by one with the condition that the denominator in Eq. (4) must also be increased accordingly.

4.2 *The Definition of RIS Characteristics*

Using study findings and detailed results coming out of references (e.g. Cooke et al. 1997; Andersson and Karlsson 2004; Doloreux and Parto 2005; Hudec 2007; Skokan 2010), Table 7 defines set characteristics for a "standard" form for the RIS.

If the set of characteristics cited above exists within one region, the authors agree that we can say that a regional innovation system exists in its basic form. At the same time, none of the authors mention the degree of development, precisely because the degree to which a characteristic has been achieved will vary from one RIS to another. Therefore, the degree to which they have been achieved increases the likelihood of positive effects being created when an RIS exists in a given region. For example,

Table 7 Regional innovation system characteristics

RIS layer	Characteristic	Abbr.
Companies	Existence of industrial clusters	A1
	Existence of specific innovating enterprises in the fields	A2
	Number of patents in the fields	A3
Support organizations	Existence of IPS	B1
	Existence of business incubators	B2
	Existence of regional development agencies	B3
	Existence of other support and complementary organizations	B4
Environment and infrastructure	Existence of an RIS not older than (or updated for longer than) 5 years	C1
	Existence of animators (actors) in the region and the fields	C2
	Existence of an organization shaping the professional community in the fields	C3
	Existence of professional societies or associations in the fields	C4
	Existence of public finance (funding) schemes	C5
	Existence of private finance (funding) initiatives	C6
	Existence of hard innovation infrastructure elements	C7
	Existence of technological infrastructure	C8
	Existence of knowledge infrastructure	C9
Relationships, Links	Existence of communication channels	D1
	Existence of projects confirming cooperation and synergy	D2

Source: Matatkova and Stejskal (2011)

these effects can be observed via an increase in regional GDP or a decrease in the unemployment rate.

However, many of these effects bring positive measurable results over the long term, which precludes the causal analysis of economic indicator changes. Consequently, it is not relevant to analyze the effects of the RIS directly.

The RIS characteristics that have been defined (see Table 7) represent criteria which will be quantified and then used to constitute the members of the criteria matrix used when applying the WSM. The quantification of the criteria must be done on the basis of descriptive analysis and information obtained from expert assessments or controlled interviews with experts on regional issues.

Particular characteristics were grouped on the basis of results derived from research findings on RIS layers. The characteristics cited above also contain those of the triple helix (these concern enterprises, support organizations, knowledge and public organizations as well as the environment and investment infrastructure). Relationships and links are two of the most important characteristics and should not be overlooked.

For the purposes of this analysis, the characteristics mentioned above are divided into three groups (see Table 8). The first two groups describe characteristics that are necessary and supportive in the region (physical infrastructure including industrial zones, technological parks, scientific research parks, innovation centers, etc.) and

Table 8 The weight assigned to each criterion based on the Fuller's triangle calculation

Criterion	v_i
I. Group: necessary characteristics	0.333
A2	0.222
B1	0.167
B2	0.028
C1	0.042
C2	0.042
C3	0.181
C5	0.083
C6	0.152
C7	0.083
II. Group: supporting characteristics	0.167
A1	0.499
B3	0.167
B4	0.167
C4	0.167
III. Group: qualitative characteristics	0.5
A3	0.3
C8	0.133
C9	0.3
D1	0.067
D2	0.2

Source: Authors' own calculations

institutions. The existence of these characteristics does not reflect whether the RIS is working or not. They only describe the physical substance of the RIS and can be used as a binary variable (whether present or not) or to quantify the number of institutions. The third group consists of characteristics that have a quantitative nature or contain characteristics whose quality significantly depends on the scope and quality of the individual RIS (typically, the number of patents). On the basis of their analysis, we can conclude that an existing RIS leads to cooperation, knowledge spillovers and a synergic effect and, thus, the creation of innovation. This type of RIS will have a positive impact as a result of the public interventions that have been created and supported.

It is logical that each characteristic will not have the same meaning for RIS existence and operation. We need to assign a weight to each characteristic inside each group; this weight provides information about the significance of each characteristic. The Fuller's triangle method was used to assign weights. Preference ranking was done by ten experts.

The expert evaluation of preferences makes it possible to determine the criteria weights and their appropriate grouping according to Eq. (4). The resulting weights are summarized in Table 8.

The sum of the weights assigned to groups I–III equals one, just as the sum of the weights within each group is also equal to one.

Next, the WSM was applied for determining the weight of each characteristic. The method's application will be divided into three progressive steps corresponding to the division of criteria from the three groups cited above. All the steps of the analysis process will correspond to the WSM as explained above.

For the case study (realized in 2015) we chose six regions[3] of the Czech Republic (NUTS 3 level):

- Kralovehradecky (KHK),
- Pardubicky (PK),
- Jihomoravsky (JMK),
- Moravskoslezsky (MSK),
- Liberecky (LK),
- Stredocesky (STC).

4.3 The Evaluation of Necessary RIS Quantitative Characteristics

Criteria included in the group of quantitative characteristics are listed in Tables 7 and 8. Descriptive analysis was provided by an expert appraisal from the creator of the Czech Republic's RIS in April 2015. The results are summarized in Table 9.

[3]The capital city is not included in any analyzed regions.

Table 9 Necessary quantitative characteristics

Region/ Criteria	A2[a]	B1	B2[c]	C1	C2[b]	C3	C5	C6	C7
KHK	6th place	Yes	Yes (2/9)	Yes	Yes (2)	Yes	No	No	Yes
PK	4th place	Yes, few	Yes (1/0)	No	Yes (6)	Yes	No	No	Yes
JMK	2nd place	Yes, many	Yes (5/33)	Yes	Yes (9)	Yes	Yes	Yes	Yes
MSK	9th place	Yes	Yes (6/78)	Yes	Yes (2)	Yes	Yes	Yes	Yes
LK	2th place	Yes	Yes (1/0)	Yes	Yes (2)	Yes	Yes	Yes	Yes
STC	6th place	Yes	Yes (3/16)	Yes	Yes (2)	Yes	Yes	Yes	Yes

Source: Authors' own calculations
[a]Order established under the World Competitiveness Yearbook 2015
[b]The number in parentheses indicates the number of animators (actors) working in the region
[c]The number in parentheses indicates the number of business incubators and the number of firms working in the region

When establishing a criteria matrix, it is necessary to give a point value to each indicator. Scoring was used for the sequence of the regions according to the assessment of each criterion. The poorest result was recorded as zero and the best as three. After point evaluation maximizing all criteria, it is possible to establish an initial criteria matrix where rows and columns correspond to Table 9:

$$\begin{bmatrix} 1 & 2 & 1 & 1 & 1 & 3 & 2 & 0 & 3 \\ 2 & 1 & 0 & 0 & 2 & 3 & 2 & 0 & 3 \\ 3 & 3 & 2 & 3 & 3 & 3 & 3 & 3 & 3 \\ 0 & 2 & 3 & 2 & 1 & 3 & 3 & 3 & 3 \\ 3 & 2 & 0 & 3 & 1 & 3 & 2 & 2 & 3 \\ 1 & 3 & 2 & 3 & 1 & 3 & 2 & 1 & 3 \end{bmatrix}$$

Criteria in this matrix are maximized; we can therefore determine the maximum value H and the minimum value D from each column j: $H = (3; 3; 3; 3; 3; 3; 3; 3; 3)$; $D = (0; 1; 0; 0; 1; 3; 2; 0; 3)$.

Using Eq. (1), the initial criteria matrix is transformed into a normalized criteria matrix. Elements of this matrix express the indicator value of each variant according to certain criteria:

$$\begin{bmatrix} 0.33 & 0.5 & 0.33 & 0.33 & 0 & 0 & 0 & 0 & 0 \\ 0.67 & 0 & 0 & 0 & 0.5 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0.67 & 1 & 1 & 0 & 1 & 1 & 0 \\ 0 & 0.5 & 1 & 0.67 & 0 & 0 & 1 & 1 & 0 \\ 1 & 0.5 & 0 & 1 & 0 & 0 & 0 & 0.67 & 0 \\ 0.33 & 1 & 0.67 & 1 & 0 & 0 & 0 & 0.33 & 0 \end{bmatrix}$$

The normalized criteria matrix makes it possible to calculate the indicator value cited in Table 9 in each region on the basis of Eq. (2). It is important for that calculation to determine the weighting vector v1; its compilation is based on values presented in Table 8: $v_1 = (0.222; 0.167; 0.028; 0.042; 0.042; 0.181; 0.083; 0.152; 0.083)$. The following results are those for the RIS development level in the selected regions according to indicator value calculations. These results are presented in Table 12.

4.4 The Evaluation of RIS Supporting Quantitative Characteristics

This group of characteristics was also analyzed using an expert appraisal and focused on their level of development in the selected regions. The completed results are summarized in the Table 10.

Once again, each criterion was evaluated using points and by following the same method used for the necessary quantitative characteristics. The results consist of a criteria matrix whose rows and columns correspond to Table 10:

$$\begin{bmatrix} 1 & 3 & 2 & 3 \\ 0 & 3 & 1 & 3 \\ 2 & 3 & 3 & 3 \\ 3 & 3 & 2 & 3 \\ 0 & 3 & 2 & 3 \\ 2 & 3 & 2 & 3 \end{bmatrix}$$

Because the criteria matrix is maximized, we can specify the maximum and the minimum values H and D for each column j: $H = (3; 3; 3; 3)$; $D = (0; 3; 1; 3)$.

Table 10 Supporting quantitative characteristics

Region/Criterion	A1	B3	B4	C4
KHK	Yes (3)	Yes	Yes	Yes
PK	Yes (2)	Yes	Yes, very little	Yes
JMK	Yes (3–5)	Yes	Yes, very little	Yes
MSK	Yes (10)	Yes	Yes	Yes
LK	Yes (1)	Yes	Yes	Yes
STC	Yes (6)	Yes	Yes	Yes

Source: Authors' own calculations

The following is the normalized criteria matrix formed on the basis of the transformation formula, (1):

$$\begin{bmatrix} 0.33 & 0 & 0.5 & 0 \\ 0 & 0 & 0 & 0 \\ 0.67 & 0 & 1 & 0 \\ 1 & 0 & 0.5 & 0 \\ 0 & 0 & 0.5 & 0 \\ 0.67 & 0 & 0.5 & 0 \end{bmatrix}$$

The calculation of the effects' values for regions resulting from Table 10 is computed according to Eq. (2) using the normalized criteria matrix. The value of each effect is then calculated according to weighting vector v_2. Values are compiled using Table 8: $v_2 = (0.499; 0.167; 0.167; 0.167)$. The calculation of the effect values gives the results summarized in Table 12.

Quantitative characteristics are concerned only with innovation infrastructure. On their basis, we can decide whether organizations that contribute and diffuse knowledge in each region exist and to what extent they exist; they make it possible to evaluate each region's innovation potential. Therefore, evaluating the use of this potential is made possible by the analysis of the third group of characteristics—the group of qualitative characteristics.

4.5 *Evaluating the Effect of the Existing Qualitative Characteristics*

The results of the experts' appraisal for the cited criteria's existence, their degree of evolution, all is summarized in Table 11.

The criteria were also point evaluated using the same methods. The result consists of a criteria matrix whose rows and columns correspond to Table 11:

Table 11 Qualitative characteristics

Region/Criterion	A3	C8	C9	D1	D2
KHK	37	Yes	Yes	Yes, few	Yes, few
PK	31	Yes, limited	Yes	Yes, few	Yes, very few
JMK	105	Yes	Yes	Yes	Yes
MSK	69	Yes	Yes	Yes, few	Yes
LK	27	Yes	Yes	Yes, few	Yes, few
STC	32	Yes	Yes	Yes, few	Yes, few

Source: Authors' own calculations

Table 12 Effect values within each group

Indicator value						
Criterion group/region	KHK	PK	JMK	MSK	LK	STC
Required quantitative characteristics	0.17986	0.16974	0.72676	0.37464	0.44934	0.35118
Supporting quantitative characteristics	0.24817	0	0.50133	0.58250	0.08350	0.41783
Qualitative characteristics	0.33200	0	0.70000	0.60100	0.33200	0.33200

Source: Authors' own calculations

$$\begin{bmatrix} 1 & 3 & 3 & 2 & 2 \\ 0 & 2 & 3 & 2 & 1 \\ 3 & 3 & 3 & 3 & 3 \\ 2 & 3 & 3 & 2 & 3 \\ 1 & 3 & 3 & 2 & 2 \\ 1 & 3 & 3 & 2 & 2 \end{bmatrix}$$

Because the criteria matrix has been maximized, we can specify the maximum H and the minimum value D for each column j: $H = (3; 3; 3; 3; 3)$; $D = (0; 2; 3; 2; 1)$. Next follows the normalized criteria matrix formed on the basis of the transformation formula, (1):

$$\begin{bmatrix} 0.33 & 1 & 0 & 0 & 0.5 \\ 0 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 1 & 1 \\ 0.67 & 1 & 0 & 1 & 1 \\ 0.33 & 1 & 0 & 0 & 0.5 \\ 0.33 & 1 & 0 & 0 & 0.5 \end{bmatrix}$$

The calculation of the effects' values in the regions resulting from Table 11 is computed according to Eq. (2) using the normalized criteria matrix. The value of each effect is calculated according to weighting vector v_3, and values are compiled using Table 9: $v_3 = (0.3; 0.133; 0.3; 0.067; 0.2)$. The calculation of the effects' values gives the results summarized in Table 12.

4.6 *The Assessment of RIS Level for the Selected Regions*

The previous sections have also assessed the effects resulting from existing RIS characteristics. This step consists of the overall quantification of RIS effects. This part analyzes the key instruments that have been assigned to each group of the regional innovation system characteristics described in Table 8. The vector of their weight is v_4, and its value is the following: $v_4 = (0.333; 0.167; 0.5)$.

The value of indicators within the selected regions obtained for each group of characteristics is summarized in Table 12.

Table 13 Overall indicator values for RIS development level

Region	Total value of the effect	Ranking
JMK	0.72676 × 0.333 + 0.50133 × 0.167+0.7 × 0.5 = 0.67573	1
MSK	0.37464 × 0.333 + 0.5825 × 0.167 + 0.601 × 0.5 = 0.52253	2
STC	0.17986 × 0.333 + 0.24817 × 0.167+ 0.332 × 0.5 = 0.26734	3
LK	0.35118*0.333 + 0.41783*0.167 + 0.332*0.5 = 0.35272	4
KHK	0.44934*0.333 + 0.0835*0.167 + 0.332*0.5 = 0.32957	5
PK	0.16974 × 0.333 + 0 × 0.167 + 0 × 0.5) = 0.05652	6

Source: Authors' own calculations

The overall values of the effects resulting from the existing RIS in the selected regions are calculated using the weighted sum of each effect. The values are listed in Table 13.

4.7 Conclusions

The level of RIS development was determined by the level to which the defined characteristics had been developed. The level of RIS development was depicted by determining values using the WSM and by the descriptive analysis summarized in Table 13.

The use of the WSM is simple in terms of calculating and obtaining specific values. On the other hand, the use of this method has some drawbacks in that it does not show the effects resulting from each characteristic. It only gives the accumulated value for the effects of each indicator. Furthermore, using such a method requires the weighting vector to be expressed numerically. The results derived from the use of the WSM can be authenticated by the use of another multi-criteria evaluation of the alternative. This method consists of the analytic hierarchy process (AHP) for validating results and is appropriate because it works on the same principle as the WSM, and its results are easy to compare. The use of the AHP method provides more detailed values than the WSM. On the other hand, the application of the AHP makes it easier to evaluate the degree of RIS advancement.

There are some limitations for generalizability of the results. The disadvantage of this approach is the lack of any discussion or international comparison of results (the comparable results on a wide platform are lacking).The results should be verified by another method. The adjustment of weights and subjectivity of criteria evaluation are the weakness of this method. The removal of these weaknesses can be subject to further research in this area.

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Identification of Intellectual Capital Performance Using Data Envelopment Analysis

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Abstract Our research approach is based on the belief that intangible factors (especially intellectual capital) are involved in the processes of territorial development as well as we express our conviction on the need to improve research tools for comprehensive public policy evaluation. The popular concept of intellectual capital (IC) has recently become a common performance measure both for organizations as well as for countries and regions. The authors have used specific approach—Data Envelopment Analysis (DEA) to evaluate intellectual capital in the Polish and Slovak NUTS 2 regions. The analysis aims to present the efficiency of chosen components of regional intellectual capital (IC). To verify the models, data on the Polish and Slovak regions are used for a dynamic comparison of their IC performance in 2011. The efficiency scores obtained show that the regions are significantly diverse in terms of their use of intellectual capital. Even though it is important to point out that the DEA methodology used for this evaluation still needs development, it is nonetheless very promising as a tool for measuring the efficiency of regional intellectual capital. This chapter attempts to contribute to the scientific discussion on methodology development in research on regional development factors. The practical dimension of this text may be to enrich the analytical implications for the paradigm of the public policies evaluation.

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1 Introduction: Conceptual and Methodological Background

The development of the world based on the use of knowledge and innovation requires continuous and consistent empirical and conceptual research. At the same time, one of the basic dimensions of the knowledge in development processes are social and intelectual capital (IC). The importance of these dimensions of capitals has been broadly analyzed in the perspective of the organization and its resources, in this case intangible. However, the relationship between the level of intellectual capital and the development of territories is also a growing area of research (Bradley 1997).

In the first period of IC concept development in the 1990s, the focus was mainly on microscale studies (Bontis 2004). At the beginning of the twenty-first century, the period of research extention into geographic spaces, as cities, regions or states began (Ståhle 2008; Cooke et al. 2005). Most often, this area of scientific interest involves the use of the regional endogenous potential and the pursuit of competitive advantages (Shiuma et al. 2008; Malhotra 2000). The classical definition of Bontis intellectual capital is interpreted as "hidden values of individuals, enterprises, institutions, communities and regions that are the current and potential sources of value creation" (Bontis 2004, p. 14). Simultaneously, from the point of view of the relationship between IC and the development of territories, Ståhle and Ståhle (2006) emphasizes that there are direct assembling and interdependence.

In addition, studies on the relationship between IC and socio-economic transformations in regions using different methodologies are relatively well developed in recent years (Etzkowitz and Klofsten 2005; Lerro and Schiuma 2008; Užienė 2014). The measurement and components of the intellectual capital in the territorial perspective were developed by the following authors, such as: Y. Malhotra—"Skandia Model" (2000), N. Bontis—"National Intellectual Capital Index" (2004), Stam and Andriessen—"Intellectual Capital Monitor" (2009), Lerro, Carlucci, Schiuma—"Knowledge Tree" (2008). At the same time, as noted by Ståhle, "intellectual capital is an abstract and complex concept that is difficult to identify and operationalize" (2008, p. 95). There are many approaches to the selection of variables in the creation of interpretative models for assessing intellectual capital. For example, public policy approaches such as the EU or the UN can be identified (Bontis 2004; Rodriguez and Martí 2006; Schiuma et al. 2008).This article contributes to the discussion of methods for measuring intellectual capital in the context of regional development.

The chapter presents a benchmarking study of selected components of regional intellectual capital using data for the Polish and Slovak regions (the EU's NUTS 2 level units) as an example. A linear programming based method, data envelopment analysis, is used to evaluate the regions' potential for development. The paper's main focus is to introduce the methodological aspects of using DEA and decomposition models to evaluate intellectual capital in regions. The analysis that was conducted aims to illustrate the efficiency of how IC components are used in regions and to point out the regions with the best IC performance. The foundation of the process of building knowledge in a region is the evaluation of its endoge-nous growth potential. National and regional growth potential is based on intangi-ble assets and special skills—just as it is for business entities. The primary objec-tive of our research is to work out a reliable method for evaluating knowledge assets that makes it possible to understand the cause and effect relationships between intellectual capital and both regional economic growth and the reasons why it differs between regions (Matlovičová and Matlovič 2005; Matlovič and Matlovičová 2011). This is a topical issue for interdisciplinary research, especially when it concerns economic and geographic boundaries (Matlovič and Matlovičová 2012).

Methods that are based on linear programming use Farrell's efficiency measures (Farrell 1957). According to these measures, enterprise efficiency is based on two components: technical efficiency, representing an enterprise's ability to maximize its outputs using the given inputs, and allocative efficiency, representing the enterprise's ability to use its inputs optimally given their prices and production technology (Nitkiewicz et al. 2014). These two measures are very often used together to evaluate overall economic efficiency (Coelli et al. 2001). Economic efficiency measures compare the results of enterprise activities to the optimal achievable results when given specific objectives (Cherchye 2001). Efficiency measures can be output oriented, defining the maximum level of output that could be achieved by a decision-making unit (DMU) with the given input. Input oriented measures provide us with the minimum level of input that is absolutely necessary to reach the given output. A DMU is inefficient if its inputs and/or output are below the best practice frontier. Nonparametric efficiency analysis using Farrell's measures has become popular due to the development of data envelopment analysis. DEA provides a number of research opportunities for use in the socioeconomic environment (Cooper et al. 2001). It includes other possibilities for cooperation among analysts and decision-makers—from cooperation on the choice of the inputs and outputs to be used to choosing the types of "what-if" questions to be addressed. Such ways of cooperation extend to benchmarking the "what-if" behaviors of competitors and include identifying potential (new) competitors that may emerge for consideration within some of the scenarios that might be generated.

2 Data Envelopment Analysis as a Method for Evaluating IC

Leitner et al. (2005) were among the first to use DEA to evaluate intellectual capital. He used units of higher education, namely the faculties and departments of Austrian universities, as the subject of his research. Afterward, DEA was used to evaluate IC, knowledge management practices, and the overall performance of higher education units by Giambona et al. (2011) at the national level and Kuah and Wong (2011) for single academic units. This approach is complemented by the additional use of Monte Carlo simulation with a genetic algorithm by Kuah et al. (2012). Leitner et al. (2005)

proved DEA's capability for evaluating intellectual capital and its elements for more than just the higher education sector. This approach was further developed by Nowicka-Skowron et al. (2006), Pachura and Nitwiewicz (2008) and Pachura and Nowicka-Skowron (2010). The use of DEA to evaluate different regional and local issues is quite widespread; it is also used in the context of the operation of business units. Stancu and Lupu (2011) built standard DEA models to evaluate IC in Romania's regions. Wang and Huang (2007) focus on environmental factors in R&D activities while Campisi and Costa (2008) have developed a DEA-based approach to identify and quantify the cause and effect relationship between IC management and improving business performance. Lu et al. (2010) used the DEA approach in order to introduce IC capability and IC efficiency measures, making it possible to assess company IC performance. IC efficiency and productivity is further explored by Costa (2012). Guan and Chen (2010) compiled DEA-based unit assessments to perform a cross-regional empirical study. Lin et al. (2011) combined DEA with the analytic hierarchy process in order to evaluate the economic performance of local governments.

3 Research Field and Method

The issue of socio-economic development at regional level in the countries of Central and Eastern Europe (CEE) began to develop dynamically after 1989, especially in the pre-accession period associated with the preparations for accession to the European Union. Subsequently, after the accession to the EU, academic research on regional development has accelerated considerably. This situation was in fact related to the adoption of European standards for regional development programming and strategic planning. The scientific community of these countries has been trying to undertake research inspired mainly by the work of scientists from Western Europe, and especially as it seems from Scandinavian countries. This has led to a large concentration of research on phenomena related to the role of intangible factors in socio-economic development processes. At the same time, there are many attempts in Central and Eastern European scientific community to develop their own research concepts and methodological approaches. The following representatives are deserving of attention: V. Baláž, J. Blažek, J., Buček, B. Domański, Z. Gal, P. Hájek, O. Hudec, E. Kiss, R. Matlovič, P. Pavlínek, J. Stejskal, L. Sýkora, and many other. Thus, staying in the mainstream of research on regional development issues in relations with aspects of intangible regional developmental factors, the authors wish to propose in this chapter a contribution to scientific discussion based on the adoption of set out above the DEA methodology.

Data Envelopment Analysis was used in this study for the purpose of evaluating intellectual capital in the Polish and Slovak regions. The choice of variables was determined by commonly accepted classification systems for intellectual capital that are suitable for regions. These variables are limited to ones measured in physical units. Determining inputs and outputs is the decisive first step in conducting a DEA.

Choosing the indicators to be classified as inputs or outputs can be quite difficult. Inputs are characterized by the fact that it is better for their quantities to be smaller (e.g., expenditures on R&D in a region), involving lower costs, whereas outputs are characterized by the fact it is better for their quantities to be larger (e.g., more patents in a region). This study's objective is to evaluate the efficiency of selected areas of intellectual capital at the regional level. Therefore, regions are used as the DMUs. At the NUTS 2 level, these are called voivodeships in Poland and regions in Slovakia. It can be argued that voivodeships/regions are not a good match for DEA analysis, because they do not meet the basic precondition for sound DEA analysis—simply because the area to be evaluated is not sufficiently homogeneous. On the other hand, the production possibility set, in this case for regional intellectual capital use, cannot be precisely defined. Another reason in support of the analysis's validity is connected to the data used as input/output variables. All the variables have been chosen rather intuitively; though their influence on shaping a region's intellectual capital is known and confirmed, it has never been explicitly described. Some assumptions have been made regarding all the concerns presented above (Nitkiewicz et al. 2014):

- The relationships between the given IC inputs and outputs were identified on the basis of common knowledge,
- The efficiency of transforming inputs into outputs was evaluated according to the relationships identified above,
- The models presented made it possible to evaluate partial efficiency because only some of the variables describing IC in regions were used in constructing them, and
- The variables used to construct the DEA models do not completely describe regional IC.

The first of these assumptions is connected with the incomplete knowledge of IC at the regional level and the many factors influencing it. Only the factors connected by an obvious or commonly acknowledged link are used in the study. The study undertaken here is experimental and may help identify similar relationships that have not yet been observed. The second assumption is a direct result of the first one, only the context of evaluating efficiency has been added and made the main research objective. Some important variables were purposefully eliminated in the efficiency evaluation to keep the focus on the relationship identified in the first step. This kind of treatment allows for a more detailed description of the given relationships but does not place them in the broader context of overall IC efficiency. The third assumption results from the specific nature of DEA analysis and its vulnerability with respect to the size of the sample and the number of variables. The number of DMUs could not be increased, because there are only 16 voivodeships in Poland and 4 regions in Slovakia at the NUTS 2 level (Nitkiewicz et al. 2014). If the number of DMUs is only 20, then the number of variables should be kept low enough to ensure

Table 1 Characteristics of the distance functions used for regional IC

Distance function	Input variables	Output variables	Special input variables
DiA	Population turnover	GDP GVA	
DiICA1	Population turnover	GDP GVA	Total intramural R&D expenditure
DiICA2	Population turnover	GDP GVA	Human Resources in Science and Technology
DiICA3	Population turnover	GDP GVA	Total R&D personnel and researchers
DiICA4	Population turnover	GDP GVA	Second stage of tertiary education
DiICA5	Population turnover	GDP GVA	Patent applications to the EPO

Source: Authors' own compilation

reliable results (Leitner et al. 2005). Statistical data on regional performance for 2011 is used, including the following variables[1] to construct distance functions:

- Inputs
  (1) Population
  (2) Turnover in industry (in millions of Euros)
- Outputs
  (3) GDP at current market prices (in millions of euros)
  (4) Gross value added at basic prices (in millions of euros)
- Special inputs
  (5) Total intramural R&D expenditure (in millions of euros)
  (6) Human resources in science and technology (in thousands)
  (7) Total R&D personnel and researchers (% of active population)
  (8) Second stage of tertiary education (number of students)
  (9) Patent applications to the EPO (number of applications)

The above set does not encompass all the factors shaping IC in regions and is limited to variables accessible in both countries. However, it is complete enough for the purposes of our research considering the assumptions that have been made. Data concerning the variables is presented in the appendix (Table 3). One basic distant function (*DiA* in Table 1) is used to decompose the efficiency of certain factors on the basis of five supporting functions (*DiICA1*, *DiICA2*, *DiICA3*, *DiICA4*, and

[1] All the data used in the research comes from the official websites of Eurostat (http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/themes), the Polish Central Statistical Office (www.stat.gov.pl), and the Statistical Office of the Slovak Republic (por-tal.statistics.sk).

Table 2 Efficiency scores for the Polish and Slovak NUTS 2 regions

Region	Code (NUTS 2)	DiICA1	DiICA2	DiICA3	DiICA4	DiICA5
Lódzkie	PL11	0.9977	0.8635	0.9864	0.9025	0.9975
Mazowieckie	PL12	1.0000	1.0000	1.0000	1.0000	1.0000
Malopolskie	PL21	0.9695	0.8754	0.9731	0.9955	0.8754
Slaskie	PL22	0.8461	0.9294	0.6582	0.8380	0.6636
Lubelskie	PL31	1.0000	1.0000	1.0000	1.0000	1.0000
Podkarpackie	PL32	0.9371	0.9993	0.9668	0.9991	0.8797
Swietokrzyskie	PL33	0.9998	0.9810	0.8980	0.9625	0.8830
Podlaskie	PL34	0.9724	0.9661	0.9480	0.9992	0.9480
Wielkopolskie	PL41	0.9840	0.9958	0.9734	0.9976	0.9178
Zachodniopomorskie	PL42	1.0000	1.0000	1.0000	1.0000	1.0000
Lubuskie	PL43	0.7961	0.9071	0.9998	0.9944	0.7961
Dolnoslaskie	PL51	0.9771	0.9861	0.9882	0.9975	0.9964
Opolskie	PL52	0.8956	0.9465	0.9373	0.9999	0.9355
Kujawsko-Pomorskie	PL61	0.9033	0.9639	0.9994	0.9990	0.9663
Warminsko-Mazurskie	PL62	0.9990	0.8567	0.9992	0.9989	0.9303
Pomorskie	PL63	0.9995	0.9703	0.9025	0.9751	0.9724
Bratislavský Region	SK01	1.0000	1.0000	1.0000	1.0000	1.0000
Západné Slovensko	SK02	1.0000	1.0000	1.0000	1.0000	1.0000
Stredné Slovensko	SK03	0.8826	0.6975	0.8688	0.9933	0.9410
Východné Slovensko	SK04	0.9935	0.9865	0.8910	0.9828	0.8744

Source: Authors' own compilation

DiICA5). In fact, Models 2 and 3 should be treated interchangeably since they deal with similar variables (employment in the R&D sector).

The scores obtained for the efficiency indicators are presented in Table 2 and Figs. 1, 2, 3, 4 and 5.

4 Closing Remarks

This proposition of intellectual capital performance identification using Data Envelopment Analysis has the value, rather as the technical analysis of the research tools rather than conceptual design. Nevertheless, it seems that the presented concept may contribute to the research tools development in the field of analysis of socio-economic evolution of space systems. As mentioned at the beginning of this text, the issue of intellectual capital is quite difficult to operationalize due to its multidimensional nature.

The efficiency scores, as shown in Table 2, present the overall assessment of IC performance in the analyzed regions with regard to certain aspects of IC. The efficiency scores that were obtained show significant diversity in intellectual capital use for the Polish and Slovak regions (five regions were fully efficient). Some

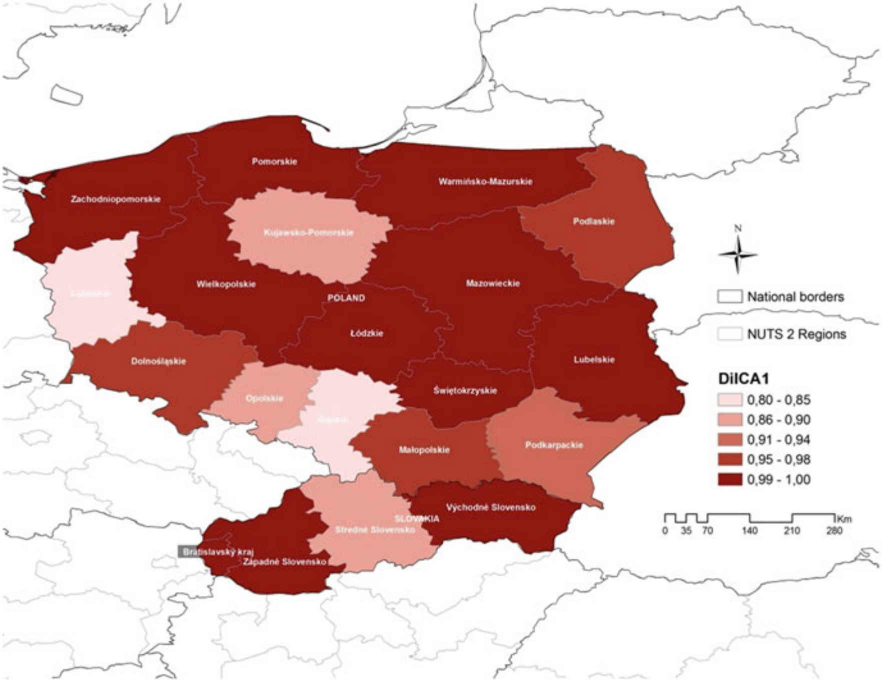

Fig. 1 Efficiency scores DilCA1. Data source: own elaboration. Administrative boundaries: © EuroGeographics, UN-FAO, Turkstat. Bace map source: GISCO—Eurostat (European Commission). GCS_ETRS_1989

regions were obviously dominant and fully efficient in all categories, but there also were some highly inefficient ones. The important trend shown in the results is related to the fact that certain variables' levels were exceptional. Therefore, some of the regions that showed variables with extreme values (having the highest out-put or lowest input level) automatically achieved full efficiency (see the Mazowieckie or

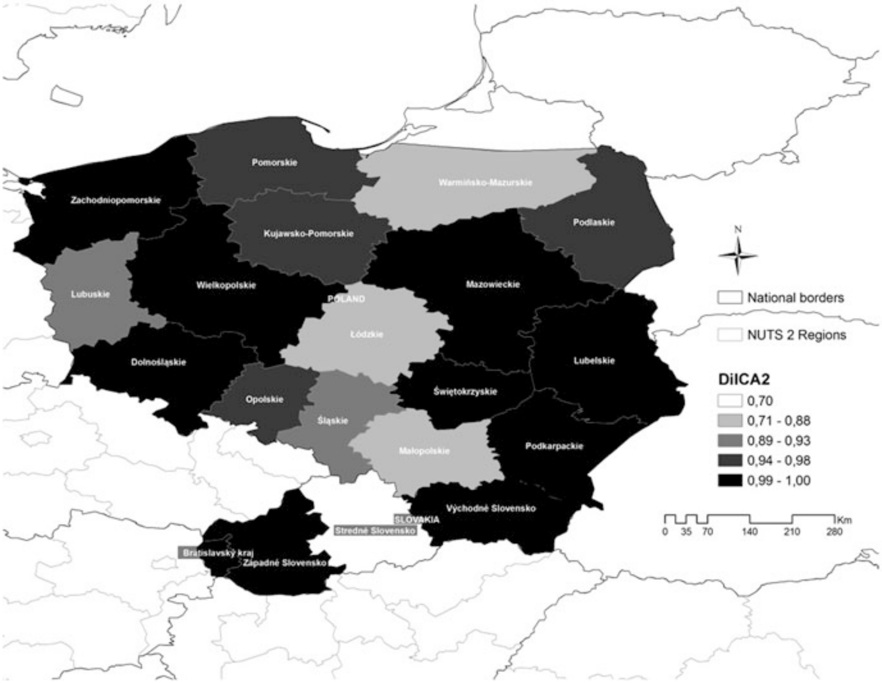

Fig. 2 Efficiency scores DilCA2. Data source: own elaboration. Administrative boundaries: © EuroGeographics, UN-FAO, Turkstat. Bace map source: GISCO—Eurostat (European Commission). GCS_ETRS_1989

Bratislavský regions). The with a bigger reference set (regions with similar variable levels) have more difficulty reaching full efficiency.

The presented research is aimed at testing an analytical research tool and the text is rather technical, not conceptual one. This approach is due to the fact that, according to the authors, the conceptualization of the intellectual capital or of the broader sense—intangible development factors is well developed in the world

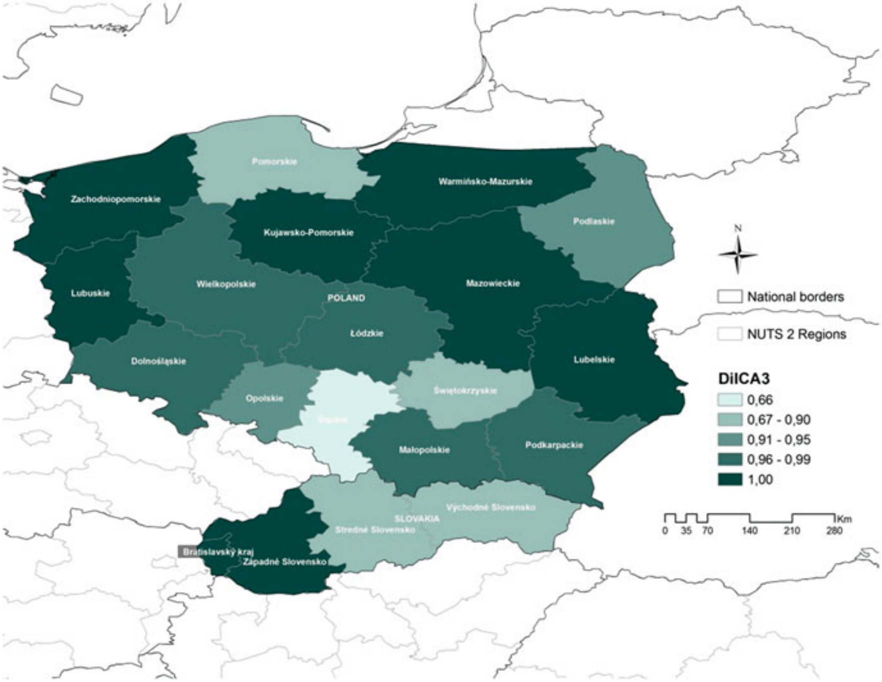

Fig. 3 Efficiency scores DilCA3. Data source: own elaboration. Administrative boundaries: © EuroGeographics, UN-FAO, Turkstat. Bace map source: GISCO—Eurostat (European Commission). GCS_ETRS_1989

scientific literature. On the other hand, the effectiveness of research tools is at a stage of development, improvement and continuous modification. The DEA methodology that has been used in this evaluation, it is important to point out that it still needs development; it is nonetheless very promising as a tool for measuring the efficiency of regional intellectual capital. The general conclusion of our research is that Data Envelopment Analysis can be adopted as a method for evaluating intellectual capital in regions. The solution presented here—decomposition models—is quite suitable

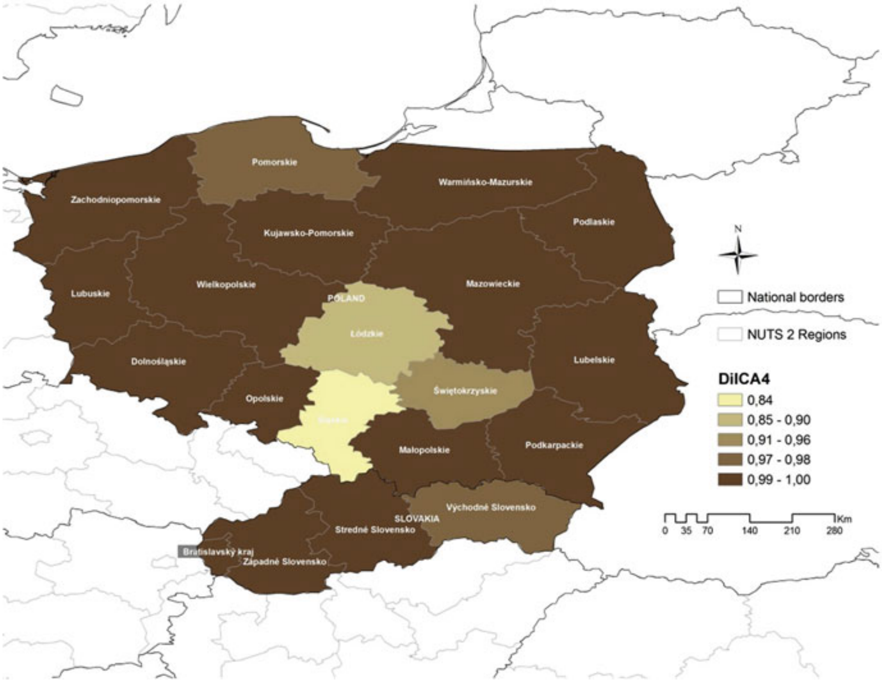

Fig. 4 Efficiency scores DilCA4. Data source: own elaboration. Administrative boundaries: © EuroGeographics, UN-FAO, Turkstat. Bace map source: GISCO—Eurostat (European Commission). GCS_ETRS_1989

for this objective. Of course, it is important to bear in mind certain limitations when using DEA, such as the need for reliable data and numerous DMUs for analysis. Nonetheless, it is possible to use it to describe regional IC. Thanks to its flexibility, this DEA methodology can significantly contribute to evaluating the efficiency of processes involving IC. The calculated efficiency scores cannot be treated as measures of absolute efficiency, but they could constitute a significant information base within the process of regional socioeconomic development based on knowledge

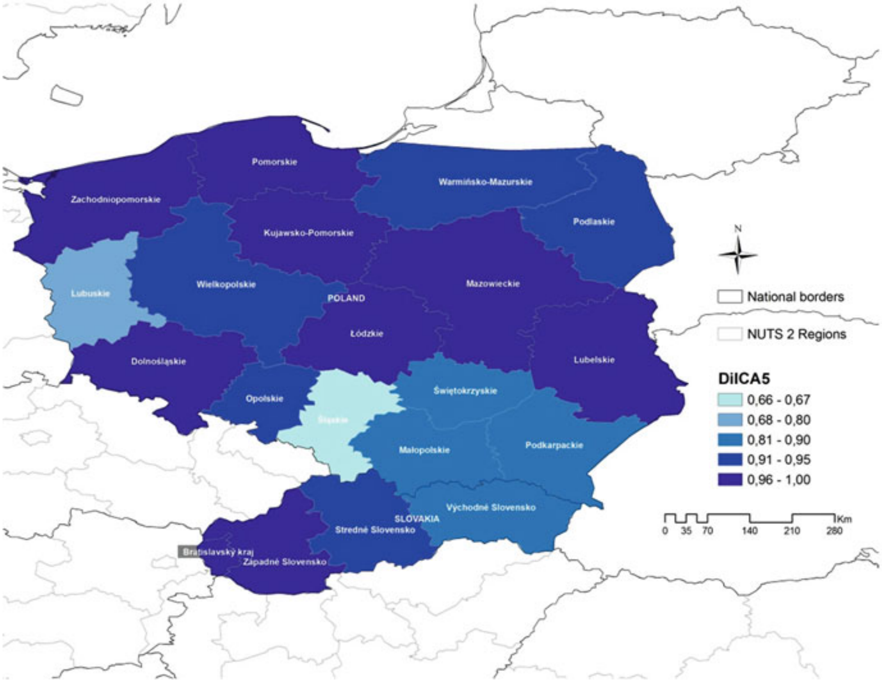

Fig. 5 Efficiency scores DilCA5. Data source: own elaboration. Administrative boundaries: © EuroGeographics, UN-FAO, Turkstat. Bace map source: GISCO—Eurostat (European Commission). GCS_ETRS_1989

factors at the regional level. It should be noted that this approach requires further research, their aim could be to develop more effective tools for public administration, whose task is to analyze the effectiveness of public policy and strategic programs implementation.

Appendix

Table 3 Values of variables in Polish and Slovakian NUTS 2 regions for decomposing IC efficiency

Region	Code (NUTS 2)	Inputs		Outputs		Special inputs				
		Population	Turnover in industry (millions of euro)	GDP at current market prices[a] (millions of euro)	Gross value added at basic prices[a] (millions of euro)	Total intramural R&D expenditure (millions of euro)	Human Resources in Science and Technology (in thousands)	Second stage of tertiary education (number of students)	Patent applications to the EPO[b] (number of applications)	Total R&D personnel and researchers (% of active population)
Lódzkie	PL11	2,542,436	16,497.6	21,720	19,129.8	140.4	534	2754	34.08	0.56
Mazowieckie	PL12	5,267,072	58,001.7	79,061	69,632.8	1134.7	1382	10,417	48.64	1.38
Malopolskie	PL21	3,336,699	18,858.1	26,057	22,949.4	293.8	595	5342	40.18	1.04
Slaskie	PL22	4,634,935	52,408.5	46,071	40,576.5	250.9	958	3202	23.35	0.59
Lubelskie	PL31	2,178,611	7257.3	13,528	11,915.0	91.7	413	2521	6.42	0.62
Podkarpackie	PL32	2,127,948	8959.9	13,145	11,577.8	131.6	335	370	5.52	0.68
Swietokrzyskie	PL33	1,282,546	6107.4	8932	7866.9	34.7	239	123	5.63	0.22
Podlaskie	PL34	1,203,448	4862.4	8033	7075.1	33.9	213	509	2.65	0.47
Wielkopolskie	PL41	3,446,745	30,433.8	33,015	29,077.8	220.9	580	3107	18.92	0.89
Zachodniopomorskie	PL42	1,723,741	8280.5	13,680	12,048.5	47.7	257	1115	4.45	0.54
Lubuskie	PL43	1,023,215	6501.2	7931	6985.5	13.6	174	116	10.00	0.23
Dolnoslaskie	PL51	2,917,242	25,425.0	30,070	26,483.8	176.0	527	3924	19.83	0.73
Opolskie	PL52	1,017,241	5247.2	7605	6698.1	20.4	141	373	1.71	0.39
Kujawsko-Pomorskie	PL61	2,098,711	12,548.4	16,116	14,194.1	45.5	314	1149	4.25	0.48

(continued)

Table 3 (continued)

Region	Code (NUTS 2)	Inputs		Outputs		Special inputs				
		Population	Turnover in industry (millions of euro)	GDP at current market prices[a] (millions of euro)	Gross value added at basic prices[a] (millions of euro)	Total intramural R&D expenditure (millions of euro)	Human Resources in Science and Technology (in thousands)	Second stage of tertiary education (number of students)	Patent applications to the EPO[b] (number of applications)	Total R&D personnel and researchers (% of active population)
Warminsko-Mazurskie	PL62	1,453,782	6831.2	9731	8570.1	48.8	221	430	0.20	0.39
Pomorskie	PL63	2,275,494	19,722.1	19,921	17,545.0	151.8	396	2040	7.42	0.85
Bratislavský kraj	SK01	599,931	36,792.1	18,297	16,635.3	242.7	235	5647	8.05	4.09
Západné Slovensko	SK02	1,838,786	14,528.1	21,206	19,280.6	81.6	316	2056	7.18	0.48
Stredné Slovensko	SK03	1,349,286	14,372.8	13,357	12,143.7	68.5	235	2009	2.14	0.68
Východné Slovensko	SK04	1,604,443	10,890.7	13,010	11,828.9	75.6	260	2470	5.98	0.66

Source: http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/themes for all variables, stat.gov.pl and portal.statistics.sk for R&D expenditures in Polish and Slovakian regions accordingly

[a]Data for 2010

[b]Data for 2009

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Part III
The Evolution and Dynamics of Regional Innovation Systems

The Evolution of Innovation Networks in Slovakia: Disintegration and Slow Recovery

Oto Hudec and Martina Procházková

Abstract Knowledge production processes during the transition period from authoritarian socialism to market economy experienced significant changes in Slovakia and other CEE countries. Such a paradigm shift has caused the disintegration of the former inventory networks followed by only a slow recovery over the last 20 years. The patenting activity analysis of Slovak institutions gives a good focal point to indicate the general decrease in innovation performance and also to justify the breakdown and fragmentation of the former long-term cooperating inventory networks during the period of 1998–2012. The Slovak regional inventory networks have been studied for a longer period using network analysis, discovering common evolutionary development as well as particular network patterns after the opening of the economy to competition and foreign investments, staying before in a comfort zone. The recovery and formation of new networks of inventors are still very slow, even if the economic growth is steadily positive. One of the main reasons for continuing lower innovation performance is not only the low expenditure on research and development, but another reason is a relatively low number and quality of the links within poorly developed regional innovation systems. The results of the network analysis demonstrate to what degree the regional innovation system is truly regional (or national or even international) by comparing Slovakia's regions and their interdependencies.

1 Introduction

In the socialistic period, Central and Eastern European countries have advocated linear innovation approach to research and development with a limited horizontal cooperation (Koschatzky 2002), although their governments considered science and technology as an integral part of each industry (Graham 1990). Fritsch and Graf (2011)

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analysed how different history and macroeconomic conditions shaped regional innovation activities. Their findings for East and West Germany indicate significant structural differences between their innovation networks. Similar to East Germany, the Czechoslovak economy after the Second World War was characterised by the massive industrialisation. The government enforced machine engineering and chemical industry, and not surprisingly the most patent applications come from those two industries, especially in the years 1988–1992 (Smith 1998).

Transition to a market economy after November 1989 has brought to the Slovak economic area dramatic fragmentation and deindustrialization. The privatisation and dynamic industrial restructuring also affected the networks of innovators. The following part aims to explain the evolution of the inventory networks in the period 1988–2012 and to catch the impact of the economic transition in Slovakia.

2 The Socialistic Period of Slovakia

2.1 Transition and Institutions

After the Communist rule came to an end in 1989, the countries of Central and Eastern Europe had to cope with the transition from the centrally planned economy to market economy and from the ultimate state ownership to the private property. However, the economic transformation has not been the only critical change. Simultaneously with the economic system change, a less quantifiable transition from the centralist authoritarian rule to a pluralist democracy, as well as from party and state-dominated societal organisation to a civil society has taken place (Illner 2000). The transition from authoritarian socialist system to democracy and market economy in Poland, Czech and Slovak republics followed a shock therapy model (Morvay 2005), and was formally and institutionally completed by the entrance to EU in 2004. In comparison to a more radical approach in the Czech Republic, where a more sharp approach for the economic recovery was ongoing, Slovakia and Hungary adopted a more gradual and modest approach (Radosevic 1996).

The discussion on the transition from the former centrally planned economies to a market economy more or less ended at a macro level. Nevertheless, the past is still preserved in the formal and particularly informal institutions. In the former communist countries, there has been a clear change to standard market formal institutions. However, the change in informal institutions is not straightforward or is even in a clash with the new economic system. The present discrepancies between the functioning of the former CEE communist countries and Western Europe at the national, regional and local levels can be certainly explained by a number of factors—although probably the weightiest variable is the heritage of centrally planned economies.

In fact, Slovakia and some other CEE countries experienced two revolutionary changes in the second half of the twentieth century, which have broken up theoretically natural economic and societal development. The former one has changed the political and economic system from market to forced state ownership after the World War II. After 50 years of living in an entirely different institutional framework, the last utter change to market economy meant a deep-drawn switch to a new, unfamiliar system, taking wide-ranging and difficult transition the second time.

That is why the CEE countries in transition constitute a considerably challenging issue for evolutionary economic theory and path dependence concepts (Buček et al. 2013). An evolutionary approach should take into account two radical shocks, to sufficiently interpret their situation at the beginning of the twenty-first century. Informal rules of the central planning are still alive or have transformed themselves into new forms of paternalism, acceptance of privileges, tolerance to rent seeking, lobbying the government, favouring national and sectoral over regional and local, or directive management influencing relations between economic agents (Tridico 2006). The evolution of new institutions is affected by the persistent old rules and path dependence shapes the transformation.

2.2 *Development of the Czechoslovak Economy in 1948–1989*

Czechoslovakia was one of the most developed economies of the world during the interwar period. Already in 1930, 45% of the population was working in manufacturing and mining and only 30% in agriculture. The neighbouring countries showed a rather different picture that time in comparison to Czechoslovakia, with 67% of the active population working in agriculture in Poland and 54% in Hungary (Myant 1989). After February 1948, the nationalisation brought 95% of industrial employment within the state sector. Based on the general plan, a new economic structure has been developed, emphasising industrialisation and heavy industry especially. To a large extent, the building of new industrial structures and focus on industrial production in the COMECON countries (COMECON—the Council for Mutual Economic Assistance, an economic organisation led by the Soviet Union, existing 1949–1991) were being subordinated to the demands of the USSR. The foreign trade of Czechoslovakia grew quickly from 40% share of the COMECON countries in 1948 to 78% in 1953. The decisions on the location of new industries have been made centrally, aiming to provide the employment in all regions of the country, but without considering regional interests, with an orientation towards East European markets (Morvay 2013).

The massive industrialisation has brought ambiguous consequences to the Slovak economy. The share of the industrial production on the national income was 39.9% in 1948 and immediately reached 53.8% in 1953. However, the industrialisation progression resulted in establishing industries with only low value-added and a low degree of finalisation (Koyame-Marsh 2011). A more sophisticated industrial production in the Czech Republic sourcing from the interwar technical basis enabled the spread of technology and development also to the Slovak part of the country. For example, the Czech automobile car, truck and motorcycle production originated at the very beginning of the twentieth century and the main producers before the WWII were Škoda, Praga, Tatra, Aero and Jawa (Pavlínek 2008). In the period of 1955–1975, the decisions of the State Planning Commission enabled the establishment of branch plants also in Slovakia following the official regional development policy to industrialise the territory of Slovakia (BAZ in Bratislava, TAZ in Trnava and several other cities). As at 2016, Slovakia and the Czech Republic are countries with the highest production of cars per capita in the world. The German Volkswagen acquired the BAZ small production plant in 1991 and the French PSA (Peugeot and Citroën) built a new car assembly plant in 2006 in Trnava taking advantage of the existing qualified workforce. This example of automotive industry evolution explains the spread of the industrialisation from the Czech to the Slovak part of Czechoslovakia, as well as from more industrialised regions to less urban and peripheral areas. Later on, a highly uncompetitive production in many cases of the plants imbedded in less urbanised regions appeared, just after the breakdown of the Soviet bloc and following stagnation and decline of Eastern markets of the ex-COMECON countries.

In the second half of the twentieth century, structural dysfunctions of the centrally planned economy, the costly arm program implemented by the socialistic regime and oil shocks in the 1970s caused Czechoslovakia to lose its former innovativeness and competitiveness. The transformation process and opening of the economy and markets in the 1990s have revealed declining Czechoslovak economy, lagging of technical infrastructure, serious deficiencies, a hidden inflation and overestimated economic indicators (Morvay 2013).

Table 1 provides officially reported and collectable data of available macroeconomic indicators in the period of communistic government (1960–1989) in Czechoslovakia based on Historical Statistical Yearbooks of Czechoslovak Federative Republic[1] (ČSFR). As Table 1 shows, the national income and customer consumption have been increasing over the whole period of the socialistic economy of scarcity in Czechoslovakia. However, the official statistics does not include the hidden inflation and other dysfunctions in the economy, which have appeared fully only after the breakdown of the previous regime. The national income and customer consumption have been increasing significantly over the whole period of the socialistic era in Czechoslovakia 1948–1989. The picture of the economic development of the Czechoslovak economy would not be complete without comparing both their parts. First, there is an obvious huge difference in the structure of the economy of the Czech and Slovak parts of the country at the beginning of the socialist period. Slovakia started its massive industrialisation only in 50ties: the share of industrial production on GNI was 39.9% in comparison to 58.6% in the Czech Republic. At the end of the period in 1989, the share of industry settled at over 60% in both territories.

[1]Official names of common state in times of Czechoslovakia:
1918–1960: Czechoslovak Republic (excluding 1945–1948),
1945–1948: Protectorate of Bohemia and Moravia and Slovak Republic,
1960–1989: Czechoslovak Socialistic Republic,
1990–1992: Czechoslovak Federative Republic.

Table 1 Basic macroeconomic indicators of Czechoslovakia (1948–1989)

	1937	1948	1953	1960	1968	1970	1975	1979	1980	1982	1983	1984	1985	1986	1987	1988	1989
		Czechoslovakia		**The Czechoslovak Socialist Republic**													
		Period of Communist government															
National income (in mill. Kčs[a]—current prices)												541,101	556,325	570,048	583,257	606,380	619,405
Personal consumption (in mill. Kčs—current prices)												287,210	297,555	306,054	315,260	330,362	343,202
Share of personal consumption on national income												53.08	53.47	53.69	54.05	54.48	55.41
Growth of national income per inhabitant																	
1937 = 100 (%)	100	113	170	257	331	376	481	544	557	556	567	585	601	615	626	639	644
1948 = 100 (%)		100	150	227	293	332	425	481	492	491	501	517	531	543	553	565	569
Czech Republic																	
1948 = 100 (%)		100	153	245	326	364	468	523	532	528	534	548	562	576	587	600	616
Slovak Republic																	
1948 = 100 (%)		100	169	311	480	536	743	860	887	885	913	955	989	1038	1077	1114	1132
Share of industry in the generation of national income (current prices)		58.6	66.8	62.3	60.1	61.0	64.7	63.3	63.5	60.6	61.2	58.7	59.8	59.8	59.9	59.6	58.3
Czech Republic		63.1	70.3	65.9	64.0	65.4	68.4	67.2	66.9	65.4	65.0	64.1	64.8	65.3	65.7	65.7	62.3
Slovak Republic		39.9	53.8	51.7	54.5	56.9	62.4	63.0	64.2	61.8	63.2	62.8	64.1	63.6	64.1	64.0	61.7
Growth of personal consumption per inhabitant																	
1937 = 100 (%)	100	97	112	176	234	252	309	327	325	322	328	333	337	344	353	370	376
1948 = 100 (%)		100	115	181	241	260	319	337	335	331	337	342	348	353	364	381	387
Selected sectors with the highest growth of industry production in economy (1948 = 100)																	
Energy industry		100	165	360	639	718	967	1135	1220	1251	1276	1317	1370	1437	1473	1497	1527
Engineering		100	294	663	1201	1414	2118	2794	2925	3148	3306	3514	3718	3900	4056	4173	4203
Chemical industry		100	230	557	1257	1534	2428	3095	3189	3223	3362	3445	3608	3754	3873	3952	3980
The industry of construction materials		100	184	529	769	872	1202	1429	1486	1487	1492	1518	1542	1573	1607	1669	1673
Wood industry		100	192	342	484	544	774	982	1027	1072	1100	1140	1159	1193	1224	1254	1248
Glass industry, ceramics and porcelain		100	122	267	421	511	705	882	909	955	961	1003	1027	1046	1063	1128	1199

Source: Historical Statistical Yearbooks of ČSFR

[a]Kčs—Czechoslovak crown (national currency)

A similar development can be seen when comparing GNI per capita; the increase was almost double in the comparison of Slovak with the Czech population.

Nevertheless, the official national income growth stopped at the end of the eighties, having no more capacity to compete with the western economies. The former source of growth in industrialisation was over, and the first signals of coming de-industrialisation were apparent in the industrial statistics (Hudec and Šebová 2012).

Within the framework of socialist planning, the rapid industrialisation has been coupled with urbanisation in less developed regions, enforcing a large-scale industrialisation of the whole economy (Hudec 2009). The regional economies have not been growing and developing gradually, but industrial plants were artificially inserted externally into previously undeveloped areas. By way of comparison, in-dustrialisation of rural areas in the western countries was based on a light and in-tensive manufacturing industry. In the Central and Eastern Europe, rural industrialisation was a political target, and its mechanical implementation caused later vulnerability of those areas after the fall of the Berlin Wall.

2.3 Systems of Science, Technology and Innovation in the CEE Countries

The systems of science, technology and innovation in the CEE countries are not easily comprehensible because of their contradictory evolution and fundamental external interventions. Their current state can be understood only by discovering the roots after WWII and following influences.

The Comecon countries have agreed on a division of labour among different industries, including research and development. With an aim to exploit the advantages of large-scale socialist production, an international industrial specialisation and interconnection have led to setting up mutually complementary industrial structures. Altogether 78% of the Czechoslovak foreign trade turnover in 1985 (Gawdiak et al. 1989) was realised with the Comecon members and only 16% with so-called "developed capitalist countries".

The authorities were later aware of the shortcomings of the economy giving low priority to research and development. A new dimension of technological capacity has been introduced in the early 1960s and gradually become a top priority also as an instrument to fight with more advanced capitalist countries. Each state has established a high-level central body (The Committee for Technology and Investment in Czechoslovakia). In the area of research and development, an ambitious "Comprehensive Program for Scientific and Technical Progress" up to the year 2000 was adopted in December 1985, aiming to interconnect and develop more efficient science and technology base. The plan included specialisation agreements, giving e.g. to Czechoslovakia a priority of research in the fields of automated production systems and robots or microelectronics in that time.

However, within the planning system, the approach was struggling to force innovations through administrative methods. Enterprise directors in the Comecon countries were not considered greatly innovation-minded (Wilczynski 1974), because of the high risk associated with innovations and serious repercussions if the venture is a failure. There was a big difference if the highest political leadership was involved in setting the technological goals such as a cosmic programme or military enjoying almost unlimited resources in the USSR. Also, a prevailing focus was on basic research and the extensive R&D system, "just as the crowd on the stage, produced paltry practical results" (Rabkin 1997). Although the mission of the applied research institutes was to introduce technological innovations to assigned peer industry, both parties had a low motivation for risky projects with a low success rate. In the end, the research institutes, having a little control over the implementation of their research results, acknowledged their situation and rather opted for a more comfortable strategy of fundamental research. With an aim to ensure their survival, they softly revised their priorities and readjusted their new outputs as scientific publications, doctoral theses, and other common products of basic research. The Soviet innovation culture has also been transmitted to Czechoslovakia and East Germany, the countries influenced by the German-speaking culture of research and innovation before, and more advanced in technology and innovation. The political strategy caused a re-orientation towards the Soviet innovation model and marked inclination to fundamental research also in Czechoslovakia. The Soviet model of Academies of Sciences, mostly divided from the innovation activities and focusing on fundamental research, have been promoted and established in all COMECON countries.

The hand of the central planning method can also be recognised in the development of the share of R&D employees on the total number of employees. In the last socialistic decade 1980–1989, the numbers are stable and well balanced for the Czech and Slovak parts of the country, but never exceeded 1.7% (Table 2). Only the proportion of R&D employees with a university education has been growing. Also, the number of R&D organisations was proportional to 2:1 population ratio: 207 firms located in the Czech part and 113 in the Slovak part of the territory. However, the big difference is in the number of R&D employees, showing Czech dominance of 70% in comparison to Slovak 30% share.

The general economic and technological backwardness and an artificial structural division explain the unpreparedness of the economies and research and technology sectors after their opening to global competition. That estimated labour productivity reached only 53% in Czechoslovakia in comparison to Austria at the end of the socialistic period. The economy was considerably more energy and raw material dependent, and technological level of the industry was lagging behind the world development by 10–15 years. Czechoslovakia was obviously first in the number of patents in the group of CEE countries until 1988, far behind followers were Bulgaria and Hungary (Lacasa and Giebler 2014). However, a strong decline in the patent intensity in Czechoslovakia started already in the 1980s. The transition process in the economy of Slovakia experienced the loss of foreign downstream markets of the former Eastern Soviet bloc. Moreover, the split of Czechoslovakia in 1993 has

Table 2 Structure of R&D employees in period 1980–1989

	1980	1983	1984	1985	1986	1987	1988	1989
Number of R&D employees	116,482	107,779	109,492	112,331	113,083	114,360	116,320	112,535
The share of R&D employees with university education	47.18	54.73	55.62	56.35	57.66	58.73	59.54	60.84
The share of R&D employees on the total number of employees in economy	1.53	1.44	1.45	1.48	1.47	1.47	1.49	1.44
Czech Republic								
Number of R&D employees	83,591	75,632	76,277	77,680	78,363	79,012	79,713	77,850
The share of R&D employees with university education	43.89	53.59	54.24	54.97	55.89	57.24	58.19	59.45
The share of R&D employees on the total number of R&D employees in CSSR	71.76	70.17	69.66	69.15	69.30	69.09	68.53	69.18
The share of R&D employees on the total number of employees in ČR	1.63	1.47	1.48	1.49	1.49	1.49	1.50	1.46
Slovak Republic								
Number of R&D employees	32,891	32,147	33,215	34,651	34,720	35,348	36,607	34,685
The share of R&D employees with university education	49.45	57.42	58.80	59.43	64.65	62.05	62.48	63.97
The share of R&D employees on the total number of R&D employees in CSSR	28.24	29.83	30.34	30.84	30.73	30.91	31.47	30.82
The share of R&D employees on the total number of employees in SR	1.44	1.38	1.40	1.46	1.42	1.43	1.47	1.39

Source: Historical Statistical Yearbook of ČSFR (1990) caused to a large extent also a loss of the research cooperation of the Slovak research and innovation workforce with the former team partners in the Czech Republic.

Following Kuznets (1965), the transformation of a country from underdeveloped into developed is not possible only by adding a stock of physical capital. It also must have a character of a thoroughgoing revolution in the life patterns, position of different groups and change in the relative powers. Also in the Slovak economy, profound institutional changes have resulted in a new vertical and horizontal organisation of the political and economic system, in different power relations among social clusters, etc. A complex process of decentralisation has also been implemented in Slovakia with an aim to bring decision-making closer to the citizens, to build democratic institutions at the regional and local levels and to activate involvement of local and regional actors in economic and social development.

In the centrally planned system of resource allocation, regional and city priorities and their financing were based on decisions at the national level, following a strict top-down approach rather. The system change has given the responsibility for local development and physical planning to "de novo" established municipal governments. Implementation of a new territorial system of decentralised governance has been one of the preconditions required from the candidate countries to access the European Union. At the regional level, rights and duties for development and planning were shifted to just recently formed or reformed regional administration. The legal autonomy of strategic planning and local economic development settled to regions and municipalities has not been accompanied by the corresponding financial resources from the government. The lack of resources at the regional and local level has resulted in fictitious strategic planning development. At one side, the financial handicap together with a lack of experience in strategic planning have caused setting their priorities analogously to the higher national level—the foremost potential sources of financing. The gifted privilege of economic planning in the first post-communist decades has got merely a form of strategic thinking training to prepare first planning documents.

Although the state has formally accepted devolution, in reality continues operating in terms of the centralistic system. On the other side, the previous top-down imperative exists in the paternalistic expectations of the subnational self-government institutions, making the state responsible for their less successful episodes.

3 The Rebuilding of National and Regional Innovation Systems in the Transition Period

3.1 Emergence of National and Regional Innovation System

The system is generally understood as a set of functionally interconnected elements, institutions, processes, flows and relationships between them (Skyttner 1996). Innovation has a central role in economic development, whether considered at the level of firm, industry, region or country. Accordingly, the innovation system can be defined as a set of economic and institutional relationships that occur in a geographical area (country, region), which is generating collective learning processes, enabling a rapid spread of knowledge and best practices (Hudec 2007a, b, 2010). Systemic and policy view of the innovation system is at stimulating innovation capabilities of firms and other economic agents in the geographical area (country, region) with an aim to boost the economic growth and competitiveness. The basis of the term innovation system is an assumption of both individual and collective dimensions of diffusion of knowledge and technology (Edquist 2001). Factors of technological changes are embedded not only in the activities of single enterprises, but also in other elements and relationships of the broader innovation system. Hence, innovation should be regarded in a context of the system, representing all its essential elements and relationships involved in the production, as well as dissemination and use of economically useful knowledge (Lundvall 1992a). Environment and institutions are considered as essential factors of uptake and diffusion of innovation; the national innovation system has, therefore, become an important part of national industrial policies.

National innovation system (NIS) and its regional subsystems constitute a systemic instrument and policy tool to increase the innovation capacity of an entity (country, region). However, national innovation systems are not always built so as to take regional interests into account. The uneven pattern of innovation geography is implicitly suggesting the importance of the role of proximity, the density of the institutions and networks in a diffusion of knowledge and drawing attention to subnational regional units (Iammarino and Mccann 2013). In the same manner, like NIS, the emphasis of Regional innovation system (RIS) is on the processes of generating knowledge and its distribution through linkages and networks. The regional innovation system, however, is much more complex to understand and evaluate than national, sectoral or technological levels. The region itself can be regarded as a complex spatial dynamic open system (Hudec 2007a, b). The interactions between the business sector and other agents of the economic system, the types, and intensity of the relations vary according to many factors (Asheim et al. 2011). In most of the definitions (Cooke and Memedovic 2003; Asheim 2007), RIS consists of two fundamental parts: regional production structure (large and small companies) and regional supportive infrastructure (universities, research institutions, technology transfer agencies, business associations, finance institutions and institutions providing public and private innovation services).

What matters for innovation performance, is not only the administrative, financial and technological institutional framework and institutional density. Other important differentiating variables of the RIS are industrial and knowledge base structure, geography, spatial structure, scale and degree of urbanisation. Evolutionary economics view is important to understand specific local institutional factors such as social norms and routines, trust, informal rules, shared norms of cooperation, untraded interdependencies, interactive learning, relative powers, the density of social networks and their employment as channels for informal knowledge diffusion, etc. All the complicated set of factors of knowledge diffusion, institutional inter-linkages and embedded innovation culture define specific territorial externalities, either providing incentives or obstacles to innovation.

Geographical proximity is increasingly mainstreamed as an indispensable condition to share tacit knowledge, in the networks and to enhance trust between innovators (Torre 2008). Hence, there is a question, which is later studied on the example of the Slovak inventory networks, how important is geographical proximity for innovation?

The current CEE variant of the national innovation system is built on the previous structure of centralised science and technology system. That was top-down directed and focusing on sectoral industrial relations, overlooking the importance of intra-regional and inter-regional horizontal networks (Hudec 2007b). The national science and technology systems were financed both from the state budgets and at the same time by means of mandatory allocations into R&D by industries. By the late 1980s, the collapsing economy of COMECON was no more able to keep the research system of the current size (Rabkin 1997). The COMECON organisation of the communist countries dropped to a minimum level and started to build concurrent cooperation with West-European countries (Gál and Rácz 2008; Hudec 2009).

Breakdown of the previous centralised vertical structure, denationalisation and privatisation during the transition period had a significant impact on regional economies, resulting in rising regional disparities and rather different regional development trajectories, including research, development and innovation. The elements of Western European innovation system models have been introduced into still centralised research and development modes of operating, resulting in diverse variations of regional innovation systems. Since the early 1990s, European Commission has built up broad institutional and financial support to implement strategies and measures in favour of weakly developed regional innovation systems. EU supported establishing of innovation centres and agencies and development of regional innovation strategies and operational programmes in the CEE regions.

Unfortunately, after almost 30 year period of the reintegration into European economy, CEE regions display a low level of cooperation between triple helix entities (knowledge institutions, industry and public authorities), poor patent performance and unsatisfactory generation, transfer and exploitation of knowledge. There is a clear conflict between the newly formed regional institutions, including self-government regional administration responsible for regional development, and a persistent continuing tendency of central, vertical decision making. Decentralisation of rights and duties has happened without providing appropriate financial and economic instruments, and there is widespread scepticism in the society towards the capacity of local and regional authorities (Hudec and Urbančíková 2008).

Not surprisingly, both centrality and the supremacy of vertical flows in the governance of the innovation system are vivid in the regional innovation policy implementation as well. The EU enforced regionalisation and decentralisation of power, and resources have been expected to have a form of regional innovation policies towards supporting competitiveness for firms with an emphasis on networking among regional actors. The national government, however, is reluctant about the intensification of research, development and innovation support in less favoured regions. On the other hand, less innovative regions do not have a sufficient absorption capacity for eventual incentives.

The EU regional innovation policy highlights change of the regional governance system towards more networking structure, embedding together cooperation and competition, in a battle with resistant old science and technology national and sectoral hierarchical structures. The modern European innovation policy instruments are in an apparent conflict with the continuing functioning of science and technology system of COMECON period. Transfer of regional innovation system instruments (innovation centres, innovative enterprise incubators, science parks, technology and knowledge transfer centres) are hindered by both formal and informal propensity to central, vertical decision-making culture. The weak, unstable and fragile regional innovation systems in Slovakia are dominated by the prevailing national science and technology system, maintaining separated roles of business, universities and academy of sciences. EU driven innovation instruments are in a serious fight with the national sectoral science and technology policy, previous models of knowledge generation and diffusion mechanisms focusing mainly on fundamental research, etc. Furthermore, the post-socialist development suffers from the disintegration of the former innovation networks, looking for a new balance of international and domestic collaboration. The result is rather mixed and incomprehensible model of regional cooperation triple helix, usually unable to establish a common language in the innovation networks. This situation gives a motivation for a deeper study and understanding of regional innovation networks, providing a multifaceted view of the Slovak regions and understanding the keystones the of their weak innovation performance.

3.2 Transition of the Science and Technology

Patents are granted to inventors for inventions which are novel, innovative and nonobvious and also useful, having an industrial application. They are considered as a large pool and comprehensive source of data on innovation activities and technological change (Hall et al. 2005) and their advantage is undoubtedly a detailed information and description on the innovation. This explains a popularity of the patent statistics use in the research of innovation performance (Griliches et al. 1991). It is evident; there is a limitation of patents in relation to innovation, as not all the innovations are registered in the patent databases because of several reasons (Koh and Reeb 2015). Not all inventions fulfil the necessary requirements of the patent office, the process is long and administratively burdensome, involves cost. A further loss of the registered patents arises if the inventor relies on secrecy or underestimates the role of intellectual property protection.

Completeness of a dataset of the innovation activities is impossible for the pre- and transition period of Slovakia. However, the patent activity can be used as a proxy variable to identify evolutionary aspects of innovation activity development. The institutional analysis of the patent statistics (Slovak Patent Office of Industrial

Table 3 Number of institutions applying for patents in 1988–2012

	1988–1992	1993–1997	1998–2002	2003–2007	2008–2012
Universities	10	8	10	7	7
Applied Research Institutions	26	8	6	3	4
Institutions of Slovak Academy of Sciences	26	13	9	12	11
Enterprises with 3 or more patent applications	33	20	19	18	15
Enterprises with <3 patent applications	103	113	95	87	91
Overall	198	162	139	127	128

Source: own

Rights) shows the decline of the patent activity after the fall of communism in Slovakia during following 25 years in 1988–2012 (Table 3). The number of institutions applying for patents is divided into five periods of 5-year intervals.

The first finding is the total number of institutions, which is decreasing over the whole period from 198 to 128, meaning one-third loss in the number of active institutions and showing no signs of recovery. The main loss of activity is evident in the category of applied research institutions, losing stepwise the support of industry associations and disintegrated industrial structure. Institutes of the Slovak Academy of Sciences and universities have also lost their initial patent performance. Moreover, originally innovation-active enterprises have submitted fewer applications or did not survive in the competition. In contrast to more frequent enterprise patentees, the group of enterprises with less than three patent applications constitutes a major part of all innovation actors over the whole period, but they usually applied for patents only once and then disappeared from the Slovak patent market. Such enterprises are usually incidental single applicants with closed research teams (inventors), having no external research cooperation.

Institutional analysis indicates in this way not only explicit downturn in patenting activity but also fragmentation of the networks of inventors in Slovakia. The disintegration of the main cluster component of the cooperating institution and the increasing share of isolated research is reflected later in the study of the innovation networks.

As could have been expected, the transition of the economic and political system in Slovakia (and other CEE countries) necessarily had to affect also innovation activity in terms of number of patenting institutions, the intensity of patenting as well as size and density of the networks of inventors. The intensity of patenting activity (as the number of patent applications) is displayed in Fig. 1, showing the patenting development of the most important single universities (labelled U1–U6), research institutes (RI), the Slovak Academy of Science (SAoS) and the group of enterprises with 3 and more patent applications in a particular 5-year time period (E). With the exception of the Technical University of Košice—TUK-U8, the fall is evident after the year 1993, the first year of independent existence of Slovakia.

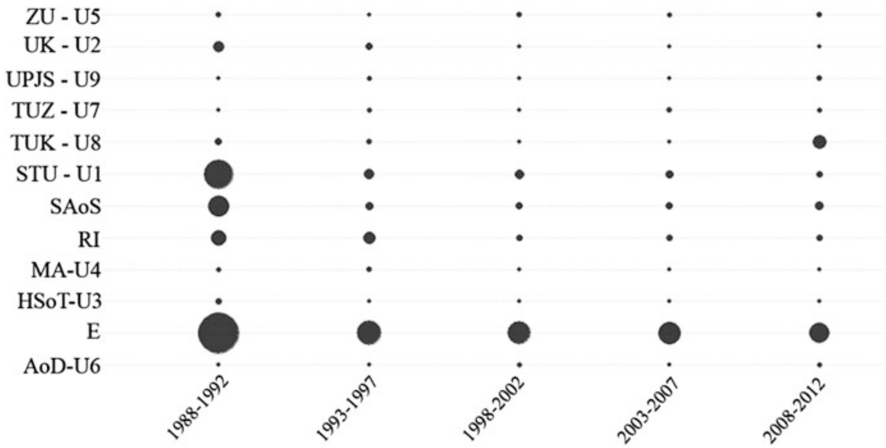

Fig. 1 Patenting activity of institutions in 1988–2012. Source: own

Czechoslovakia in the communist era was spending massive sources on defence and was among the top ten largest arms exporters in the world (Hardt and Kaufman 1996). Dual structure of the economy consisted of a strong military sector and a weaker civil sector. Duality inhibited spin-off effects from the military sector, hindered knowledge transfer and self-propagating virtuous circle between military and civilian technologies (Chiang 1990; Radosevic 1999). Typically, in many firms, concurrent military and civilian R&D and production co-existed in separated parts, but the diffusion of knowledge from military to the civil sector was not desired. Ever-present strict control of information and hierarchical vertical central planning have caused a kind of silo effect in science and technology, separation of R&D institutions from market and production. According to the socialist science and technology model, R&D was externalised, "in hands" of "science and scientific services" sector (Radosevic 1999) and technology was a commodity for trading. In other words, R&D was organised for industry, not in the industry (Radosevic 1996) and this fact is probably one of the main problems of later adaptation of Slovak businesses on new demand conditions in a market economy (inability to support own R&D and decreasing in patenting activity—Fig. 1).

Slovak enterprises are typically small or medium-size firms with low knowledge intensity and limited access to external financial sources. Only few large enterprises were applying for patents during the whole period. Table 4 shows the number of patent applications according to NACE sections in the period 1988–2012. The branches of mechanical engineering and chemical industry accounted for the highest growth in the Czechoslovak post-war economy (Table 1), and accordingly the greatest number of Slovak institutions applying for patents can be found in the same fields in the period 1989–1992 (Table 4). As already highlighted in Table 3, the number of patenting institutions has been decreasing, and the branch structure of the patents remains stable.

Table 4 Distribution of patent applications in 1988–2012 (Number of institutions in different fields of technology)

	1988–1992	1993–1997	1998–2002	2003–2007	2008–2012	Overall
Section A—Human Necessities	35	31	23	12	22	123
Section B—Performing Operations; Transporting	47	36	31	28	21	163
Section C—Chemistry; Metallurgy	63	55	54	47	39	258
Section D—Textiles; Paper	3	2	1	1	4	11
Section E—Fixed Constructions	14	7	11	4	15	51
Section F—Machine Engineering; Lighting; Heating; Weapons; Blasting	21	21	18	23	18	101
Section G—Physics	29	17	10	18	19	93
Section H—Electricity	17	11	7	8	21	64

Source: own

4 Evolution of the Regional Networks of Inventors

4.1 Networks of Inventors

At the end of the 90ties, new concepts emphasizing the systemic nature of innovation appeared as an approach of regional innovation systems (Cooke et al. 1997), taking into account the geographical proximity, as well as the concept of technological (Carlsson and Jacobsson 1997) and sectoral systems (Malerba 2002). All the three new concepts are usually presented as alternatives to national innovation systems, highlighting the dimensions of the region, technology branch or sector, and offering cross-cutting and cross-border views, and revealing limitations of the simplified notion of the national innovation system. However, the national view is critical if the political dimension of the concept of innovation systems is stressed (Lundvall 1992b). Findings with regard to knowledge, learning processes and interactions of different agents are placed at the forefront of research factors such as knowledge, networks and co-evolution processes. These factors are likely to create conditions boosting generation of innovation. Therefore the following research is aimed at analysis of the networks of inventors, which is understood as a part of the innovation system, and builds on the theoretically expected flows of knowledge between innovation actors.

The systems approach assumes that economic performance of an area (region or country) does not depend only on business performance, but also on the interactions between innovative actors in the public sector in terms of production and dissemination of knowledge. Innovations can be understood as a result of cumulative processes that are affected by institutional settings (Fischer 2001). Inventor networks are usually monitored through patent applications (Graf and Henning 2006; Cantner and Graf 2006; Fritsch and Graf 2011; Miguélez and Moreno 2013). Using patent applications and network analysis relates to the narrower definition of innovation. Analysis of innovation networks is mostly applied to regional level, as intra-regional linkages and proximity remain relevant despite the current era of globalisation. The innovation ability depends on the access to "invisible factors of production" (non-codified knowledge, sticky information) that is easier to get through the existing links in networks. Regional networks improve access of SMEs to regional knowledge. However, their true strength lies in linking to global networks. In the approach of this chapter, the links are also classified as intra-regional and inter-regional relations, to understand the importance of proximity and external links to region.

Evolution of the system leads to a growing concentration of actors in the network; the actors are clustered around key players. A critical mass of innovation actors and their collaboration is essential to the survival of specific technologies in the local system. In contrast, regions with a strong knowledge base (characterised by broad technological areas), are typical by a more fragmented network of innovators (Cantner et al. 2010). One of the main problems is to achieve cooperation between different actors, which supposedly leads to the generation of the desired output—new knowledge, innovation, economic and social benefits in a region). The actors of the innovation system have their own expectations regarding the behaviour of other parties (Belderbos et al. 2014). Reluctance to enter into partnerships of inventors also relates to the problem of appropriating the benefits arising from a common patent.

Data obtained from the database of patent applications are principally relational data (data indicating relations between entities and individuals), and social network analysis (SNA) can be used for their analysis, bearing in mind actors (nodes) present in the network and common patenting as links (edges). Once we have the adjacency matrix (matrix of relations between the inventors), by the SNA method can be expressed the size and density of the relationships, the centrality of the networks, the number of pairs or triples, diversity of the network patterns, and many other network-based properties.

Inventory networks in Slovakia are studied based on the long period from 1988 to 2012 to watch the transformation of socialistic Slovakia to a market economy. In the case of Slovakia, most of the institutions apply for patents at home (institutions registered as applicants under Slovak Office of Industrial Property). In such a case thereafter do not apply for patents under EPO or WIPO[2] or they applied for patents on the international markets only a few times. The number of patenting institutions as well as patent applications has been decreasing after 1989, and the loss of ties with the former Eastern markets and split of the Czechoslovakia should also affect the number and density of the innovative networks.

This justifies the hypothesis of a progressive fragmentation of inventory networks in Slovakia and a decreasing rate of cooperation due to transition. However, after 25 years, new stimuli for networking related to growth of the Slovak economy, integration to European economy and implementation of European regional innovation policies should result in a renewal of remaining linkages between the actors as well as to bring into patenting pool new actors and their interconnections.

The research required to collect data registered in the patent applications for the period 1988–2012 from the website of the Industrial Property Office of the Slovak Republic. The process of collection was rather complicated, as the information on each patent application exists only in a pdf file and no possibility to obtain XLS or CSV format data existed. In total, 28,510 patent applications have been reached with information on 48,170 inventors. All patent applications contained information on the names of the patent applicants, the names of inventors, addresses, description of the invention, patent classification, the state of the patent application (published in the proceedings, suspended grant, refuse), etc.

The decline in the size of inventory teams is visible in Fig. 2, visualising the gradual degradation of the main components and the creation of fragmented and crushed networks. Decomposition of the main component (the core network) is caused by the disappearing of some links, meaning completion of the former cooperation between two actors, or disappearance of actors with their links (star-type graphs of the node and the set of its edges).

The Fig. 2 recounts visual patterns of the fragmentation and disappearance of the former networks. A lower average degree of nodes (average number of links), break-down of the main components and increasing proportion of isolated actors, of course, mean much less interest in cooperation between the innovation actors and weak national and regional innovation systems.

Connections among inventors in the first period 1988–1992 form more developed networks than in the later periods in terms of higher mean degree and a lower share of isolates. In comparison to inventory network in the first period, the number of edges (links) decreased by around 64% in 1993–1997. The overall number of innovation actors (nodes) has been decreasing gradually. Hence, a structural hole in the evolution of inventory networks can be identified after 1993. It could be assumed that networks would be more developed (with more links/edges) after opening the economy and markets to innovative foreign companies, inventory networks are more and more fragmented over the time. This is, however, not the case, a potential innovation output realised in Slovakia is assigned to foreign countries (Lengyel et al. 2013). Domestic enterprises are usually small and medium

[2]These institutions are not registered like appliers under the ESPACENET database which includes EP (European published applications) database and WIPO (PCT published applications) database

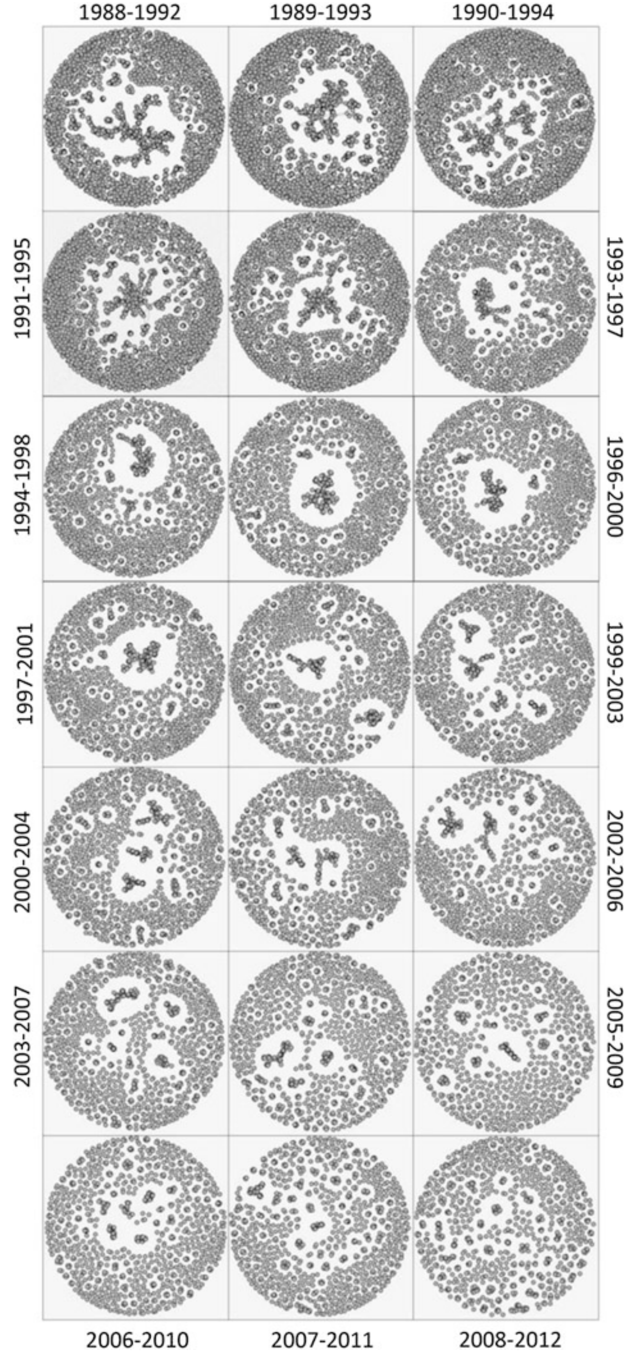

Fig. 2 Networks of inventors in Slovakia—1988–2012. Source: own

size firms, characterised by lower knowledge intensity and limited access to external funds.

The loss of actors and ties highlights the growing dependence of the Slovak economy on foreign inventions. The massive entry of foreign investors has influenced domestic innovation capacity in a rather negative way, as their research and innovation units are typically not located in Slovakia (Morvay 2013; Smith 1998). The local researchers have either relocated abroad or work in Slovakia as members of the research teams located and led out of Slovakia. Both models usually contribute to eventual patent applications in a country of investor origin.

The maturity of inventory networks is analysed with the help of network properties: the number of patent applications, the number of nodes, number of links, network density, the average node degree, centrality of the network, the number of components in the network, the number of nodes and links forming the main component, the average distance between the nodes of the main components and the proportion of isolated actors.

Also, the level of inter-regional and transnational cooperation is analysed. The individual innovative activity is defined as the number of patent applications in which an individual inventor is involved. The total number of patent applications representing a network innovation activity is assigned in a similar way to a network of inventors. Involvement in the networks (both within the country or region, inter-regional and transnational) is a measure reflecting the innovation activity of an innovation system.

Inventors (institutions or individuals) correspond to nodes of a regional inventory network, the edges between nodes correspond to at least one common patent application. The number of actors involved in the whole period in the patent applications is n. The relational data express the relationships between the pairs of inventors in the form of links, and the number of links corresponds to the number of pairs of actors which occurred together as partners in at least one patent application. A maximum possible number of links is $n(n-1)/2$. A node is assigned to a region if at least one inventor on a patent application is its resident. The analysis of the inventory networks is based on additional characteristics of the networks as defined in the graph theory (Cohen and Havlin 2010):

- **The edges/nodes ratio** is defined as the number of edges divided by the number of nodes; the value varies between 0 and the maximum value of is $(n-1)/2$.
- **The number of components and the size of the main component**: connected components are sub-graphs in which any two nodes are connected by a path of the unbroken links. The connected component represents a group of actors who are interconnected directly or via other actors in the component. The main component is comprised of the largest number of linked actors (Hanneman and Riddle 2005).
- **The share of the main component (%)**: percentage of the number of nodes contained in the main component. A proper interconnection between the actors should be evident by a large share of main component of the cooperating actors.

- **Intraregional, interregional and transnational dependence**: the indicator is determined as the share of the inventors having their address outside the region or abroad.
- **The average distance in the main component**: distance between two nodes is the number of links on the shortest possible path from one actor to another. In a dense and connected network the shortest distance between two actors is low, reflecting the relatively rapid flow of information. As the monitored networks are not fully connected, the analysis deals only with the average distance in the main component only.
- **Number of isolates and share of isolates (%)**: the isolates are actors with no any patent cooperation. The high percentage of isolates reflects the existence of a group of single actors outside of the innovation system environment.
- **Centrality**: the value of *CD(n*)* identifies the most important node within a graph, involved in the largest number of interactions, i.e. the most prominent institution or individual in a whole network, a key innovator or accelerator of the innovation performance. An individual degree centrality is defined as the number of links incident upon a node and the whole network centrality is $\boldsymbol{C_D} = \frac{\sum_{i=1}^{g} [\boldsymbol{C_D}(\boldsymbol{n}^*) - \boldsymbol{C_D}(\boldsymbol{n_i})]}{\max \sum_{i=1}^{g} [\boldsymbol{C_D}(\boldsymbol{n}^*) - \boldsymbol{C_D}(\boldsymbol{n_i})]}$.
- **Density of the network**: If n indicates the size of the network (number of nodes) and d_i the number of connections passing through the node i, $(i = 1, \ldots, g)$, the network density D of the network is defined as the ratio of the total number of edges (links) in the network to the total number of all possible edges: $D = \sum_{i=1}^{g} d_i / (g^2 - g)$. The density of the network reflects the diffusion of information between nodes, or the extent of the social capital within a network. Denser, interconnected networks are able to mobilize their resources more effectively, as well as to address emerging issues (research questions) in different ways (Hanneman and Riddle 2005).
- **The degree of a node and average node degree**: the measure of the number of direct links of a given actor. The higher the average node degree across the whole network, the greater it's power to create mutual innovation-based relations between the actors.

  Actors having more links compared to others have an advantageous position, as more links mean more alternative ways to ensure their needs. Thanks to their advantageous position, they act as intermediaries of knowledge within their networks.

The set of network characteristics can serve to monitor the extent, density, centrality and other qualities of cooperation among innovation actors within the country or regional innovation systems. The following Table 5 depicts the development of network density, network centrality and evolution of the number of edges in the number of nodes. First, the decline in the number of nodes is apparently stabilised at around 1000 actors, which is about 30% lower than at the beginning of the period. Even greater is the loss of connections. Cooperation on patent applications is much smaller, the number of connections decreased from 4545 in 1988–1992 to a little over 1000 in the last 5-year periods. Declining cooperation tendency is captured by the edges/nodes ratio.

In Slovakia, the R & D exhibits structural gap. Old companies have ceased their original innovation activities, while new institutions potentially replacing the original inventors are sporadic. In comparison to period 1988–1992, the number of edges (links) in the period 1993–1997 decreased by about 64%. The loss in the number of connections led to fragmentation of the whole innovation system. In the beginning, the main component consisted of 507 members, but at the end, it counted only 28 members. In the period 1992–1996, altogether 15% of actors disconnected from the main component and after separation from the Czech Republic, the next 27% of actors have left the main component. In the period 1997–2001, nearly 40% of new actors with at least 5 links appeared. However, this new research teams form only a small number of links (maximum 10).

Fragmentation is a huge problem, as the dominance of small groups of inventors, increasing proportion of the isolated actors, and undermined relations inside the system indicate low functioning innovation system. The network analysis also confirms the low level of social capital in relationships, lack of trust and so far poor results of the new innovation policy. Hence, an urgent focus of innovation policy in Slovakia should be on building trust and links and to overcome present fragmentation, and to bring new actors onto the national innovation stage. Another way of improvement exists in the concentration on the regional innovation systems, which are studied in the following subsection.

4.2 Regional Networks of Inventors

A more detailed view on the knowledge production process can be explained by analysis of the regional inventor networks. The importance of geographic proximity shifts the attention to regional level towards regional innovation systems (Cooke et al. 1997; Doloreux and Parto 2005), mainly due to limits of non-codified knowledge transfer.

In the socialistic period, Central and Eastern European countries have advocated linear innovation approach with a limited horizontal cooperation (Godin 2006). These hierarchies led especially Czechoslovakia to the integration of the whole branch including R&D into one concern and to limited cross-branch cooperation (Von Hirschhausen 1999; Radosevic 1999). Regional horizontal economic relations were not in the focus of the central planning.

Fritsch and Graf (2011) analysed how different history and macroeconomic conditions shaped regional innovation activities. Their findings for the East and West Germany indicate significant structural differences between their innovation networks. Also in the case of Slovakia, a long time series of the statistics of patent applications makes possible to evaluate the path dependence and evolutionary dynamics of the regional inventory networks. Deindustrialisation particularly

Table 5 Networks characteristics—inventors in Slovakia 1988–2012

Slovakia	*1988-1992*	*1989-1993*	*1990-1994*	*1991-1995*	*1992-1996*	*1993-1997*	*1994-1998*	*1995-1999*	*1996-2000*	*1997-2001*	*1998-2002*	*1999-2003*	*2000-2004*	*2001-2005*	*2002-2006*	*2003-2007*	*2004-2008*	*2005-2009*	*2006-2010*	*2007-2011*	*2008-2012*
Number of patent applications:	1364	1544	1577	1502	1478	1176	1124	1091	1083	1135	1180	1165	1163	1080	1027	1008	967	937	1030	1059	986
Number of nodes:	2393	2544	2428	2200	2080	1616	1483	1417	1364	1404	1346	1350	1336	1302	1210	1174	1109	1032	1094	1124	1124
Number of edges	4545	4563	3899	3285	2920	2091	1863	1797	1873	1849	1815	1843	1830	1772	1642	1464	1318	1111	1216	1363	1475
The edges/nodes ratio	1.899	1.794	1.606	1.493	1.404	1.294	1.256	1.268	1.373	1.317	1.348	1.365	1.370	1.361	1.357	1.247	1.188	1.077	1.112	1.213	1.312
Number of components	704	790	821	800	813	695	669	645	620	640	619	617	608	580	544	565	545	530	543	529	485
Size of the main component	507	440	376	309	217	147	149	165	148	150	97	79	70	56	104	72	66	41	28	36	28
Share of the main component (%)	21.19	17.3	15.49	14.05	10.43	9.097	10.05	11.64	10.85	10.684	7.207	5.852	5.24	4.301	8.595	6.133	5.951	3.973	2.559	3.203	2.491
Average distance in the main component[a]	6.458	5.624	5.957	6.031	4.802	4.208	3.770	3.408	3.261	3.476	3.199	3.232	3.401	3.677	3.338	3.195	3.156	2.301	1.880	2.313	2.235
Share of isolates (%)	12.45	13.99	16.39	18.91	21.73	25.06	26.9	27.03	27.57	27.564	28.97	28.07	28.59	26.65	27.69	30.49	31.29	31.98	30.71	29.45	25.98
Number of isolates	298	356	398	416	452	405	399	383	376	387	390	379	382	347	335	358	347	330	336	331	292
Centrality[b]	0.025	0.022	0.018	0.015	0.015	0.020	0.026	0.029	0.026	0.028	0.026	0.023	0.020	0.019	0.028	0.020	0.022	0.021	0.017	0.013	0.018
Density	0.002	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.0019	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Average node degree	7.597	7.175	6.423	5.973	5.615	5.176	5.025	5.073	5.493	5.268	5.394	5.461	5.479	5.444	5.428	4.988	4.754	4.306	4.446	4.851	5.249

Source: own

[a]Based on the average shortest path

[b]Based on degree centrality

Table 6 NUTS3 regions in Slovakia

NUTS code	The name of the region
SK042	Košice region
SK041	Prešov region
SK032	Banská Bystrica region
SK031	Žilina region
SK023	Nitra region
SK022	Trenčín region
SK021	Trnava region
SK010	Bratislava region

Source: own

affected sectors and regions with poor ability to respond to rapid liberalisation. The main factors of the decline of regional economies in 90ties were rapid industrialisation, regional dependence on single large enterprise, a one-sided industrial structure with a concentration of the armaments industry, heavy engineering, mining, steel or chemical industries. For the regional innovation focus, Slovakia is divided into eight NUTS III regions (Table 6).

Figure 3 depicts the development of the regions using the network indicators defined in the previous subsection. The size of the circles reflects the values of particular network characteristics to compare the regional evolutionary dissimilarities. The decrease in the number of inventors is general, ongoing in all regions. Typically, only a few regional enterprises ensure patenting activity, and similarly, the number of patent applications is going down, with the exception of the Košice region. In the Bratislava region, the number of inventors in the main component decreased during 20 years by 94% (from 377 inventors in 1988–1992 to only 23 in 2008–2012).

In the Bratislava region, there are more than 55% of all employees of science and research, which shows a regional imbalance in the distribution of R&D human resources. Therefore, it is necessary to examine the Bratislava region separately, as it is critical for the overall country innovation output. Decreasing size of the research teams is shown on Fig. 4 and Table 7, displaying dismantling of the main component. In the beginning, there were 1232 inventors creating 2739 links in the Bratislava region, while in the last period only 469 inventors with 747 links in the patent applications. The capital region of Bratislava shows similar pattern of development as the whole country.

In comparison to the country level, regional focus gives a possibility to find out new evidence on the intra- and inter-regional links, as well as the transnational cooperation (Table 7). The principal economic and R&D centre of the country provides only a little impetus to other regions, having 68% intraregional partners within the Bratislava region.

One-quarter of the existing partnerships in patent applications is inter-regional, mostly with the neighbouring regions in the west of the country. Transnational

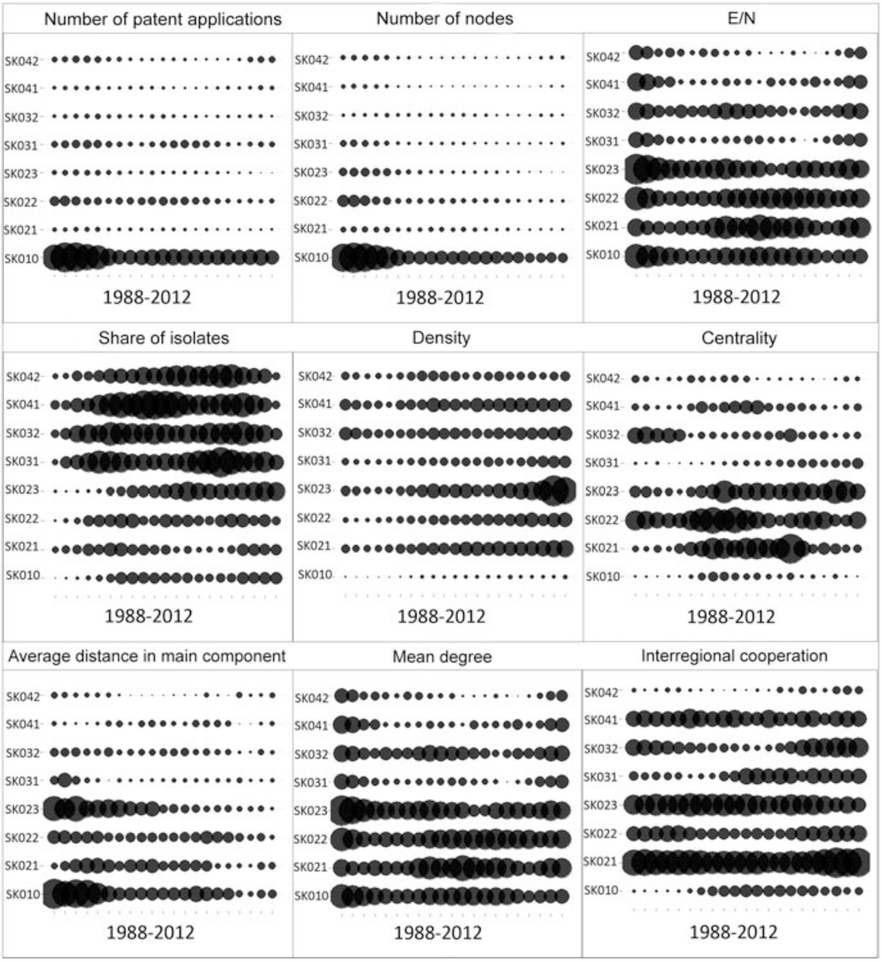

Fig. 3 Network properties of the 8 Slovak regions (NUTS3) in 1988–2012. Source: own

cooperation has not been well developed before, and it is still decreasing. Although the economy is open, the innovation sector continues in the previous path of separated science, education and business, having only formal relations in the triple helix innovation system. Most of the institutions are living in the comfort zone of publicly financed fundamental research and using European structural funds for non-registered intellectual property products. Only Žilina region did not undergo decomposition of its regional networks (Fig. 5).

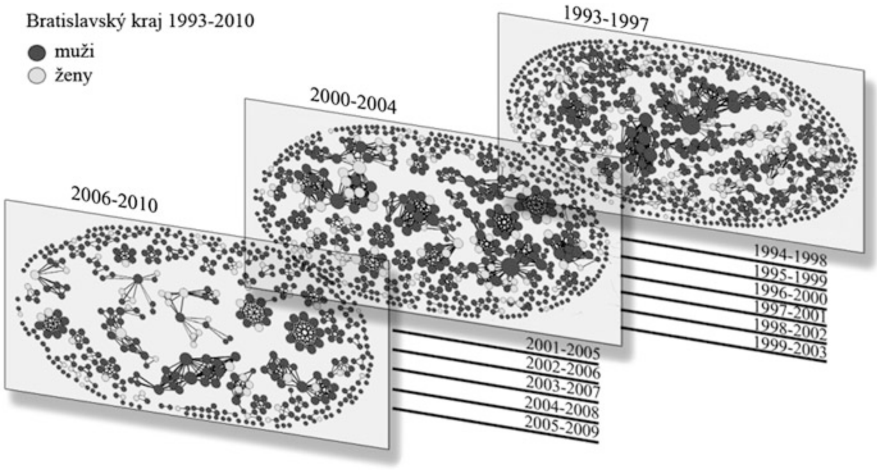

Fig. 4 Networks of inventors in Bratislava region 1993–2010. Source: own

5 Conclusions

The number of inventors in Slovakia decreased more than 50% during the 25 year period... During the period 1988–2012, almost all organisations (universities, research institutions, Slovak Academy of Science and enterprises) suppressed their patent activity, and the largest decline was found after the year 1993. Fragmentation and decline in the inventory networks suggest structural hole in the innovation network evolution in Slovakia. This structural hole is mirrored in the disintegration of research teams which have not been replaced by new research networks.

The innovation systems, whether national or regional, are underdeveloped and lack the main substance—well-functioning linkages between the actors. Creation and diffusion of knowledge, skills and best practices are not well used and established. A later small increase in the number of patent applications is not accompanied by an appropriate increase in the number of inventors. The share of single inventors—individuals who are also appliers on the patent applications is higher in the last periods in comparison with periods of Slovak transformation. An indication of unleashing the innovation potential can also be found in a slightly increasing cooperation among a smaller number of inventors. Regional networks of inventors, if formed, are mostly star-shaped clusters (all actors are connected to one central inventor), less usual are triangles or dyads.

Inter-regional dependence shows dominant position of the west and east Slovakia centers—Bratislava and Košice. Cooperation or dependence in innovation networks exists on the side of six regions in relation to Bratislava and Kosice regions, although the highest proportion of the links exists within the regions showing the greatest importance of the regional than national innovation systems. The decrease in the patent performance has also been caused by the split of Czechoslovakia and

Table 7 Networks characteristics—inventors in Bratislava region 1988–2012

Bratislavský región SK010	*1988-1992*	*1989-1993*	*1990-1994*	*1991-1995*	*1992-1996*	*1993-1997*	*1994-1998*	*1995-1999*	*1996-2000*	*1997-2001*	*1998-2002*	*1999-2003*	*2000-2004*	*2001-2005*	*2002-2006*	*2003-2007*	*2004-2008*	*2005-2009*	*2006-2010*	*2007-2011*	*2008-2012*
Number of patent applications:	599	694	685	620	575	417	352	356	369	385	400	403	400	380	362	369	379	368	376	385	335
Number of nodes:	1232	1304	1238	1102	1010	739	616	593	607	628	606	614	602	604	567	542	526	465	471	485	469
Proportion of women actors (%)	17.13	17.33	17.93	17.88	17.33	15.29	14.29	14.17	13.67	14.809	15.68	16.78	16.61	19.7	19.75	18.45	16.54	16.77	14.86	15.46	14.71
Proportion of men actors (%)	82.87	82.67	82.07	82.12	82.67	84.71	85.71	85.83	86.33	85.191	84.32	83.22	83.39	80.3	80.25	81.55	83.46	83.23	85.14	84.54	85.29
Intraregional cooperation(%)	68.91	70.71	71.97	71.78	71.88	71.18	68.67	64.92	64.09	65.605	63.2	64.01	65.28	64.24	65.26	66.05	64.83	65.59	64.33	67.84	67.38
Interregional cooperation (%)	20.62	20.02	19.22	19.6	20.79	22.87	25.65	28.84	29.65	29.618	31.68	30.94	30.23	30.63	29.28	28.97	29.47	27.31	28.66	25.57	25.8
Transnational cooperation (%)	10.47	9.279	8.805	8.621	7.327	5.954	5.682	6.239	6.26	4.7771	5.116	5.049	4.485	5.132	5.467	4.982	5.703	7.097	7.006	6.598	6.823
Number of edges	2739	2735	2389	1982	1695	1167	981	979	1095	1102	1107	1152	1119	1071	1038	966	847	669	705	745	747
The edges/nodes ratio	2.223	2.097	1.93	1.799	1.678	1.579	1.593	1.651	1.804	1.7548	1.827	1.876	1.859	1.773	1.831	1.782	1.61	1.439	1.497	1.536	1.593
Number of components	273	310	314	303	297	249	222	216	219	225	207	209	200	197	179	181	186	179	177	179	170
Size of the main component	377	329	290	244	149	92	93	121	112	117	71	68	56	48	65	57	49	27	25	27	23
Share of the main component (%)	30.6	25.23	23.42	22.14	14.75	12.45	15.1	20.4	18.45	18.631	11.72	11.07	9.302	7.947	11.46	10.52	9.316	5.806	5.308	5.567	4.904
Average distance in the main component[a]	6.266	5.525	6.004	5.905	4.753	3.645	3.075	3.062	2.996	3.0718	2.988	3.05	3.117	3.664	3.262	2.956	2.873	1.981	1.706	2.211	2.28
Share of isolates (%)	7.792	9.126	10.34	11.89	13.66	15.97	18.83	19.06	18.45	17.994	17.49	17.59	17.44	15.89	15.34	16.42	16.35	19.14	18.47	18.97	18.98
Number of isolates	96	119	128	131	138	118	116	113	112	113	106	108	105	96	87	89	86	89	87	92	89
Centrality[b]	0.028	0.024	0.021	0.027	0.028	0.035	0.05	0.059	0.057	0.0504	0.045	0.046	0.039	0.037	0.048	0.032	0.034	0.028	0.038	0.027	0.021
Density	0.004	0.003	0.003	0.003	0.003	0.004	0.005	0.006	0.006	0.0056	0.006	0.006	0.006	0.006	0.006	0.007	0.006	0.006	0.006	0.006	0.007
Average node degree	8.893	8.39	7.719	7.194	6.713	6.317	6.37	6.604	7.216	7.0191	7.307	7.505	7.435	7.093	7.323	7.129	6.441	5.755	5.987	6.144	6.371

Source: own

[a]Based on the average shortest path

[b]Based on degree centrality

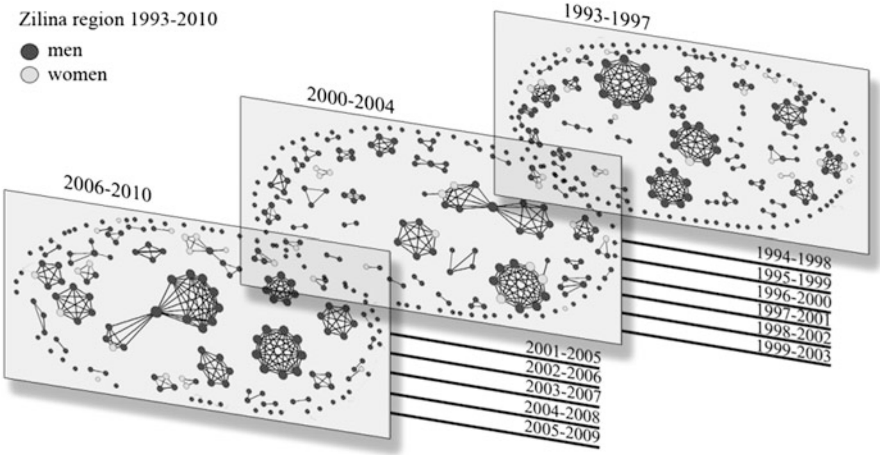

Fig. 5 Networks of inventors in Žilina region 1993–2010. Source: own

disruption of previous cross-border innovation networks. Vanishing of innovation linkages with institutions from the Czech Republic is reflected in networks primarily in the period 1992–1996, when approximately 15% of the former inventors with more than 5 connections were completely disconnected from the Slovak main network component.

A heritage of the socialistic system and following path dependence exist in the separated science, education and business components and a more comfortable focus on fundamental research. Separated roles of the knowledge sectors established by the former central planning are firmly preserved and cause communication gaps.

A well working triple helix system of industry-university-government relationships could be a driver of innovation performance. However, the relations of the triple helix institutions in Slovak regions are rather formal, non-productive and inefficient, with the exception of the Žilina region.

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International Collaboration and Spatial Dynamics of US Patenting in Central and Eastern Europe 1981–2010

Balázs Lengyel and Mariann Leskó

Abstract How did post-socialist transition and a parallel shift in international labor division restructure regional innovation systems in Central and Eastern Europe? This question is increasingly important, because current EU innovation policy is combined with regional development in Smart Specialization Strategies; however, spatial trends of innovation in Central and Eastern Europe are not fully understood which might lead to less than perfectly efficient policy. In this paper we describe the spatial dynamics of inventor activity in the Czech Republic, Hungary, Poland and Slovakia between 1981 and 2010—a period that covers both the late socialist era and the post-socialist transition. Cleaning and analyzing the publicly available data from the United States Patent and Trademark Office we illustrate that Central and Eastern European patents made in international co-operations with partners outside the region receive more citations than those Central and Eastern European patents that lack international co-operation. Furthermore, the technological portfolio of the former patents has become increasingly independent from the technological portfolio of the latter class. A town-level analysis of the applicant-inventor ties reveals that inventors have started to work for foreign assignees in those towns where no innovation activity had been recorded before. However, the positive effect does not last long and patenting seems to be only periodic in the majority of these towns. Therefore, innovation policy in Central and Eastern European countries, as well as in

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other less developed regions, shall foster synergies between international and domestic collaborations in order to decrease regional disparities in patenting.

1 Introduction

The growing scale of international collaboration in knowledge production has been a frequently reported phenomenon since globalization in science and patenting sped up (Archibugi and Michie 1995; Guellec and de la Potterie 2001; Wagner et al. 2015). Scholars also warn us that cross-country co-operation is still weak in areas like the European Union where research integration is an explicit aim (Picci 2010; Chessa et al. 2013) and thus suggest policy focusing on international labor division in science and innovation. International collaboration is important in innovation because a greater variety of knowledge can be combined in the invention process when involved parties are from different locations and institutional settings (Boschma 2005; Hoekman et al. 2009; Bathelt et al. 2010; Hansen 2015). For example, the number of technological claims and thus the cover of legal protection and the value of the patents are larger in cases of international co-operation compared to domestically-owned patents (Beaudry and Schiffauerova 2011). Furthermore, international knowledge flows can bring dynamics to domestic innovation and regional development when the knowledge of internationally active agents spills over to co-located firms and inventors (Jaffe et al. 1993; Breschi and Lissoni 2001; Varga and Schalk 2004; Guan and Chen 2012). This latter aspect is especially important for less developed countries that can benefit from international collaborations in their knowledge production (Penrose 1973; Goldfinch et al. 2003; Montobbio and Sterzi 2013; Marzucchi et al. 2015; Grillitsch and Nilsson 2015; Fitjar and Huber 2015; Varga and Sebestyén 2016). Although the territorial dynamics of patenting are often analyzed in developed and also in developing countries (Crescenzi et al. 2007, 2012), very little is known about the effect of international collaborations on the spatial dynamics of knowledge production (e.g. the start and survival of innovation activities in towns).

In this paper we look at the spatial dynamics of patenting at the United States Patent and Trademark Office (USPTO) of four Central and Eastern European (CEE) countries—the Czech Republic, Hungary, Poland, and Slovakia—in the 1981–2010 period on town level. These countries are often referred to as the Visegrad countries and were part of the Eastern Bloc and COMECON before 1991 (the Czech Republic and Slovakia constituted Czechoslovakia at that time). They have gone through a major economic transition from planned economy to market economy in the 1990s and joined the European Union in 2004. The four selected countries have always been lagging behind the average EU15 level in terms of innovation performance; for example, only the best performing CEE country (Czech Republic) could exceed the worst performing EU15 country (Portugal) in 2016 (European Commission 2016). However, the selected countries produced 3 times more USPTO patents altogether over the investigated period than the rest of CEE transition economies (based on information described in Sect. 2.1).

Our historical case is particularly interesting, because the radical political and economic turn was followed by a sharp fall in innovation activities in the early 1990s mainly because R&D-intensive state-owned companies were either closed down or got privatized. The latter process resulted in a thorough portfolio-cleaning (Radosevic 1999; Radosevic and Auriol 1999; Marinova 2001). Globalization gathered speed simultaneously, opening up new possibilities of international collaborations for CEE researchers but foreign control has increasingly dominated patenting, posing a riddle for national and regional policies (Wagner et al. 2015). The question how foreign-controlled innovation should be handled in CEE is still not clear. On the one hand, international R&D collaborations embodied in foreign-owned patents can be very important sources of new knowledge that can spill over to domestic firms (Penrose 1973; Goldfinch et al. 2003). On the other hand, foreign firms can crowd out domestic firms by taking over too much of the innovation capacities (Radosevic 2002; Lengyel et al. 2015). Although large efforts have been devoted to strengthen regional and national innovation systems in CEE after the countries joined the EU (Blažek and Uhlíř 2007; Suurna and Kattel 2010), there is a common agreement that innovation policy could not cope with its duties due to weak local institutions and poorly developed innovation links between local actors (Havas 2002; Inzelt 2004; von Tunzelmann and Nassehi 2004; Radosevic and Reid 2006; Varblane et al. 2007; Radosevic 2011). More recently, the efforts of EU innovation policy and cohesion policy are combined in the Smart Specialization Strategies, which is mostly based on best practices of EU15 regions (McCann and Ortega-Argilés 2015; Morgan 2015; Muscio et al. 2015). However, the lack of deep understanding of CEE trends could lead to less efficient policy and therefore, further research is needed.

To contribute to the policy-related discussion, we outline three major trends of collaboration of CEE inventors with non-CEE and CEE firms in patenting. The paper has a descriptive nature; we demonstrate various associations in the data but do not aim to explore the causal relationship between international R&D collaborations and domestic innovation. We collect information about those USPTO patents that contained at least one CEE inventor over the investigated period and test three hypotheses formulated on the basis of the above literature.

Hypothesis 1 (H1) *The USPTO patents assigned to non-CEE firms and invented or co-invented by at least one CEE inventor receive more citations than USPTO patents assigned to CEE firms and invented or co-invented by at least one CEE inventor*. The rationale behind *H1* is the positive association between international collaboration and other patent quality indicators (Beaudry and Schiffauerova 2011; Guan and Chen 2012). Although criticized in the literature (Beaudry and Schiffauerova 2011) the number of citations has been frequently used to predict patent quality (Trajtenberg 1990; Mowery and Ziedonis 2002; Hall et al. 2005). Another reason to choose this indicator is that it is easier to access than other types of measurement. The verification of *H1* would imply that policy should foster international collaborations in patenting because participating inventors can learn from these projects.

However, the question whether the knowledge of these inventors can spill over to other co-located inventors is less clear (Penrose 1973; Breschi and Lissoni 2001; Goldfinch et al. 2003) because brain-drain from domestic to foreign firms can reduce the absorptive capacity of domestic R&D (Lengyel et al. 2015). Furthermore, the technological distribution of foreign- and domestically-controlled innovation can be very different, which can also hinder the effect of knowledge spillovers because CEE inventors active in international projects might gain experience in very different fields than domestic CEE inventors work in (Radosevic and Auriol 1999). Therefore, we have to better understand if foreign-controlled patents have restructured CEE innovation over the post-socialist transition similarly as it was shown by using other type of R&D data (Radosevic 2002). Hypothesis 2 (*H2*): *There is a significant difference between the technological distributions of the group of patents invented or co-invented by at least one CEE inventor and assigned to non-CEE firms and the group of patents invented or co-invented by at least one CEE inventor and assigned to CEE firms.*

Finally, we test the effect of international collaboration on the spatial dynamics of CEE patenting, which might be important because regions might benefit from the access to external R&D funds and thus produce more innovation (Bathelt et al. 2004; Boschma 2005; Hoekman et al. 2009). On the contrary, inventors might also take advantage of geographical proximity and shared institutional background when collaborating with domestic firms (Breschi and Lissoni 2001; Boschma 2005). In order to gain a better understanding, we look at the start and survival rate of invention activities in CEE towns depending on the two types of collaborations. Hypothesis 3 (*H3*): *The collaboration of CEE inventors with non-CEE assignees increases the likelihood that patenting appears and survives in towns, as opposed to the collaboration with CEE assignees.*

2 Materials and Methods

2.1 Data

Using techniques for USPTO data collection and organization developed recently by (Leydesdorff 2004; Leydesdorff and Bornmann 2012; Leydesdorff et al. 2014), we have downloaded the full set of patents, in which at least one inventor participated from the Czech Republic, Poland, Slovakia, and Hungary between 1981 and 2010 on August 5, 2013. USPTO data was used instead of European Patent Office (EPO) data because the accession of CEE countries into the common EU market may have affected the number of EPO patent applications for reasons other than inventions (Hall et al. 2012). Also, USPTO patents can be expected to capture globally competitive innovation output better than EPO data (Ginarte and Park 1997; Hall et al. 2007).

The download retrieved 5777 patents. The data includes the name and address of inventors and assignees and the number of citations the patent received until the date of download. The dataset also contains the full codes for technological fields according to Cooperative Patent Classification (CPC) that is the harmonized classification system based on the existing former classifications of ECLA (European Classification) and USPS (United States Patent Classification).[1]

This was followed by a thorough cleaning process concerning the technological field of patents, the name of assignees and CEE inventors and the name of the town of assignee locations and CEE inventor home addresses. We had to exclude those patents that could not be cleaned. As a result, the data contains 5078 patents from 1570 assignees located in 47 countries and 11,405 inventors located in 57 countries. In the next step, we identified the geo-coordinates of assignees and CEE inventors based on the cleaned names of towns. In the last step, we matched NUTS3 region codes and population sizes to every CEE town in our data from a publicly available EUROSTAT database.[2]

We provide further information on data collection, cleaning and patent exclusion criteria in Appendix 1.[3]

2.2 Methods

In order to test *H1*, we compared the total number of citations of patents assigned to non-CEE firms to patents assigned to CEE firms by using two methods. First, we binned the data into 5-year periods and applied the *U*-test (see also as Wilcoxon–Mann–Whitney test) for each period. This method is a non-parametric analog of the t-test but we do not have to assume that the dependent variable is normally distributed, which is very important because citation distributions are typically strongly skewed to the right. If the null hypothesis is verified, the case that a patent assigned to non-CEE firms exceeds a patent assigned to CEE firms in terms of total number of citations has equal probability to the contrary case when the number of citations of patents assigned to CEE firms is higher. A significant test would reject the null hypothesis and the comparison of rank sum values to the expected values can enable one to detect which distribution is greater. Second, we visualized the distribution of citations of patents in both groups and for the full 1981–2010 period on a log-log scale and checked whether one fitted curve could describe both distributions.

For testing *H2*, we compared the technological distribution of patents assigned to non-CEE firms to patents assigned to CEE firms and tested the independence of the

[1]Description of the classification system at http://www.cooperativepatentclassification.org

[2]Assess at http://ec.europa.eu/eurostat/web/nuts/correspondence-tables/postcodes-and-nuts

[3]The cleaned dataset that contains all necessary information for the analysis can be retrieved from http://datadryad.org/review?doi=doi:10.5061/dryad.5c820

categorical variables of technological class versus the type of assignees with Pearson's chi-squared test and the Fisher's exact test. The inclusion of the latter test is important if we want to assess the independence of the variables over time because splitting the data leads to cells with low expected values. We performed the tests on the basis of the full 1981–2010 period and on a 5 year and 1 year basis as well in order to understand the dynamics of technological change. A significant result would suggest a dependent relationship between the type of assignees and the technological classification of patents.

Finally, we binned the data into 5-year periods and aggregated the inventor-assignee links to the town level for mapping purposes and illustrated the change in the spatial patterns of domestic and international collaboration in CEE patenting. Then, we constructed a panel of CEE towns where at least one inventor was found over the full 1981–2010 period and ran two types of pooled probit regressions to test *H3*. First, the binary dependent variable is *ENTRY* that is only equal to 1 at period t if at least one inventor resides in the town at period t but not at t − 1 and 0 otherwise. Second, the binary dependent variable *EXIT* is only equal to 1 at period t if at least one inventor resides in the town at period t − 1 but not at t and 0 otherwise. For example, if inventors reside in the CEE town only in periods 1986–1990, 1991–1995, and 2001–2005; *ENTRY* is equal to 1 in periods 1986–1990 and 2001–2005, while *EXIT* is equal to 1 in periods 1991–1995 and 2001–2005.

We used dummy variables to estimate the effect of international collaborations on the likelihood that patenting starts and survives in CEE towns in comparison to domestic collaboration. The indicator $NONCEE_{it}$ takes the value of 1 if the inventors in town i worked solely for non-CEE assignees at period t and 0 otherwise. Similarly, the variable CEE_{it} takes the value of 1 if the inventors in town i worked solely for CEE assignees (be the assignees located in identical or in other CEE towns) at period t and 0 otherwise. The baseline category of the regression is the group of those CEE towns where inventors cooperate with both non-CEE and CEE inventors at period t, which is mutually exclusive with the above two groups. Significant point estimates would suggest that starting and finishing innovation activities have significantly different probabilities in the above defined groups than in the baseline group. In order to track and compare these probabilities over time, we introduced period fixed effects that are interacted with the above explanatory variables. Significant estimates of the interaction term would suggest significant change of the explanatory variables over time. The formula of the estimation is given by

$$Y^*_{it} = \beta_1 CEE_{it} + \beta_2 NONCEE_{it} + \beta_3 CEE_{it} \times T_t + \beta_4 NONCEE_{it} \times T_t + \gamma D_i + \delta POP_i + \theta T_t + \varepsilon_{it}, \quad (1)$$

where

$$Y = \begin{cases} 1 & \textit{if } Y^* > 0 \\ 0 & \textit{otherwise}. \end{cases}$$

D_i denotes a combination of country and regional dummies. Country dummies are used in order to control for institutional differences and also for deviation in spatial dynamics across CEE countries. Further regional dummies reflecting the NUTS3 regions of European classification are used to control for unobserved regional differences within countries (e.g. R&D infrastructure). POP_i refers to the log-transformed value of population of town *i* in year 2010 that is used to control for the type of towns; and T_t refers to time fixed-effects. The point estimates and standard errors were calculated by the maximum likelihood method.

3 Results

The results of the paper are divided into two parts. In the first step, we describe the trend of international collaboration and the share of foreign assignees; illustrate how internationally collaborative patents differ from domestic patents in terms of number of citations and technological profile and test *H1* and *H2*. This is followed by a geographic investigation of assignee-inventor ties on the town level, in which we test *H3*.

3.1 International Collaboration, Impact and Technological Profile of CEE Patenting

Figure 1a and b illustrate a significant acceleration of international co-operations between CEE inventors and non-CEE assignees over the 1990s. This may be associated with the regime change in the post socialist countries, when markets became more open and thus, working with assignees from other countries became accomplishable. The high share of non-CEE assignees found here supports the idea (Lengyel et al. 2015) that international collaboration dominates innovation in CEE countries to a larger extent than in more developed innovation systems. Furthermore, CEE inventors not only worked for a growing number of non-CEE assignees, but collaboration with non-CEE inventors became very important as well. Figure 1c illustrates that the number of CEE inventors fell dramatically from the middle 1980s and only started to rise again in the mid-1990s. Meanwhile, the number of non-CEE co-inventors grew over the 1990s, and the acceleration only slowed down in the 2000s, when the ratio almost reached 50% (Fig. 1d). These illustrations are based on yearly distributions because the number of observations does not allow for the aggregation for longer periods.

In order to illustrate the difference in the number of citations between patents assigned to CEE firms and patents assigned to non-CEE firms, we binned the distributions into 5-year intervals to avoid the problem of low numbers; calculated the mean and standard deviation and compared them in Fig. 2a. Naturally, the

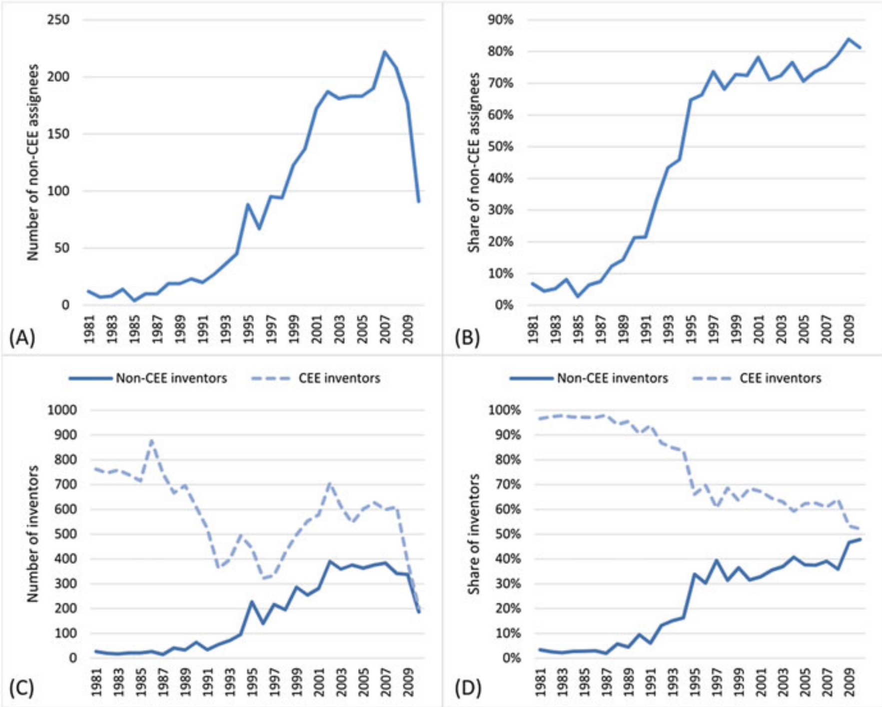


Fig. 1 Non-CEE assignees and inventors working with CEE inventors, on yearly basis, 1981–2010. (**a**) Number of non-CEE assignees weighted by the number of patents filed by them. The result is identical when using the non-weighted raw number of individual assignees. The sharp decline in 2009 is not the result of data cleaning and might be due to the temporal drop related to the post-2007 financial crisis as it was demonstrated in other cases (Lundin 2011; Lee et al. 2015). (**b**) Share of non-CEE assignees. The ratio of non-CEE assignees are only slightly more than 5% in 1981 and reach more than 80% at the end of the period. (**c**) The number of CEE- and non-CEE inventors authoring CEE patents weighted by the number of authored patents. (**d**) Share of non-CEE and CEE inventors authoring CEE patents weighted by the number of authored patents

average citation falls near the end of the period, since old patents had more time to be discovered and cited than the young ones. With having this in mind, we observe that the patents of non-CEE assignees are at least two times more cited on average than the patents of CEE assignees.

However, the citations are not normally distributed in either groups and can be better described by a power-law (Fig. 2b), which is typical for a variety of empirical data, including patents (Clauset et al. 2009; Gao et al. 2010; O'Neale and Hendy 2012). One can observe a slightly higher probability of CEE patents at the lowest value interval but the *P* value is higher for the non-CEE group in almost all other intervals. This suggests that the negative exponent is smaller in the case of non-CEE patents. Indeed, the solid line fitted to the medium values of the non-CEE distribution by hand has a slightly higher fit ($R^2 = 0.34$) than the one fitted to the CEE patents' distribution ($R^2 = 0.25$).

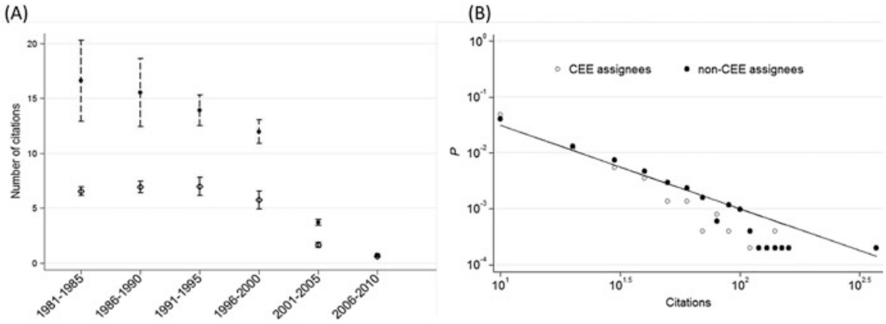


Fig. 2 Citation distributions of patents assigned to CEE and non-CEE firms. (**a**) The mean and standard deviation of citations per patent. *Black dots* and *dashed* ranges depict the mean and standard deviation of patents assigned to non-CEE firms. *Hollow diamonds* and *solid* ranges depict the mean and standard deviation of patents assigned to CEE firms. (**b**) Probabilistic distribution of citations on log-log scale, 1981–2010. Citations of CEE and non-CEE patents were binned into 10^1 intervals for *P* calculation. The slope of the *solid line* is −1.5

In a next step, we binned the data into 5-year periods to collect enough observations and applied *U*-test to assess if there was significant difference across the above distributions; results are reported in Table 1. The *P* values are below 0.001 in the majority of periods and it is 0.012 in the 2005–2010 period. Based on recognized standards of statistical significance, we can reject the null hypothesis of identical distributions. The comparison of rank sum and expected values by types of assignee confirms that the citations of patents owned by non-CEE firms are higher in every period than the citations of patents owned by CEE firms. Therefore, *H1* is verified. The result suggests that international co-operation results in a better quality of invention, if one accepts the number of citations as an indicator of quality (Trajtenberg 1990; Mowery and Ziedonis 2002; Hall et al. 2005).

In order to evaluate whether technological portfolios are different, we compared the distribution of patents across the main categories of Cooperative Patent Classification (CPC) and by assignee type over the full 1981–2010 period in Table 2. Although there can be overlaps at lower levels of CPC aggregation, Pearson's chi-squared test reveals that the technological distributions of CEE and non-CEE assigned patents are independent from each other. Therefore, *H2* is verified.

In a further step, we tested the independence of the above distributions over time. We first binned the data into 5-year periods and calculated chi-squared for every period. Figure 3a demonstrates that *P* values are below 0.008 (the significance level after Bonferroni correction) in all but the first period, which is further evidence of the independence of the distributions. To get an even closer picture, we repeated the exercise on a yearly basis. Besides the chi-squared test, here we applied Fisher's exact test as well because the yearly samples contain cells with a very low number of observations, which might distort the level of significance in the chi-squared test. Figure 3a illustrates that *P* values of the two methods strongly correlate. Interestingly, one can find no independent technological distributions of Non-CEE and CEE

Table 1 Citations of patents by type of assignee, U-test

	1981–1985		1986–1990		1991–1995		1996–2000		2001–2005		2005–2010	
Type of assignee	Non-CEE	CEE	Non-CEE	CEE	Non-CEE	CEE	Non-CEE	CEE	Non-CEE	CEE	Non-CEE	CEE
Observations	45	762	81	602	216	275	516	210	906	325	888	252
Rank sum	24,700	301,327	34,704	198,882	62,767	58,018	199,201	64,699	599,225	159,070	515,139	135,230
Expected	18,180	307,848	27,702	205,884	53,136	67,650	187,566	76,335	558,096	200,200	506,604	143,766
z	4.316		4.222		6.201		4.563		7.792		2.493	
$P > \|z\|$	<<0.001		<<0.001		<<0.001		<<0.001		<<0.001		0.0127	

Table 2 Technological distribution of patents by assignee type

CPC technology class	Assignee type	
	Non-CEE	CEE
A	385 (488.3)	550 (446.7)
B	213 (263.7)	292 (241.3)
C	547 (748.4)	886 (684.6)
D	130 (145.2)	148 (132.8)
E	10 (27.1)	42 (24.8)
F	150 (167.6)	171 (153.4)
G	603 (428.2)	217 (391.8)
H	614 (383.3)	120 (350.7)
Total	2.652	2.426
Pearson's chi-squared (7)	649.3081	
P	<<0.001	

Note: Expected values under the validity of the null hypothesis in parantheses. The number of non-CEE patents is higher than the expected value in the case of G and H classes

patents in the 1980s because the large *P* values do not allow us to reject the null hypothesis. The higher values of overlap are in line with our expectations because it might have been difficult for CEE inventors to get engaged in international collaboration in the socialist era and therefore these collaborations could be solely based on domestic capacities. However, regardless of data aggregation, the independence of foreign-controlled patenting from domestic CEE patenting from the mid-1990s until the mid-2010s holds.

Appendix 2 contains a table with the exact number of patents by technological classes, 5-year periods, and types of assignees and provides further details regarding the significance of technological change over time.

The findings concerning the post-socialist transition suggest that international collaboration led to a shift in the technological profile of CEE inventors and support the idea that the overlap is small between the innovative capacities controlled by foreign and domestic firms. However, the interesting results regarding the last period need to be addressed by further research because our findings can be attributed to coincidence, an emerging co-evolution of foreign and domestic control, or a mixture of these two.

3.2 *Inventor-Assignee Links and Spatial Dynamics*

A set of maps were drawn in order to illustrate the spatial dynamics of CEE patenting binned into six 5-year periods in Figs. 4, 5, and 6. In order to show the dynamics of assignee-inventor collaboration of CEE towns in space, we categorized the towns into three classes. Nodes depict those towns where (1) only inventors (light-blue), (2) only assignees (dark-blue), and (3) both inventors and assignees were located

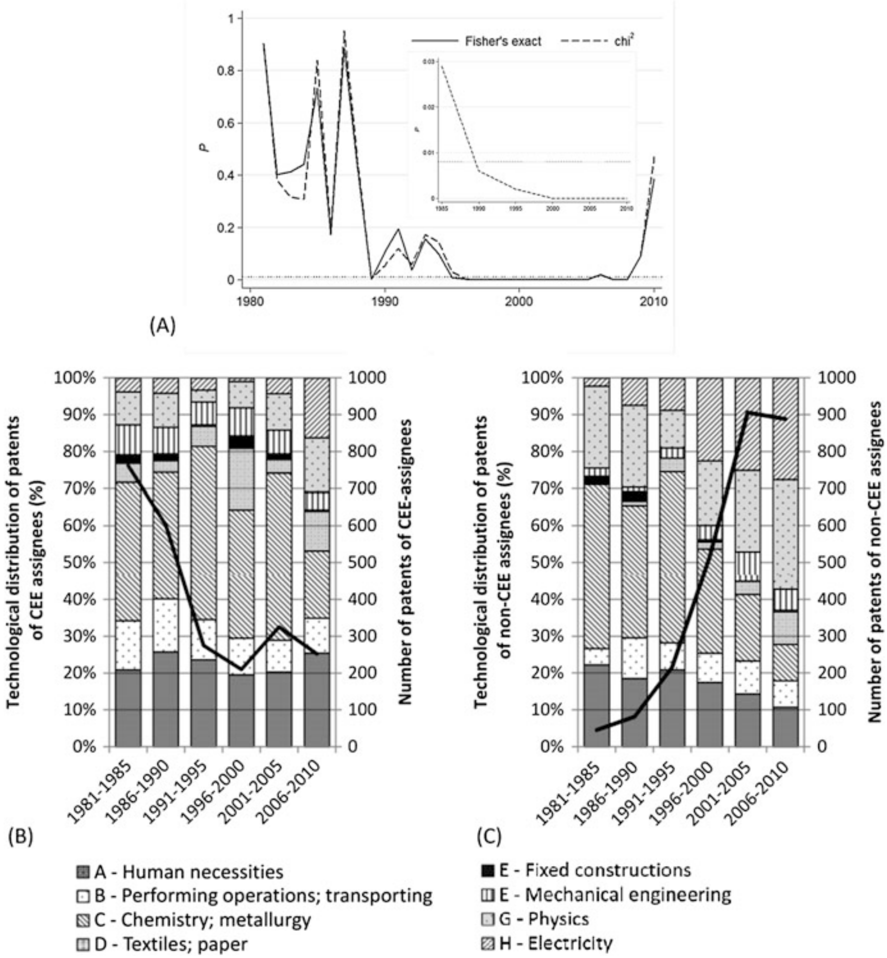


Fig. 3 Technological distribution of patents by type of assignee. (**a**) *P* values of independence tests. The nested figure illustrates the test run on 5-year periods; the framing figure illustrates test results on a yearly basis. The *solid line* represents Fisher's exact test; the *dashed line* denotes Pearson's chi-squared test and the *red dotted line* depicts the significance level after Bonferroni corrections. (**b**) The number and technological distribution of patents owned by CEE assignees. Chemistry and metallurgy and Human necessities dominated patenting of domestic CEE firms in the socialist era and these CPC classes did not lose dominance in the post-socialist transition either. (**c**) The number and technological distribution of patents owned by non-CEE assignees. Chemistry and metallurgy and Human necessities have been an important field of the widening cooperation with non-CEE assignees. However, most of the patents filed by non-CEE firms starting from the 2000s were classified into Electricity and Physics. These two categories were present in CEE patenting over the entire examined period but their shares stayed quite low throughout

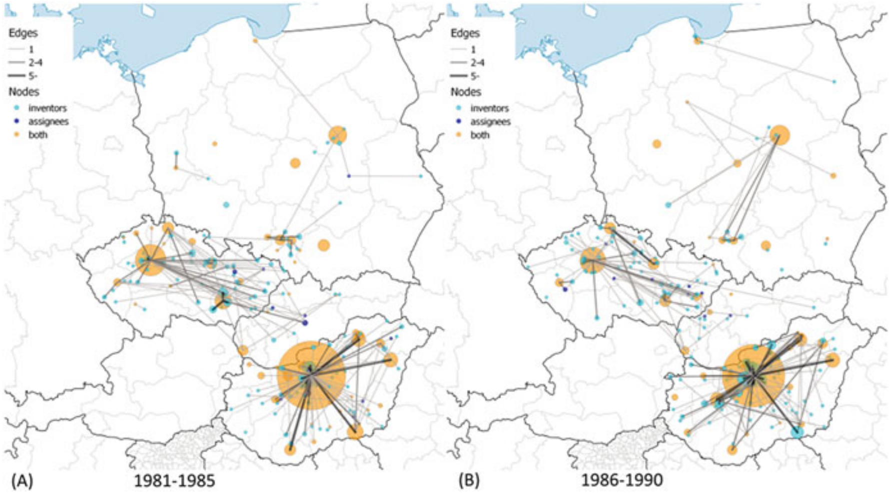


Fig. 4 Assignee-inventor links between towns in CEE countries, 1981–1990. (**a**) 1981–1985. The largest CEE innovation centers are Budapest, HU with 475; Prague, CZ with 100; Warsaw, PL with 33; Brno, CZ with 26; and Szeged, HU with 26 patents. (**b**) 1986–1990. The largest CEE innovation centers are Budapest, HU with 397; Prague, CZ with 87; Warsaw, PL with 41; Dunakeszi, HU with 22; and Debrecen, HU with 21 patents. Own work with Natural Earth base map (free vector and raster map data). Cartography licensed under CC BY-SA 4.0

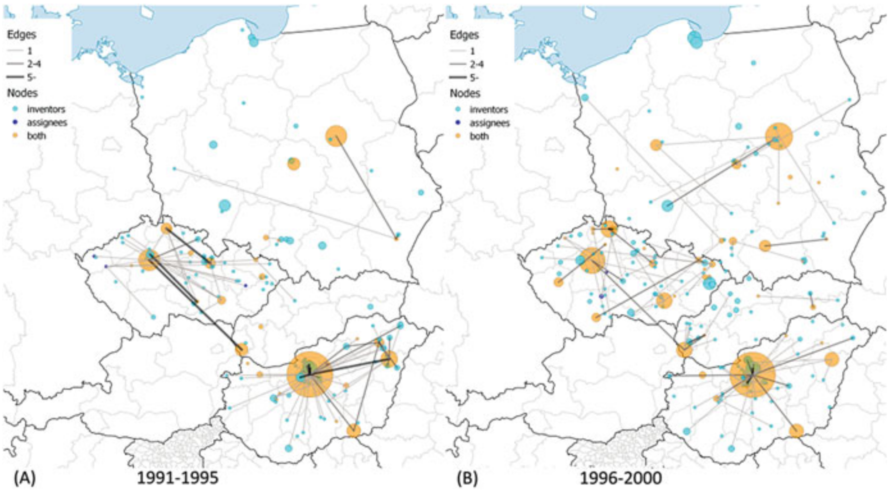


Fig. 5 Assignee-inventor links between towns in CEE countries, 1991–2000. (**a**) 1991–1995. The largest CEE innovation centers are Budapest, HU with 214; Prague, CZ with 59; Warsaw, PL with 46; Debrecen, HU with 29; and Dunakeszi, HU with 20 patents. (**b**) 1996–2000. The largest CEE innovation centers are Budapest, HU with 210; Prague, CZ with 97; Warsaw, PL with 76; Liberec, CZ with 29; and Bratislava, SK with 25 patents. Own work with Natural Earth base map (free vector and raster map data). Cartography licensed under CC BY-SA 4.0

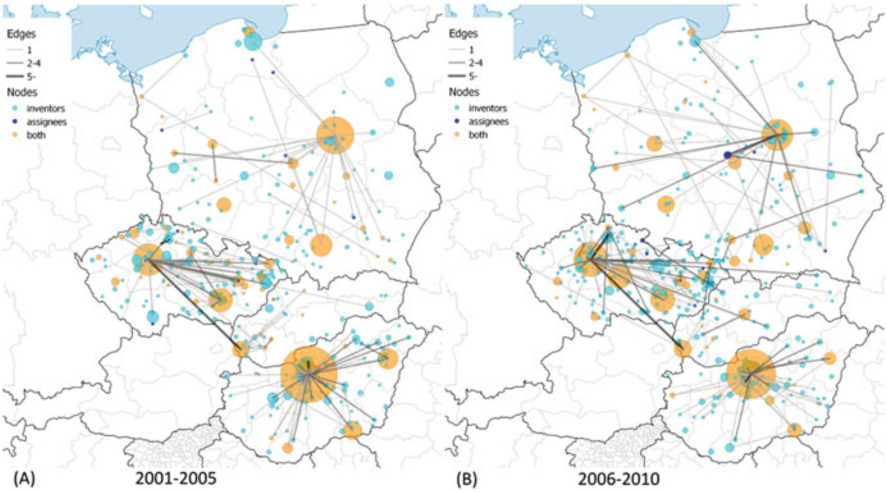


Fig. 6 Assignee-inventor links between towns in CEE countries, 2001–2010. (**a**) 2001–2005. The largest CEE innovation centers are Budapest, HU with 324; Warsaw, PL with 141; Prague, CZ with 127; Brno, CZ with 55; Cracow, PL with 47. (**b**) 2006–2010. The largest CEE innovation centers are Budapest, HU with 243; Prague, CZ with 141; Warsaw, PL with 96; Hroznetin, CZ with 60; and Brno, CZ with 56 patents. Own work with Natural Earth base map (free vector and raster map data). Cartography licensed under CC BY-SA 4.0

(orange) in the given period. The size of the nodes indicates the number of patents filed by inventors living in the given town in the case of light-blue and orange nodes. It is important to compare these two types of towns with the dark-blue nodes, the sizes of which are determined by the number of patents filed by assignees. If at least one patent was filed in collaboration between an inventor in town A and an assignee in town B, then there is a link between towns A and B. The thickness of the edges depicts the number of patents filed as it is indicated in the legend of the maps.

One can make a few important observations when examining the maps. Not only the spatial distribution and dynamics of inventors and assignees in CEE countries but also the spatial dynamics of their collaboration can be described.

The distribution of orange nodes suggests that patenting is concentrated in agglomerations of capital cities and regional centers like university towns. However, there is a considerable difference regarding the above statement across CEE countries, which is especially true after 2001. Hungarian major university towns could not increase the volume of patenting and catch up to the Budapest agglomeration; meanwhile one can observe that regional centers emerged in the Czech Republic and Poland. Cross-country differences prevail in terms of the light-blue nodes as well. Hungarian inventors are concentrated with a growing intensity in the Budapest agglomeration, while the spatial distribution of inventors in the Czech Republic and Poland became more equal over time. Slovakia had very few towns that were active in US patenting over the period, but a small agglomeration around Bratislava emerged in the late 1990s.

Collaboration with partners from other CEE countries was rare. The only exceptions were the co-operation links between Slovakian inventors and Czech assignees before 1990. The majority of these collaborations disappeared after the cessation of Czechoslovakia despite the strong link between Prague and Bratislava. However, the maps contain many small inventor towns and a few regional centers as well—like the Gdansk area in 1991–1995 and 1996–2000—that have no connections in the map. The inventors in these towns co-operated with assignees located in foreign countries and not in CEE. The amount of these towns grew continuously over the full period. As we illustrated above, international collaboration intensified, due in large part to the strengthened collaboration with assignees in US cities. Figures 7 and 8 visualize the global map of town-level collaboration in CEE patenting.

Table 3 provides additional descriptive information of the assignee-inventor town-level networks. The number of edges grew over the period, which is not true for edges across CEE towns. The number of the towns where assignees and inventors are found as well fell in the early 1990s and then rose back to the level of the 1980s only after 2000. In contrast, the number of the towns with inventors more than doubled after 1995. The growth is true for non-CEE assignee cities as well, which evidently accords with the emergence of non-CEE edges.

International collaboration might be an important source of spatial dynamics. To provide a descriptive illustration about the entries in Table 4, we define a town ENTRY at period t if at least one inventor resides in the town at period t but not at $t-1$. A majority of the towns that started patenting in a given 5-year period were

Table 3 The global network of CEE patenting

Period	1981–1985	1986–1990	1991–1995	1996–2000	2001–2005	2006–2010
Edges	277 (332)	315 (360)	279 (308)	442 (482)	809 (860)	770 (808)
Edges in CEE	242 (297)	249 (294)	111 (140)	121 (161)	195 (246)	172 (210)
Inventor towns in CEE	154	165	112	170	338	367
Assignee towns in CEE	12	11	4	3	11	11
Towns with inventors and assignees in CEE	60	50	29	44	64	64
Non-CEE assignee towns	25	52	98	178	237	199

Note: Town-level self-loops, when the inventor and assignee of the patent are located in the same town, are in parenthesis

Table 4 The probability of town entry by the type of international collaboration

Period	1986–1990	1991–1995	1996–2000	2001–2005	2006–2010
Number of ENTRY	116	67	145	279	236
CEE (%)	95	61	53	36	37
NONCEE (%)	3	37	42	54	60
CEE and NONCEE (%)	2	1	5	10	3

Table 5 The probability of town exit by the location of assignees

Period	1985–1990	1991–1995	1996–2000	2001–2005	2006–2010
Number of CEE	199	191	80	101	129
INCUMBENT (%)	43.2	30.4	37.5	47.5	37.2
EXIT (%)	56.8	69.6	62.5	52.5	62.8
Number of NONCEE	5	6	37	74	202
INCUMBENT (%)	60	16.7	48.6	54.1	36.6
EXIT (%)	40	83.3	51.4	45.9	63.4
Number of CEE and NONCEE	10	18	24	39	71
INCUMBENT (%)	100	83.3	87.5	89.7	80.3
EXIT (%)	0	16.7	12.5	10.3	19.7

only linked to other CEE towns in the 1980s and the 1990s as well. However, inventors in most of the entering towns worked only for non-CEE assignees in the 2000s.

In Table 5, a town is defined EXIT at period t if at least one inventor resides in the town at period $t-1$ but not at t. The town is INCUMBENT at period t if at least one inventor resides in the town at period $t-1$ and then at t as well. One can observe that CEE and non-CEE towns have almost equal EXIT rates in 2001–2005. However, the vast majority of the towns where inventors worked for both CEE and non-CEE firms continue patenting.

In order to test *H3*, we ran the probit regression specified in Sect. 2.2. We ran the regression separately on a balanced panel of inventing towns for dependent variables *ENTRY* (Models 1–3) and *EXIT* (Models 4–6) and for three time periods. Results are summarized in Table 6.

The estimates of *CEE* and *NONCEE* variables can be interpreted as the effect of the independent variables on the probability of *ENTRY* and *EXIT* in a comparison to the baseline category. This latter baseline category is mutually exclusive with the explanatory categorical variables and takes the value of 1 if the inventors in the town work for both CEE and non-CEE assignees as well in time t and zero otherwise. The application of such a baseline category is reasonable because those large towns where inventors work for both domestic and foreign firms are constantly patenting and do not enter or exit the data.

Table 6 Spatial dynamics of patenting, cross-sectional probit regression

	ENTRY	EXIT
CEE	3.070*** (0.208)	2.604*** (0.184)
NONCEE	2.750*** (0.188)	2.523*** (0.166)
CEE × period 1981–1985		4.903*** (0.275)
CEE × period 1986–1990	0.192 (0.307)	1.140*** (0.287)
CEE × period 1991–1995	0.362 (0.418)	0.921*** (0.303)
CEE × period 1996–2000	0.420 (0.292)	0.470 (0.305)
CEE × period 2001–2005	−0.422 (0.260)	
NONCEE × period 1981–1985		4.847*** (0.699)
NONCEE × period 1986–1990	0.294 (0.623)	1.085* (0.635)
NONCEE × period 1991–1995	1.114** (0.446)	0.766** (0.353)
NONCEE × period 1996–2000	1.122*** (0.301)	0.415 (0.304)
NONCEE × period 2001–2005	−0.243 (0.231)	
Pseudo R-sq	0.615	0.613
N	5136	4340

Note: Additional control variables are town population, region dummy, country dummy and period dummy. The reference category in the period fixed effects is the 2006–2010 interval in the *ENRTY* model and the 2001–2005 interval in the *EXIT* model; the use of other intervals provide similar results. Missing coefficients are due to collinearity and omitted variables. Standard errors in parentheses. Wald test suggests that all coefficients are different from zero
*$p < 0.10$, **$p < 0.05$, ***$p < 0.01$

The *ENTRY* model implies that local CEE collaboration induced the probability that a new town begins patenting more than international collaboration did over the full 1981–2010 period. However, the difference between the two main effects is not significant and one can only observe divergence in the interaction terms. We find that none of the *CEE*-period interactions are significant, and thus we find no significant changes in the effect of domestic collaboration over time. The significant coefficients of *NONCEE*-period interactions mean that the effect of international collaboration is significantly stronger in the 1991–1995 and 1996–2000 periods than in the baseline period, which suggests that international collaboration gained importance in the 1990s. The *EXIT* model reveals an even more crucial finding: international collaboration has no long-lasting footprint on regional patenting. The positive and significant coefficients of the main effects mean that both town categories are more likely to exit than the baseline category. Moreover, the coefficients do not differ significantly from each other suggesting that the towns where the inventors worked for non-CEE assignees only, are equally likely to stop patenting as the ones where inventors worked solely for CEE assignees. Further, one can observe a very similar pattern in the interaction terms as well, which implies that international collaboration does not support the survival of patenting in CEE towns. Therefore, we have to reject *H3*. Logit and ordinary least square regression models with identical variables have been run to check the robustness of the findings, which did not change the interpretations of the results.

In summation, we find that international collaboration inevitably became a major engine for spatial dynamics of US patenting in CEE, but its effects are not long-lasting, which calls for policy intervention.

4 Discussion

In this paper, we carefully cleaned and analyzed the publicly available USPTO data for the Czech Republic, Hungary, Poland, and Slovakia over the 1981–2010 period and focused on international patent collaborations in order to draw consequences regarding regional development and innovation policy. Our case is interesting because urban scaling was found to be more intensive in CEE than in EU15 countries (Strano and Sood 2016) suggesting that big cities converge quickly to the European trend but peripheral locations in these countries do not. Although it is questionable how innovation plays a role in the above process, the case of Portugal shows us that the lack of innovation hinders the chance for long run convergence (Marques 2015). Other examples from peripheral areas including New Zealand (Goldfinch et al. 2003), Norway (Fitjar and Huber 2015) and Sweden (Grillitsch and Nilsson 2015) highlight the importance of interregional and international collaboration. Because the innovation infrastructure is poorly developed in CEE locations, innovative firms build extensively on sources located elsewhere and thus, are more active in interregional and international collaboration. One might also argue that international collaboration is an important source of knowledge spillovers in less developed innovation systems (Varga and Sebestyén 2016), such as the ones in CEE, because inventors can learn from their foreign partners—especially when they participate in high impact innovation—and might transfer new knowledge to their domestic peers.

However, our results imply that there is a very low chance of local knowledge diffusion derived from international patent collaborations. In line with previous literature, we found that international collaborations produced better patents in terms of received citations (Beaudry and Schiffauerova 2011) but also illustrated that the growing scale of international collaborations were associated with a shift in the technological portfolio of CEE innovation (Radosevic and Auriol 1999). The shrinking overlap between international and domestic innovation is shocking because it is hard to imagine the knowledge transfer between very different technological fields. A well established argument in the literature claims that shared technological background is necessary for learning (Boschma 2005) and thus diverging technological portfolios of domestic and international collaboration decrease the probability of knowledge spillovers in CEE.

Another important observation of our study is that due to international collaborations CEE inventors started to patent in towns where no patenting activity has been documented before as well and this effect has been increasing over time. This is an important trend, because patenting activity fell sharply in CEE over the post-socialist transition (Radosevic 1999; Marinova 2001), from which regions with an inflexible industrial structure suffered the most (Lengyel et al. 2015). International collaboration might bring extra sources for innovation into these lagging areas, and can help them catch up and consequently decrease the regional inequalities in patenting (Grillitsch and Nilsson 2015; Fitjar and Huber 2015). However, the spatial effect of international collaborations does not seem to last long; innovation is not automatically maintained in the towns after an inventor worked for a foreign company. The patenting activity is only periodic in isolated peripheral locations and only those big towns innovate permanently that have access to both international and domestic sources.

The innovation capacity of regions highly depends on the policy mix (Rodríguez-Pose and Di Cataldo 2015) and thus our findings have important policy implications. The collaboration with international partners has been in the focus of national and regional CEE innovation policy since 2004 when these countries have joined the EU (Lengyel and Cadil 2009; Lengyel et al. 2015). However, the efficiency of CEE innovation policies is questionable at best (von Tunzelmann and Nassehi 2004; Varblane et al. 2007) and should be improved according to the recent EU Cohesion Policy that aims for sustainable and inclusive local economies by strengthening innovation (McCann and Ortega-Argilés 2015). Taken our findings together, policies should focus more on the synergy between international and domestic collaboration. For example, special attention should be paid to the strengthening of domestic CEE innovation in those technological sectors that internationally active inventors are working in, so that learning from foreign colleagues can create higher potential for local spillovers. Furthermore, inventors with international experience and located in peripheral locations should be helped in building connections with other CEE inventors and especially with inventors in CEE cities. A tighter network of inventors might enable a better use of innovation sources, in which central locations can be of high importance. Certainly, further research is needed to identify the specific tools for improving knowledge spillovers and for decreasing the volatility of the spatial effect of international collaborations.[4]

Acknowledgments The help of Loet Leydesdorff in data collection is gratefully acknowledged. Useful comments have been received from Zoltán Sápi, Attila Varga, László Czaller and the participants of the 2015 Conference of the Hungarian Regional Science Association. Fábián Szekeres helped us to edit the text.

[4]In doing this, one might take advantage of the dataset that we used in this paper and made available on the following link: http://datadryad.org/review?doi=doi:10.5061/dryad.5c820

Appendix 1: Data Collection and Cleaning

The database of the USPTO contains all patent data since 1790 and patents are retrievable as image files since then and after 1976 also as full text. The HyperText Markup Language (HTML) format allows us to study patents in considerable detail. One can, for example, search with names of countries, states, or city addresses in addition to the issue and/or application dates of the patents under study or classifications at the 'Advanced Search' engine of the USPTO database of granted patents at http://patft.uspto.gov/netahtml/PTO/search-adv.htm or patent applications at http://appft.uspto.gov/netahtml/PTO/search-adv.html. A set of dedicated routines download and organize the data into a relational database that contains patent characteristics (e. g. technological field, total number of citations), and inventor and assignee data (e.g. name and settlement level location of inventors and firms).[5]

For the sake of the recent paper, we collected USPTO patents with at least one inventor in Poland, Hungary, Czechoslovakia and the successors of the latter country the Czech Republic and Slovakia, for the 1981–2010 period using the search string 'icn/(cs OR cz OR pl OR sk OR hu) and isd/1981$$->2010$$' on August 5, 2013. The download recalled 5777 patents.

The publicly available data contains errors that have to be cleaned carefully. Our data cleaning focused on identifying the main technological field of patents, the names of the assignees, and the addresses of both the CEE and non-CEE assignees and CEE inventors. The location data of non-CEE inventors was not cleaned, because we do not used it in the paper.

The dataset contains the full codes for technological fields according to the Cooperative Patent Classification (CPC) that is the harmonized classification system based on the existing former classifications of ECLA (European Classification) and USPS (United States Patent Classification). One can find detailed description of the classification system at http://www.cooperativepatentclassification.org. CPC contains nine main classes identified by the first digit of the CPC code ranging from A to H, and an additional Y class; the latter was not present in our dataset. A patent can have more CPC codes and these can refer to more than one main class. We identified the main technological field of patents by taking the most frequent main class appearing in its technological field description.

Identical assignees were often recorded under multiple names, which stemmed from (1) unusual letters or typographical errors due to various language usage, and (2) divergent notation of company forms (e.g. ltd and l.t.d. cannot be considered identical). Therefore, assignee names were unified by changing all the characters into capitals and removing full stops, commas, semicolons, and further typo errors like double spaces. Subsequently, divergent formats due to different language use

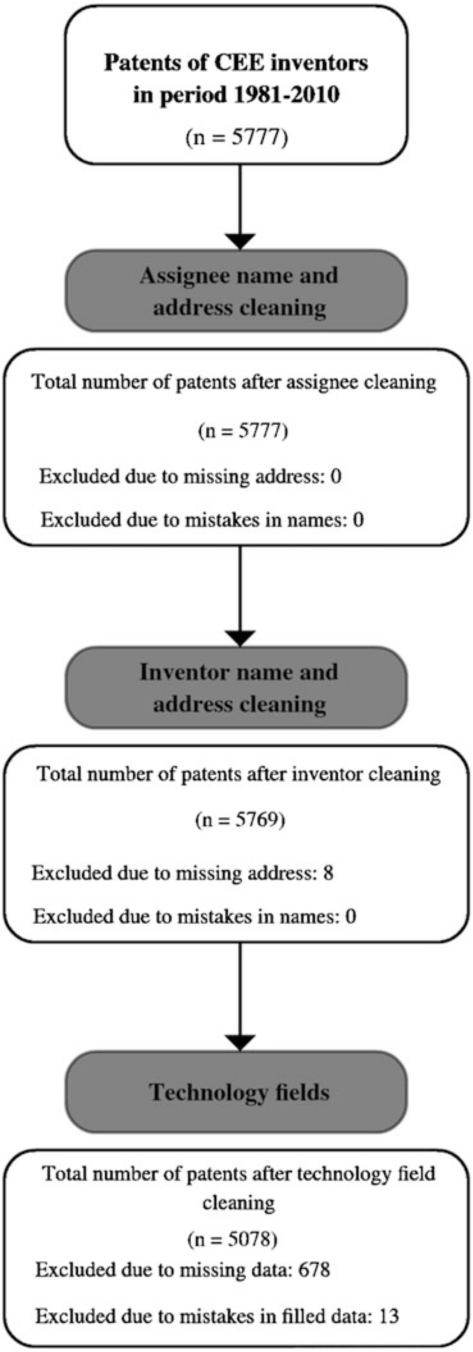
[5]These routines are open source, thus can be downloaded and further instructions can be found at http://www.leydesdorff.net/software/patentmaps/index.htm

were unified (for example when the same university was recorded in English and Polish as well in distinct patents). Finally, the data contains institutes and their sub-institutes as different assignees; these are sometimes located in a different city (e.g. the Hungarian Academy of Sciences in Budapest has its sub-institute Biological Research Centre of the Hungarian Academy of Sciences in Szeged, 170 km from Budapest). The remaining errors were incorrect fillings of the patents such as country or street names instead of the names of the cities, which could not be corrected and therefore were deleted from the data.

The typographical errors in the addresses were corrected by putting each assignee and inventor locations on GoogleMaps and the different formats were unified. For example, 'Praha', 'Praza' and 'Raha' in the Czech Republic were changed into 'Prague'. Some of the country codes were changed during the period 1980–2010 for reasons like the dissolution of Czechoslovakia (CS) into Czech Republic (CZ) and Slovakia (SK) in 1993. In these cases country codes are only indicated as they exist currently based on the ISO 3166 standard two-digit codes at https://www.iso.org/obp/ui/#search. There were several addresses where only the country or the street name was given instead of the city names, so they were not identifiable for the map application. In these cases the headquarters of the assignees were searched manually on the internet by their names and countries. Inventors' addresses were searched by their names, countries and the assignees of the patent on which they worked assuming if these parameters match, they are the same person. In many cases other patents were found on different sites where the address was correctly given in a more detailed format. The thorough cleaning enabled us to identify the location of most assignees and inventors.

Our remaining concern regarded the fact that settlements around large cities are recorded as separate towns in the data; however, inventors are likely to commute to the cities from the agglomeration. Therefore, we recoded those settlements that belonged to large agglomeration areas according to the following criteria. (1) Capitals, industrial and county centers have been re-coded to agglomerations. (2) If a bypass route surrounds a large city, those settlements (sometimes district names, small villages or towns) that are within that route were re-coded to the agglomeration. (3) In the case of European locations, CEE and non-CEE locations likewise, we used a 10 km radius from the city centre for supplementing the bypass ring if there was no such route found. (4) In the case of US locations, we used a 15–20 km radius, because people travel bigger distances by car and also because the usual radius of ring roads is broader in the USA than in Europe (see for example the approximately 15–20 km circle for Richmond, VA). Additionally, cities in colossal agglomerations such as New York were re-coded to the superior city even if they were remarkably further than that 10 km ring.[6]

[6]The geo-coordinates of relevant cities have been collected by the GSP Visualizer (http://www.gpsvisualizer.com//geocoder/) and later corrected manually using GoogleMaps.


Patents of CEE inventors in period 1981-2010
(n = 5777)
Assignee name and address cleaning
Total number of patents after assignee cleaning
(n = 5777)
Excluded due to missing address: 0
Excluded due to mistakes in names: 0
Inventor name and address cleaning
Total number of patents after inventor cleaning
(n = 5769)
Excluded due to missing address: 8
Excluded due to mistakes in names: 0
Technology fields
Total number of patents after technology field cleaning
(n = 5078)
Excluded due to missing data: 678
Excluded due to mistakes in filled data: 13

Not all the data could be cleaned and therefore we had to exclude the patents with uncertain information. The exclusion criteria and process is illustrated in Fig. 7. The addresses of assignees were all recognizable; thus, no patent had to be removed from the database due to incorrect filling. However, addresses of inventors were of worse quality. Focusing only on determining CEE inventors' cities of residence, eight patents had to be deleted from the database resulting from errors in addresses. The technological fields caused the biggest cut to the database: data on technological classification was missing in the case of 678 patents and contained error in the case of 13 patents. These patents were excluded from the database. As a result, the data contains 5078 patents from 1570 assignees located in 47 countries and 11,405 inventors located in 57 countries.

In the final step, we identified the geo-coordinates of assignees and CEE inventors based on the cleaned name of towns. In the last step, we matched NUTS3 region code and population size to every CEE town in our data from a publicly available EUROSTAT.[7]

Appendix 2: Technological Change

In order to provide detailed information regarding the nature of technological change in CEE patenting and the role of foreign-controlled innovation, we break the data into 5-year periods and count the patents by technological classes and types of assignees (Table 7). The P values of the chi-squared test are reported in Fig. 3a of the main text.

To test whether technological change of CEE patenting was significant over the full 1981–2010 period, we apply the repeated ANOVA method. We chose a model in which the number of patents by technology classes is described by a between-subject effect that is the type of assignee (CEE equals 1 in the case of CEE assignees and 0 in the case of non-CEE asignees) and a within-subject factor that is constituted by the 5-year periods. The error term of the between-subject effect the technological class nested in CEE; while the error term of the within-subject factor is the residual of the model.

The model in Table 8 suggest a significant effect of the within-factor and the interaction of within-factor and the between-subject effect because the p-values of the period variable and the CEE#period interaction is lower than 0.01.

[7] Assess at http://ec.europa.eu/eurostat/web/nuts/correspondence-tables/postcodes-and-nuts

Table 7 Number of patents by technological classes, 5-year periods, and types of assignees

	1981–1985		1986–1990		1991–1995		1996–2000		2001–2005		2006–2010	
	Non-CEE	CEE	Non-CEE	CEE	Non-CEE	CEE	Non-CEE	CEE	Non-CEE	CEE	Non-CEE	CEE
A	10 (9.4)	159 (159.6)	15 (20.2)	155 (149.8)	45 (48.4)	65 (61.6)	90 (93.1)	41 (37.9)	130 (144.3)	66 (51.7)	95 (123.9)	64 (35.1)
B	2 (5.8)	102 (98.2)	9 (11.4)	87 (84.6)	16 (20.2)	30 (25.8)	41 (44.1)	21 (17.9)	81 (80.2)	28 (28.8)	64 (68.5)	24 (19.5)
C	20 (17.0)	285 (288.0)	29 (27.9)	206 (207.1)	100 (100.7)	129 (128.3)	146 (155.7)	73 (63.3)	164 (228.9)	147 (82.1)	88 (104.4)	46 (29.6)
D	0 (2.2)	40 (37.8)	1 (2.4)	19 (17.6)	8 (10.1)	15 (12.9)	10 (32.0)	35 (13.0)	32 (32.4)	12 (11.6)	79 (82.6)	27 (23.4)
E	1 (1.0)	17 (17.0)	2 (1.5)	11 (11.5)	0 (0.4)	1 (0.6)	3 (7.1)	7 (2.9)	1 (4.4)	5 (1.6)	3 (3.1)	1 (0.9)
F	1 (3.5)	62 (59.5)	1 (5.2)	43 (38.8)	6 (10.1)	17 (12.9)	20 (25.6)	16 (10.4)	71 (67.7)	21 (24.3)	51 (49.1)	12 (13.9)
G	10 (4.3)	68 (73.7)	18 (8.8)	56 (65.2)	22 (13.6)	9 (17.4)	90 (74.6)	15 (30.4)	200 (170.7)	32 (61.3)	263 (233.7)	37 (66.3)
H	1 (1.7)	29 (28.3)	6 (3.7)	25 (27.3)	19 (12.3)	9 (15.7)	116 (83.9)	2 (34.1)	227 (177.4)	14 (63.6)	245 (222.8)	41 (63.2)
Chi2	15.56		19.71		22.22		121.33		157.25		71.12	
P	0.03		0.01		0.00		0.00		0.00		0.00	

Note: Expected values under the validity of the null hypothesis in parantheses

Table 8 The significance of technological change

Source	Partial SS	df	MS	F	Prob > F
Model	280,552.571	25	11,222.103	7.66	0.000
CEE	238.115	1	238.116	0.02	0.887
tech ∣ CEE	158,655.810	14	11,332.558		
Period	26,329.824	5	5265.965	3.59	0.006
CEE#period	101,970.460	5	20,394.092	13.91	0.000
Residual	99,671.386	68	1465.756		
Total	380,223.957	93	4088.42965		

Note: Number of obs = 94; Root MSE = 38.285; R-squared = 0.738; Adj R-squared = 0.642

Table 9 The significance of technological change under conservative F-tests

			Prob > F			
Source	df	F	Regular	H–F	G–G	Box
Period	5	3.59	0.0061	0.0383	0.0488	0.0795
CEE#period	5	13.91	0.0000	0.0000	0.0002	0.0023
Residual	68					

Huynh-Feldt epsilon = 0.4227; Greenhouse-Geisser epsilon = 0.3488; Box's conservative epsilon = 0.2000

However, repeated ANOVA assumes that the within-subject covariance structure is compound symmetric and the violation of the assumption the p-values may be biased. Therefore, we computed p-values for conservative F-tests that report correct p-values even if the data do not meet the compound symmetry assumption. Results in Table 9 illustrate that the CEE#period interaction is still significant but the period effect is only significant at the 5% level in case of the Huynh-Feldt and Greenhouse-Geisser tests but looses significance in case of Box's conservative F-test.

The strongly significant effect of the CEE#period interaction and the loosely significant effect of period main effect suggests a significant technological change over 1981–2010 in CEE patenting, in which the foreign-controlled innovation played a major role.

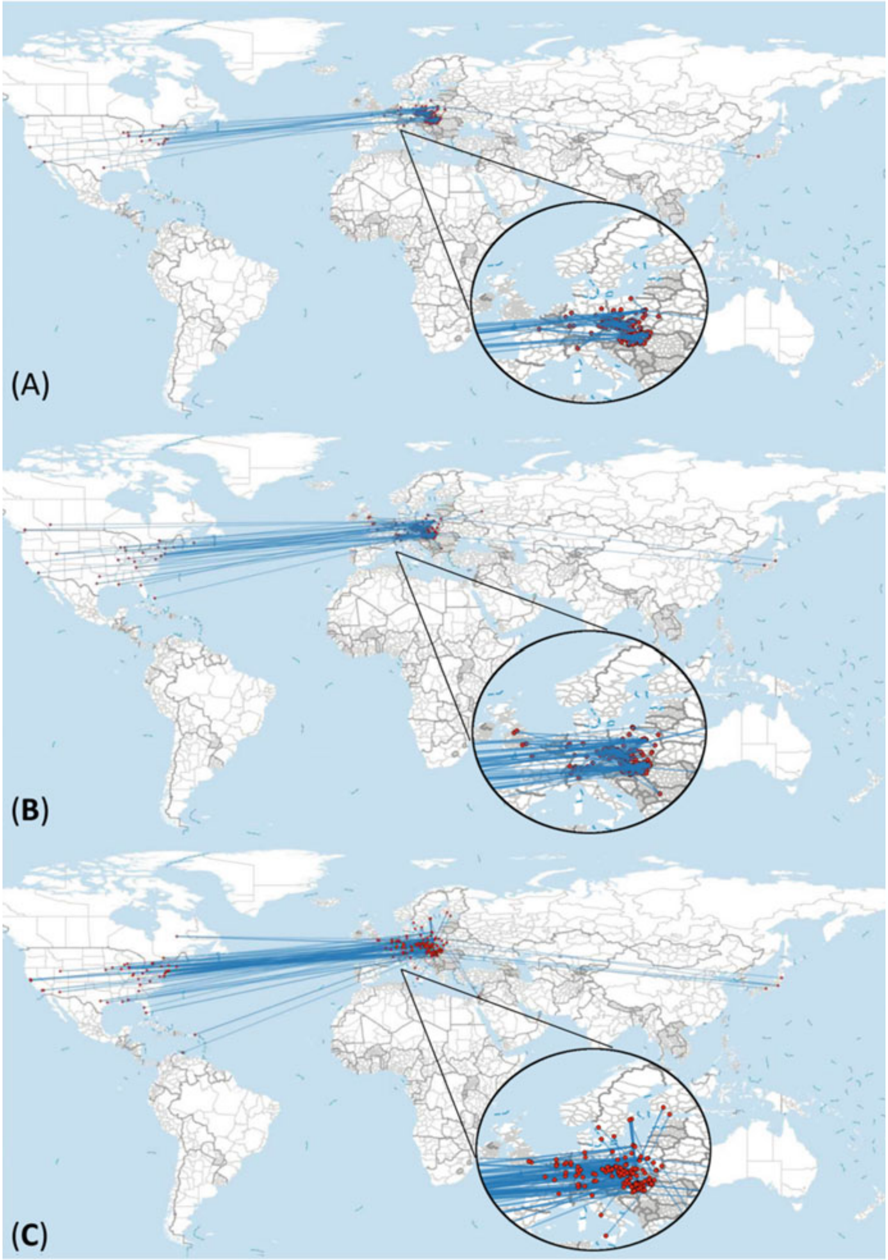


Fig. 7 The global map of USPTO patenting collaboration of CEE countries 1981–1996

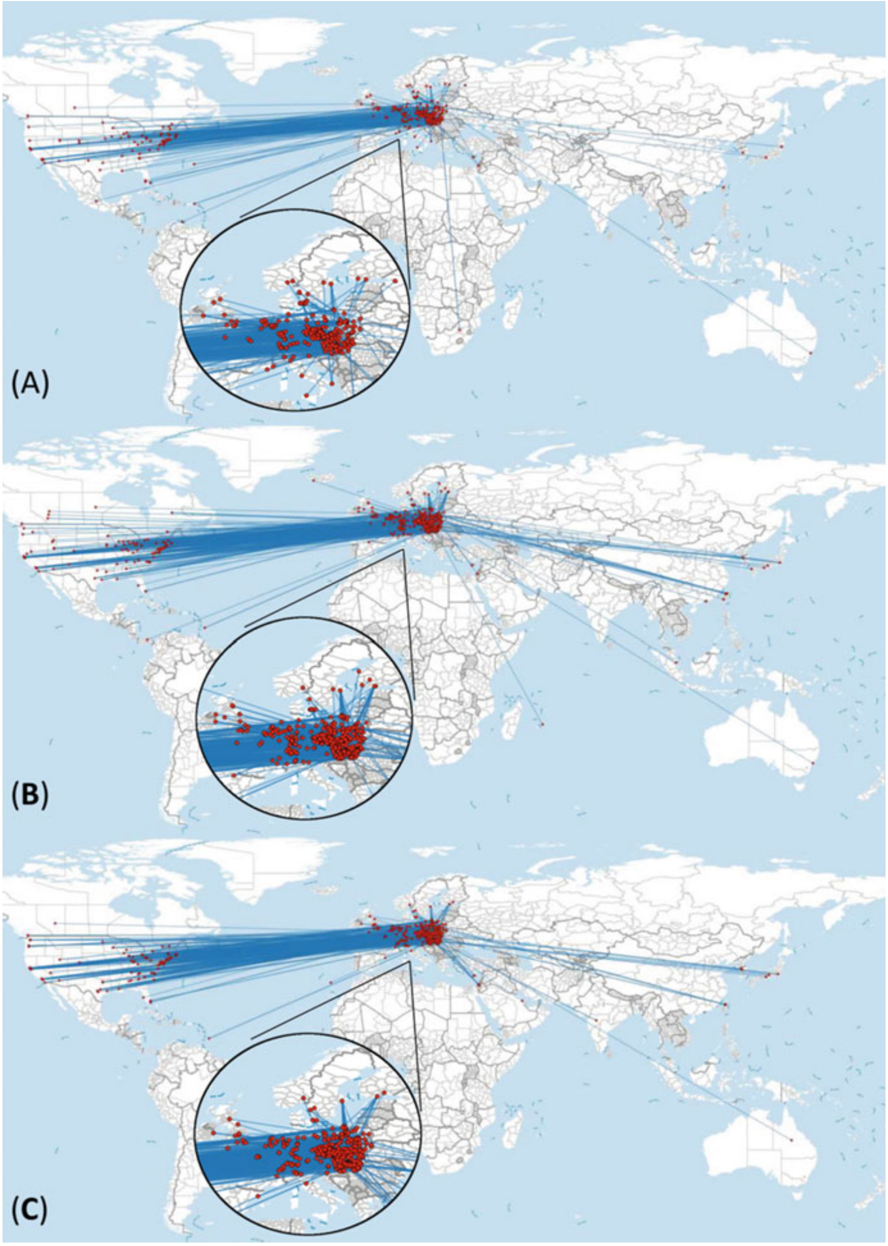


Fig. 8 The global map of USPTO patenting collaboration of CEE countries 1996–2010

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Part IV
The Economic and Social Impact of Knowledge Spillovers in Regional Innovation Systems

The Role of FDI in Regional Innovation and Its Influence on the Emergence of Knowledge Spillover Effects

Miroslav Šipikal and Milan Buček

Abstract Innovation plays a crucial role in regional development. There are a lot of ways how regional innovation could occur. One of them, important specially for less developed countries, is through foreign direct investment (FDI). Still, how these external flows of knowledge and innovation can influence regional growth and which policies are relevant to support them are not yet fully understood. This is especially important for CEE regions, which still show limited local knowledge and innovation endowment compare to European research area. We approached these issues by concentrating on the successful development of the automotive sector in Western Slovakia. Vast majority of companies in the sector are foreign owned, so the regional capabilities to utilize FDI as a most important source of knowledge and innovation are investigated. We chose the case study methodology based mainly on interviews with different actors in the industry. We showed the reasons and preconditions for the successful sector's development from adaptive to an endogenous innovation pattern. As result, evidence suggests that national policies' effectiveness very much depended on being tailored to regional and sector conditions for innovation creation or acquisition.

1 Introduction

Knowledge and innovation are considered to be key drivers of economic development. In a global world with a rapidly growing volume of knowledge and their complexity, it is almost impossible to create all the necessary knowledge for innovation within a single region or company (Krugman 1991). In other words, the ability to acquire knowledge from external environment and combine it with place-specific local resources is becoming the necessary precondition for successful innovation activities (Asheim and Isaksen 2002; NESTA 2010). One of the main external sources of knowledge is Foreign Direct Investment (FDI), specially

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Multinational Corporations (MNCs). Their global structures, networks and specific relations with their subsidiaries provide them better access to specific knowledge compare to domestic companies (Mudambi and Navarra 2004), leading to their better innovation performance (Criscuolo et al. 2010). However, regions differ very much in their ability to exploit available channels how to absorb knowledge from external environment (Capello et al. 2012).

From the theoretical perspective, this lead us to conceptual framework of "territorial patterns of innovation" enables us to understand the different modes of performing the different phases of the innovation process, highlighting the territorial specificities and preconditions that are behind different these modes (Capello et al. 2012). The concept identifies three main modes of using external knowledge to innovate depending mainly on ability of regions to produce or acquire the needed knowledge for innovation. We will look more closely on role of foreign direct investment, which is a key external factor influencing these flows, specially in countries like Slovakia. Several studies already confirm that FDI can ultimately be an important source of economic growth (Tiwari and Mutascu 2011; Driffield and Jones 2013), specially for Central Europe countries because of urgent need for restructuring (Ferenčíková and Fifeková 2006).The FDI function mainly in the role of transfer channel of knowledge and innovation, resulting in different spillovers effects to the host region.

Most previous studies concentrate on forward or backward linkages to domestic companies driven by FDI and the embeddedness of FDI in the local environment (e.g. Blomström and Kokko 1998, 2001; Meyer 2004; Javorcik 2004; Barrios et al. 2011). The vertical linkages in the Central and Eastern European countries as one of main recipient of FDI were also often analysed (Bosco 2001; Gorodnichenko et al. 2014; Jindra et al. 2009; Bučar et al. 2009; Havranek and Iršová 2011; Gentile-Luedecke and Giroud 2012) and some of them related also to automotive sector (Pavlínek 2004; Lábaj 2014; Pavlínek and Žížalová 2014). Considerably less attention is paid to inter-sectoral linkages from FDI as their importance is considered to be lower compare to other types of spillovers, mainly due to looser tights among different industries or their lower intensity compare to vertical linkages (Javorcik 2004; Nicolini and Resmini 2010). However, in case of FDI related linkages could play an important role (Kugler 2006). These studies brings very mixed results on importance of FDI, most of them found positive vertical spillovers, but for other types of spillovers are results more evenly distributed among positive, neutral and negative effects, concluding that the effects of FDI spillovers are usually depended on the specific factors as type of FDI, level of home or host country development or type of subsidiaries (Meyer and Sinani 2009; Narula and Dunning 2010).

Several studies try to investigate these factors influencing the spillovers (Blomström and Kokko 2003; Zhang et al. 2010; Nicolini and Resmini 2010) and have agreed than one of main factor could be consider the technology gap between foreign and domestic companies or absorptive capacity of domestic companies in broader terms, including the differences in technology, the institutional environment or human capital (Kokko 1994; Noorbakhsh et al. 2001; Iršová and Havránek 2013; Narula and Driffield 2012). The higher the differences are, the lower probability of spillovers. Another important factor is embeddedness of FDI (Phelps et al. 2003;

Mytelka and Barclay 2004; Masso et al. 2010) and several studies some studies show increasing embeddedness and spillovers in Central Europe countries, including Slovakia (Pavlínek 2004; Šipikal 2013; Domanski and Gwosdz 2009).

Special attention is given to role of FDI in innovation activities (Narula and Driffield 2012). In many host countries, the contribution of FDI to regional innovation is substantial compared with domestic contribution (Radosevic 1999). However, the empirical results of FDI effects are mixed. Some studies show a positive effects of FDI on ability of host countries to integrate in global value chains (Carlsson 2006), on mechanism of international technology transfer (Damijan et al. 2003) or on regional innovative performance (Cheung and Ping 2004). On the other hand, there are few studies referring the possible negative effects. FDI could crowd out the domestic technology or science oriented companies (Dyker 2001), increase the risk of technological lock-in by transferring their lower value-added production into host countries (Dunning 1994) or concentrate the sector in the hands of a few MNC with decision making outside the region (Rama 2008). Also regional specific characteristics (Rondé and Hussler 2005) as well as sectoral aspects (NESTA 2007) influence the ability to exploit FDI. The time also plays an important role; as FDI related R&D occur very often through the expansion of existing affiliates rather than through totally new investments or at least after some business experiences in host countries (Feinberg and Gupta 2004; UNCTAD 2005; Demirbag and Glaister 2010). All these suggest that real FDI impact could be seen in the longer term and that conditions during this evolution play a crucial role.

The aim of this chapter is to investigate the role of FDI as key channel of knowledge and innovation transfer in automotive sector in west part of Slovakia. Starting from the conceptual framework of territorial pattern of innovation (Capello et al. 2012), we investigate the role of FDI behind the upgrade of the automotive industry from an imitative to a creative adoption pattern of innovation.

From methodological point of view, mostly econometric studies (Damijan et al. 2003; Srholec 2009; Nicolini and Resmini 2010) or surveys (Javorcik 2008; Bučar et al. 2009) were used to investigate spillovers. Although these type of studies contribute to understand the scope and intensity of existing linkages, they usually do not offer a complete view of subsidiaries behaviour (Kennel 2007). To offer more complete overview, we used a case study methodology that enabled us to investigate in details interconnected linkages between different factors and actors of the innovation system to fully understand the impact of regional and sectoral characteristics on the creation, acquisition and implementation of knowledge and innovation. This allows us to be more precise to identify key elements of sector as well as region successful growth. By adopting both these perspectives, our qualitative case study focuses not on quantitative data or just single company, but rather on a specific and important sector within single region, analysing evolution of different stages of development with special attention to the role of FDI and it's different type of spillovers.

The rest of the chapter is organized as follows. At the beginning, we briefly describe the rationale for selecting this region and sector as well as used methodology. We continued with the sector's and region's development during the last two decades. In the following part, we analyze this evolution from innovation pattern theoretical framework and try to identify the key local and external factors (with special attention to FDI as a key channel of knowledge and innovation creation and acquisition) that contribute to this evolution, including the support policies. Next, we discuss whether and how this mostly FDI driven development has influenced change of regional innovation pattern. At the end, we summarize some policy implications from this development.

2 Motivation of the Case Study and Methodology

The case study is interesting for two main reasons. Firstly, the region and the sector has experienced successful development in the last two decades. From basically non-existence of the sector in 1990, Slovakia has become the number one car producer per capita in world (Pavlínek et al. 2009), mainly due to three top level car producer: Volkswagen Slovakia (VW) in Bratislava; PSA Peugeot Citroën Slovakia (PSA) in Trnava and Kia Motors Slovakia (KIA) in Žilina, expecting fourth final car producer Jaguar Land Rover to start production in 2018. Furthermore, auto-components companies have increased the volume of their production more than tenfold within the last 10 years and their turnover is comparable to turnover of manufacturing plants of final car producers in Slovakia. The sector is today also key industrial sector in Slovakia, representing more than 30% of industrial production in Slovakia and generated more than 11% of value added directly or indirectly (Luptáčik et al. 2013). Despite the fact that Central European countries like Slovakia were supposed to concentrate on the labor intensive and most cost-sensitive segments of the automotive production value chain (Šipikal and Buček 2013), country has achieved higher degrees of industrialization, remarkable industrial upgrading and higher economic growth rates than some core economies of Western Europe (Pavlínek et al. 2009).

We analyse the west part of Slovakia, which includes two NUTS II regions—Bratislavský kraj (Bratislava) and Západné Slovensko (Western Slovakia). These NUTS II regions achieved remarkable growth in the last two decades compared to other European Union regions. The Gross Domestic Product (GDP) per capita in Purchasing Power Standard (PPS) in the NUTS2 region of Bratislava increased from 108% in 1999 of the EU average to 184% in 2013 and in Western Slovakia region from 48% in 1999 to 71% in 2013 (source: Eurostat). However, the knowledge and innovation activities measured by most used indicators as R&D spending, share of researchers or number of patents have been substantially lower compared to other Western Europe regions with a similar GDP level. For example, Bratislava region reached only 9.4 high tech patents per million inhabitants in 2008 (0.4 in Western Slovakia) and 23.39 patents per million inhabitants in 2008 (2.34 in Western Slovakia), much lower than in most of Western Europe metropolitan regions. On the contrary, the neighbouring NUTS2 to Bratislava—Austrian region Burgenland with GDP level around 75% of EU average, reached 76.39 patents per million inhabitants. The situation has been improving over the time, but very slowly. In 2011, Bratislava still have only 32.08 patents and western Slovakia region only 7.07 patents per million inhabitants (source: EUROSTAT).

Secondly, vast majority of the companies in this industry is owned by foreign parents, mainly MNC. In most of the previous studies investigated the role of FDI in vertical and horizontal spillovers to domestic companies (e.g. Blomström and Kokko 1998; Pavlínek and Žížalová 2014; Kolasa 2008; Giroud et al. 2012). This case study shows the process of new industry creation and development nearly entirely based on firms external to the region. Instead of foreign to domestic linkages, whole industry is relies on "foreign to foreign" linkages. Due to non-existence of domestic companies the spillovers effects to them within the sector are basically at a zero level. However, this underlined the importance of inter sectoral linkages and the spillovers among FDI and all kind of public sector institutions as the main external knowledge and innovation sources into the region (Šipikal and Buček 2013). We try to show that environment itself (domestic companies in other sectors or knowledge based intensive services) with adequate support policies could change the innovation pattern within the region and lead to upgrading the innovation and productivity capabilities.

For inter-sectoral linkages, it is important that FDI comes from more innovative sector. From this perspective, the automotive sector is amongst the largest in R&D spending in the European Union. Total investment for research and development in the categories 'commercial vehicles and trucks' and 'automobiles and parts' reached nearly 45€ billion investment in 2015 (EC 2015). The actual investment and impact can be even multiplied, as these categories do not cover all automotive service or supplying industries. The development of patents applications registered by the sector underline the industry's innovative performance as well. In 2014, almost 14,600 patents were registered by this sector (EC 2015), number more than doubled from 2008 (EC 2009). All these figures suggest the decisive role of FDI in the local automotive industry in upgrading the innovation performance of the sector within the region.

We used qualitative case study methodology in the research. Data were mainly collected from a several personal interviews conducted with relevant actors. Together we interviewed 11 companies in the sector, dominantly foreign direct investors. We interviewed companies from small tier 3 firms at the bottom of the value chain through first level suppliers to final car producer. It was complemented with interviews at universities, research centers and other support organizations at the regional and national levels. Most of the interviews were held in 2012 and 2013, with some following questions later. Additional information was collected from official statistics, telephone interviews, existing studies, websites and other written official or internal materials of companies or institutions (specially their annual reports).

3 The Evolution of the Automotive Sector

After the collapse of the communist regime at the end of the 1990s, the automotive industry in Slovakia virtually did not exist. At that time, Volkswagen started a joint venture company for automotive components production with a Slovak company "BAZ" (Jakubiak et al. 2008). Due to uncertain development in Central Europe after regimes changes, foreign investors usually started with a low volume or bottom end value chain production (Pavlínek et al. 2009), viewed region as place for production, not research (Pickles et al. 2006), as it was also the case here.

The whole sector has undergone dramatic changes since then. The automotive production value rose from EUR 620 m in 1998 to EUR around 12,600 m in 2014 in the whole Slovakia, peaking at 13,682 m EUR in 2008 (Statistical Office of Slovak Republic). Vast majority of production has been produced in Western Slovakia. Slovakia has become the number one car producer per capita in world (Pavlínek et al. 2009). In 2016, VW ranks number one, KIA number two and PSA number six among biggest companies in Slovakia from all sectors based on their revenues (source: www.finstat.sk). Now, there is more than 300 firms in the automotive industry, but most of them foreign. From Top 50 companies in 2016, only one was domestic (source: www.finstat.sk). This increasing concentration of the production of the automotive sector in CEE has led to the increase in external economies of scale (Pavlínek et al. 2009). For incoming investors, the possibility to have several customers or suppliers within a "just in time" distance was very attractive. It was very good precondition for strengthening their competitiveness by enabled them to have only one production plants for several of them. As stated in an interview with Tier 1 supplier:

> We came here to supply VW. Now, VW counts for only 25% of our turnover. We have several other customers in the region, some in other sectors and large part of production is also exported. Today, we are here, because the place has good logistics and labour force.

This positive development of the automotive sector in Central and Eastern Europe was confirmed by several studies (Lorentzen et al. 2003; Pavlínek et al. 2009; Hardy et al. 2011). Although the key product innovation and implementation production decisions were still decided outside of the region, some shifts can be observed. This was mainly increased autonomy for subsidiaries on the side of MNCs and change from defensive low cost strategies to strategies associated with knowledge and innovation seeking as well as an introduction of aftercare programs on the side of public sector (Hardy et al. 2011).

Evolution has occurred also from spatial point of view. At the beginning, sector was established only in Bratislava. In the 90s, the sector production facilities spread also to other regions, but still was remain highly concentrated in Western Slovakia with around 60% of all employment and 70% of the production of the sector at the national level (Šipikal and Buček 2013). Now, more and more companies have started production also in less developed regions of Central and Eastern Slovakia.

Several specific factors contributed to the high inflow of FDI. One of them was the geographical proximity. This proximity works in two ways. Firstly, Western

Slovakia was very good connected to the main Europe car markets allowing to export to them quite easily. Secondly, it was a very good complementarity of these two neighboring regions in terms of FDI needs. The Bratislava is a metropolitan region with strong urbanization effects (Buček et al. 2011) and one of the most developed region in Europe in terms of GDP per capita (186% of EU average, source: Eurostat), characterized by a well-diversified economy with good public research infrastructure (including public universities and research centres), skilled and qualified work force and many supporting organizations (including the sector of KIBS). Western Slovakia was one of the less developed regions with GDP per capita under 60% of EU average at the beginning, but with a lot of qualified and very cheap work force in the engineering and army industry from previous regime. This combination of quality and productivity/price ratio of work force together with relatively lower living costs and the proximity to the Bratislava region and its advantages and services enabled Western Slovakia to attract a critical mass of foreign investments, mainly in the automotive industry. This leads to the strong specialisation of Western Slovakia on the automotive industry. The accession of Slovak Republic to the European Union represented a further important opportunity for the sector's development, with the access to the whole European Union market without tariffs or trade limitations on exported production volumes (Šipikal and Buček 2013).

A special feature of this industry in Slovakia is its market diversity. While Volkswagen is oriented top-end cars, PSA Peugeot-Citroën assembles middle-class cars with orientation more on Central and East Europe market and Kia Motors has only factory in Europe here and produced lower-class models. Another final car producer Jaguar announced its investment, again with different type of car production. Moreover, car component producers are interconnected and often supply to not only carmakers in Slovakia, but also several carmakers abroad (mainly Hungary and Czech Republic) or even to other industries. This may be one of the reasons why the sector also has relative successfully managed to cope with the economic crisis.

The automotive has become also dominant among industry sectors in Slovak Republic. Three companies of the sector are among top ten companies in the country according the revenues. All of them are MNC, confirming dominant positions held by foreign firms. Except FDI in the final car production, the foreign subsidiaries are dominant also in the supplier sectors (specially in manufacture of engines, car electronics, cable harnesses and gears). For domestic enterprises is still very difficult to enter the even in the bottom level of value chain of the industry. In fact, first level suppliers are multinational foreign owned companies, while few domestic companies can be found among next levels of suppliers (Šipikal and Buček 2013), leading to depended market economy model (Nölke and Vliegenthart 2009). This is also consider as one of the main weaknesses for future development of the sector as well as region (Šipikal 2013; Pavlínek 2015).

All these preconditions were supported by strong government policy to attract FDI. In case of Slovakia, government investment incentives were "very aggressive" and could (mainly through infrastructure projects for investors, tax holidays or investment incentives) have important impact on the localization decisions of

MNC (Pavlínek et al. 2009). These measures were additionally complemented also by some support activities at a regional level (Šipikal et al. 2010). As several other studies shows (Pavlínek et al. 2009, 2016; Šipikal and Buček 2013), all above mentioned elements through FDI finally enabled the successful integration of Western Slovakia into the European automotive production system.

4 The Dynamics of Innovation Patterns

The innovation dynamics has evolved in a similar way to the sector itself. Based on concept of territorial patterns of innovation, Western Slovakia represents an imitative pattern of innovation (Capello et al. 2012) at the beginning of the industry development during last decade of previous millennium. The detailed theoretical concept of flow of knowledge and innovation is showed in Fig. 1.

Imitative innovation pattern relies on territorial attractiveness to FDI as a source of innovation in the region. The Western Slovakia was in the same position and nearly all knowledge and innovation was acquired through established foreign multinationals corporations. Development at the local level in terms of knowledge or innovation creation was the result of a passive reception of innovations from the environment external to the region.

As result, nearly all decisions about innovation, including product series or process technologies, were conducted outside the region. At this time, parent MNCs made decisions on nearly everything in the subsidiaries, even the basic production processes functionality was implemented by labour force from parent companies. Research activities were fully concentrated in parent companies. As summarized in the interview:

> At the beginning, we invested there just as market opportunity. Only few years after the collapse of the soviet bloc, we really were not sure what to expect there and it was related not only to political stability, but also to the quality of workforce and the business environment. Our Austrian technicians came here every week to set up and control crucial production processes, so we did not even think about research there.

Established subsidiaries were integral part of their own knowledge, innovation and production foreign networks with nearly no linkages with local environment. Even the mutual links among the foreign automotive companies were very limited. As an interviewee with production manager from one of subcontractor's reported:

> Customer centres allocated in several regions were responsible for the contact with clients. For example, the centre for Suzuki, which had factories in Hungary, was located in the Bratislava region. On the contrary, the customer centre for Volkswagen, where the biggest part of our production in Slovakia is supplied, was located in Germany. Neither of them had any interaction within the region.

Also the public sector did not play any positive role in innovation activities. There were nearly no regionally specific, but internationally recognized, research in public

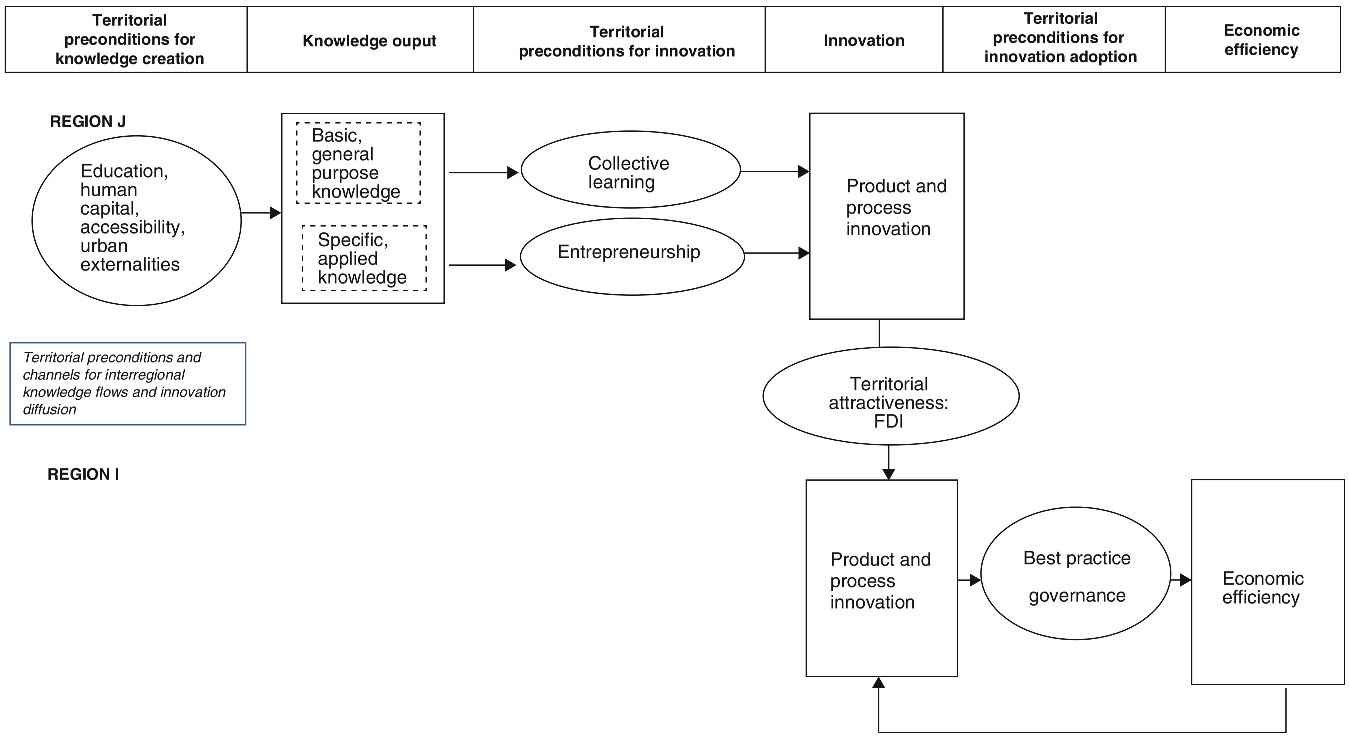

Fig. 1 Original imitation innovation pattern. Source: Capello et al. (2012)

universities or research centers which could be seen as a contribution of the region to international knowledge creation in the relevant fields of automotive sector.

However, this *"pattern is not necessarily the less efficient innovation pattern"* (Capello et al. 2012). Territorial attractiveness with adequate preconditions (mainly skilled and cost effective labour force and aggressive support policies in case of Western Slovakia), has led to huge inflows of FDI to automotive sector, resulting in high industry growth in the region and consequently in high economic growth of whole region.

At the beginning, innovation design, development and implementation were exclusively tasks of parent MNCs. The task of the subsidiaries was only smoothly executed these prepared innovations. Due to cost effectiveness, many foreign companies started to shift the whole production into regions like Western Slovakia, while still keeping research in their parent countries. However, certain kind of research activities needs experiences from production processes or testing on devices directly used in production. Since the whole production was relocated apart from home countries, it was necessary for the firms to transfer a substantial proportion of their R&D tasks to their subsidiaries (Šipikal and Buček 2013). This reallocation also required to change organizational structure and establishment of specialised units within subsidiaries responsible for the development of R&D. As CEO of one of automotive suppliers reported:

> Higher involvement in innovation activities compared to the past is related to the progressive labour force improvement as well as to knowledge acquisition directly from the production process. This shift was more visible mainly after production cancellation directly in the company head office. The development of new products without a direct possibility to examine some of the items in the production process cannot be fully done in the parent company and, therefore, started to be partly executed in this plant. In the last year, this plant also introduced its own innovations based on its own patent protection solution, which was previously the domain of the parent company. The firm also uses the system of innovatory movement for the moderate improvement of production processes. Tacit knowledge from the direct experience of production process plays a key role.

Experiences from production process also contribute to higher involvement of people from subsidiaries in global network as they became members of the different international teams of their parent companies. This consequently increases their own knowledge and abilities to contrive and develop innovative solutions.

Process innovations were also strongly demanded by management of subsidiaries. The main role of Slovak subsidiaries within the global value chains has been the efficient production of allocated products. The knowledge acquisition from the production process and its improvement represents for management of local companies a key success factor.

Above mentioned facts leads to a clear division of innovation activities between parent firm and subsidiary. The subsidiaries have started to be strongly involved in the process innovations and, in certain cases, have gained partial autonomy in these processes. Supporting the fact that subsidiaries' age (Gentile-Lüdecke and Giroud 2012) and higher degree of autonomy (Birkinshaw et al. 1998) are positively related to the volume of knowledge and innovation transfer, MNCs gradually developed confidence in the knowledge and innovation creation abilities of their local suppliers and subsidiaries.

These types of innovations primarily rely on information from internal sources about the process of production, so they are very hard to be captured by typical measures of innovation output such as patents or R&D indicators. This could explain why regions like Bratislava or Western Slovakia shows lower innovation activities, measured by traditional indicators as patents, compare to their economic performance measured by GDP. However, despite not being measured, 'hidden' innovations are very important for companies in this very competitive industry. As confirmed by an interviewee responsible for process innovation (Šipikal and Buček 2013):

> Product innovation is handled within the head office. Any idea oriented to these innovations which will arise in Slovakia is automatically shifted to the head office. The firm has opened departments in Slovakia which are focused on process innovation. At the same time, the firm mainly uses own internal programme, in the framework of which we are implementing innovative activities suggested by employees. These activities generate savings of approximately 10 m EUR per year. Within this system, we implement more than 6000 small process innovations per year. Innovative improvements are consistent with the strategic targets of the factory and there exists also an ongoing comparison with other subsidiaries of the parent company.

This could be also one of the reasons why regions as Western Slovakia have lower traditional innovation output (e.g. number of patents) despite of a quite frequent innovation activity within industry, if we consider innovation as a continuous upgrade of products and specially processes that leads to improvement of economic performance of company, not only as research related activities. Several interviewed firms confirm this scenario of the continuous implementation of innovation within them, which are not a result of internal R&D activities.

Moreover, as several companies mentioned in interviews, intellectual property rights system does not offer the necessary benefits regarding process innovations. These innovations are closely interconnected with concrete production facilities of the company, so they do not usually plan to sell these achievements to competition or companies from different sector. This make the patent protection only administrative workload without any planned benefits. On the contrary, there are some negative aspects. One of them is the risk of patent abuse by the competition, specially out of European Union, where the enforcement of patent protection is very low. Finally, the process innovation requires tacit knowledge from production processes and it is very difficult to transfer them into patents. As mentioned by CEO of one of KIBS in the interview:

> We did some patents application for process innovation before, but it doesn't help us very much. For each customer, the solution is unique, so we must adjust our solution every time. On the other hand, we have no chance to find out if someone else used our solution or not. It's not visible on final product and we cannot goes to the factories and look at their production processes.

All above mentioned processes, mainly including creation of external linkages, diversification of innovation activities and demand driven upgrade of public research centres and universities, has led to gradual shift from *"imitative innovation pattern to a creative application innovation pattern"* (Šipikal and Buček 2013). As shown the Fig. 2, innovation activities within this pattern lies on the combining of external knowledge, incoming from linkages with external regions, with local specialised knowledge in the regional economy (Capello et al. 2012).

The presented shift very much helps also during the 2008–2009 economic crisis. At first, it led to a substantial decrease (19.2%) in the sector's output following by similar decrease of output in the supplier industry. There were 13 bankruptcies, closures and relocations abroad in the Slovak automotive industry during and immediately after the economic crisis. Nine of these involved the labor-intensive assembly of cable harnesses, an area especially sensitive to labour costs (Pavlínek 2015). However, in 2013 all total numbers for whole sector were back and sector is now stronger than before crisis. The specialization on process innovation could play a role why sector, despite of economic crisis and excessive capacities of the industry in Europe, still raise. It looks like economic crisis prioritizes the effectiveness of the production process.

5 The Factors Behind the Change

However, the change of the innovation pattern has occurred under certain conditions that have led to successful transformation of the innovation pattern in the region. From theoretical perspective, the main advantage of the regions in upgrade of the innovation pattern is usually considered the human capital (Capello et al. 2012) and this was confirmed also in this case. The labour force played a key role in attracting of FDI flows (Šipikal and Buček 2013), with a competitive position in all important areas—availability, quality and wage level of labour. Especially a great availability of workforce after collapse of many state owned engineering and defense industry companies after velvet revolution leads to excessive supply of qualified workforce. Human capital represents the important factor of knowledge acquisition or creation also in later stages of the development, because it plays a decisive role in region's ability to create, acquire or implement process innovations. The quality of this capital allows to understand highly advanced multinational companies production processes and even to propose additional upgrades or improvements. This is the case of manpower working directly in the production as well as intermediate management. Specially abilities of management in the field of production and organisational innovation seems to be very important for successful innovation upgrade of companies, which result in higher efficiency and production flexibility.

The improvement of the human capital was also partly happened thanks to established foreign multinational companies. Most of them had visiting programmes and on regular basis sent their managers and employees from Slovakia to their head offices or international training centers for acquiring new knowledge. Another frequently used practice was participation of employees from subsidiaries in centrally planned innovation activities or R&D projects as a part of international teams.

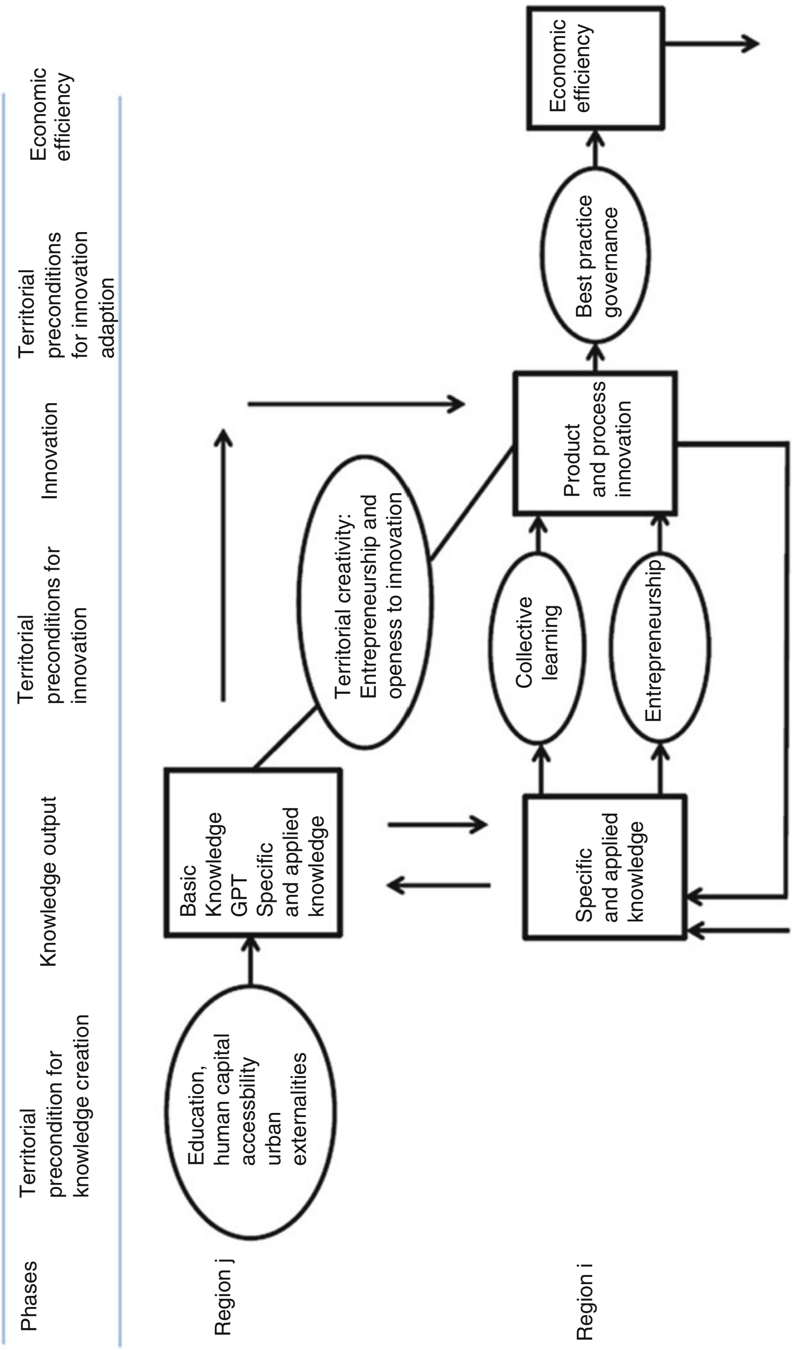

Fig. 2 Present innovation pattern in the region of Western Slovakia (automotive industry). Source: Šipikal and Buček (2013)

This was also important part of mind changes of the local labour force, lead to better understanding of the purpose and necessity of innovation. These activities were carried out in spite of the risk that part of the labor force subsequently remained abroad and had to be replaced, because those who stayed remarkably contributed to improvement of innovation processes within subsidiaries. As mentioned in interviews (Šipikal and Buček 2013):

> We have been regularly sent employees to our other branches. Some of them remained abroad and never came back, but still help our company in other positions there. But those who's came back are very important for us, because they came back with much more positive attitude toward innovations. We are not sure why, but it's probably because they left routine, experienced new people and equipment and feel privileges that company gave them these opportunities. But numbers has showed important increase in their innovation suggestions after their arrival from abroad experience.

It looks like this short-term inter-regional migration was much more important in the upgrade of innovation pattern compare to intra-regional migration (Šipikal and Buček 2013). According to the interviews, the intra-regional migration has insignificant influence on knowledge or innovation activities of local companies.

The key benefit of this short term programmes within these companies was a dramatic change of perception of knowledge and innovation creation or acquisition and their role to improve or maintain competitiveness of local firms. The employees in the socialist establishment did not consider their role to be actively involved in the development or innovation of the enterprise. After they saw the employees from their parent companies, they perception usually changed. This has gradually led to the formalisation of the innovation process within companies. Although the important role of knowledge and innovation for competitiveness has been recognized, there was no formal structures of innovation management within organizational structure of firm. Companies usually did not have a special department or responsible manager directly oriented on innovations. Currently, situation is quite different. Vast majority of firms have a sophisticated supporting system of knowledge and innovation creation and implementation. However, the more internationalized and multinational a company is, the more detailed this system is and the more it is connected to the strategic planning and firm management (Šipikal and Buček 2013). We observe two reasons for it and both are result of more developed organizational structures within multinational companies. Firstly, they pay much more attention to measure achieved improvements from implementation of proposed innovation activities and evaluation of their impact on economic performance, productivity, or employees' satisfaction are more integrated into company managerial decisions. Secondly, their internal system to support employees to suggest innovation suggestions improvement is much more elaborated and with better and tailored motivation tools. Several companies in the interviews confirm the fact that improved system lead to much higher innovation activities from employees compare to the past.

Higher formalization of R&D activities also occurred in the form of new research departments, occasionally as new R&D centres. These activities have also stimulated creation of new knowledge, but their role in the innovation activities is still quite limited in the region and only very few of them are in Slovakia (Švač 2010).

Reallocation to Central Europe countries is more oriented on applied “routine” research and development, while basic and product research or radical innovation usually remain allocated in parent and centralized R&D centres of foreign multinationals (Pavlínek et al. 2009). The investment in R&D has increased over the years. In 2012, total value was more than 29 Mil. EUR, several times higher amount than few years before and it represents 6% of total private R&D spending in Slovakia (Luptáčik et al. 2013). Regarding the tasks of these centers, two-thirds of them in Central Europe are located together with manufacturing plants (Pavlínek et al. 2009), so we could expect incremental and applied R&D related to process innovations at these centers.

The one way flow of innovation and knowledge flows at the beginning has changed to bidirectional and complementary. Subsidiaries no more only acquire innovation from their parent MNCs, but also contribute to enlarging the knowledge base of their MNC’s headquarters. Foreign investors built 1062 new plants in Central and Eastern Europe during 1997 and 2009 and 121 from them in Slovakia (EY 2010). All these factories located here continuously develop and accumulate important knowledge about the production processes and could significantly contribute to future product and process innovations within whole production network of MNCs. Therefore, also other supporting firms in the region as universities or KIBS are mainly focused on innovation activities aimed to improve the efficiency, logistics or fluency of production processes. They are concentrated on process and product innovations including new tools and devices for production, new types of materials used in their production processes, new software for production logistics to find out the ways that the current production would be more quick, economically, easily, or with the lower level of waste (Šipikal and Buček 2013).

Very important role played a support policy, especially from national government. At the beginning, support was massive and mainly in the form of investment stimuli. These incentives can be considered as aggressive. Moreover, they could strongly affect the new plants’ location (Pavlínek et al. 2009). Only three final car producer companies (Volkwagen, PSA Peugeot-Citroën and KIA Motors) obtained more than 700 million euro of state aid (Šipikal and Buček 2013). Many foreign suppliers including companies like Deplhi, Hella, Getrag Ford, Mobis, Eismann, Sachs or Continental which followed those MNCs also obtained investment incentives. The tax allowances, grants for newly-created work positions, land and infrastructure provision were most common stimuli provided by the national government (www.statnapomoc.sk). The initial concentration on the generation of a critical mass of FDI rather than on the higher value added or R&D foreign investment was critical for the future success of the region’s development (Šipikal 2013). This stress the role of a close relationship between two traditionally separated policies—innovation policy and FDI promotion policy (Guimon 2009). A majority of industry consists of foreign investors which are on higher technology level than local companies of local public sector, so they are usually not interested in cooperating with them if not properly motivated, so some new policy measures were introduced as sector progress over the years. Most of the them are no longer related to the support of territorial attractiveness (Šipikal 2013) The government introduces new support

R&D activities and special support for creation of specialised competence centers at universities focused on the specialised areas of R&D with obligatory participation from private as well as public sectors (Šipikal 2013). However, policy must continuously adjust to remain competitive. Long-term investment in human capital (technical higher education, dual vocational training system), measures for supporting networking, creativity and knowledge creation seems to be very important for maintaining and improving the competitiveness of companies based in Slovakia in the sector and it is crucial for the increase in value-added production activities (Šipikal 2013; Pavlínek 2016). This strongly support the theoretical framework of pattern of innovation as well as other similar approaches like smart specialization, highlighting the need to adjust innovation policies to the current level of sector and region innovation development to achieve successful economic growth (Foray et al. 2009; Capello et al. 2012; Šipikal 2013).

The critical mass of FDI play also crucial role. Critical mass is important to stabilize the whole system and allow to create synergy effects (Szanyi et al. 2010). We already mentioned that more than 300 companies are active in automotive. *"Increased concentration of automotive production in Slovakia led to increasing external scale economies which improved the competitiveness of Slovak based automotive subsidiaries (Pavlínek et al. 2009)"*. This is one of the main differences compare to other analysed sectors, where FDI were isolated with difficulties to find adequate partners (Capello et al. 2012). Without critical mass the pressure was not strong enough to change the behavior of universities or other domestic companies.

All these factors influence the shift of automotive industry in Western Slovakia from imitative innovation pattern to creative innovation pattern. Table 1 summarizes the key factors influencing this shift.

However, one of main question now is question of sustainability of this development. The region remained only in imitative pattern with territorial attractiveness would be vulnerable to MNCs decisions in long term, also never able to achieve the wages of most developed regions, otherwise it will lost the attractiveness for MNCs. Also the flow of FDI based only on territorial attractiveness may become stagnant or declining over the time. This development can be partly observed in the automotive sector in Bratislava and Western Slovakia regions (Šipikal and Buček 2013). At the beginning, FDI inflow was very strong and most of the growth was achieved by the

Table 1 Main factors influencing the innovation pattern shift

Key factors for FDI inflow and upgrade	Main advantages allowing upgrade
Human capital	Quality and availability of workforce Favorable cost/productivity ratio
State policy	Very aggressive policy towards inflow of FDI Strong investment stimuli
Institutional factors	Upgrade of public institutions Membership in the European Union
External factors	Achieving critical mass of FDI Division of labour between parents and subsidiaries

Source: Own

establishment of new foreign companies. Gradually, the expansion of existing companies become more relevant compare to new entries. Currently, both processes are much less intense, mainly due to lack of adequate workforce and general increase of wage level. However, the FDI positive effects expand to neighboring regions of Slovakia, with two new final car producers KIA (in Central Slovakia) and Jaguar (in east part of Western Slovakia) established, followed by several of their sub-suppliers. Productivity increases and higher value added production look like the most probable way how to achieve sustainable future growth. However, not only territorial attractiveness is required, so needs for innovation and knowledge creation arise. The mentioned process innovation activities could be one of development path, but region must intensively seeking for other possibilities for productivity and value added improvement.

6 Spillovers to Local Economy

One of the main questions in this case study is if region or sector is able to use FDI for benefits of local economy. We discussed change of innovation pattern and the most relevant factors behind this successful innovation shift. However, nearly the whole automotive industry consists of foreign investors and most of the innovation and knowledge flows involve only foreign firms, especially large MNCs, and the empirical evidence confirm a small spillover effect to domestic companies in case of automotive sector (Lábaj 2014). This creates the danger of dual economy (Narula 2015). This suggest that the interaction between foreign companies and the local environment is crucial for local innovation performance in the future. It is also important for the ability of region to build and reinforce endogenous innovation capabilities. In other words, there are some processes whose strengthen ties between MNC's and region which will either support the embeddedness of these companies or the development of related industries of public institutions (Šipikal and Buček 2013).

Because very low presence of domestic companies within automotive sector, the inter-sectoral linkages seem to be key channels of knowledge and innovation flow to regional economy. This was confirmed also by survey done by Ferenčíková and Fifeková (2006) showed that indirect technology transfer was much more common than direct transfer. There are at least two good preconditions for it. First, The industry is one of the most innovative industries in Europe, as we already argued before. Second, automotive sector multiplier is one of the highest among industrial sector in Slovakia. Multiplier of value added had rose from 0.17 in 2000 to 0.39 in 2008. Output multiplier was 3.82 in 2011 (Luptáčik et al. 2013). Therefore, through multisectoral suppliers, these two preconditions allow possible diffusion of innovation to other sectors. As observed from interviews, process innovations already spread to other industries, mainly chemical, engineering or electronics. Some formalized cluster initiative also occurred, but usually only able to cooperate in the field quality of labour force or vocational training, not innovation activities (Zamborsky 2012). Another diffusion possibility are knowledge intensive business services. Bratislava region is a highly urbanized and diversified region with lot of KIBS which are very active engaged in innovation activities in the region. Therefore, the automotive industry strongly influences regional development and innovativeness of the region. However, still large part of it spreads outside the country, output multiplier without export was only 1.54 (Luptáčik et al. 2013). Several interviews confirm diversification in such a way, here the one example interviewed the head R&D of company:

> We found out increasing pressure on more effective process innovation. Firstly, we used our internal R&D capacities to improve our own technologies to be more competitive for automotive sector. Later, we established the new division of industrial automatization, which was responsible for process innovation. This division becomes very successful and it's production is now oriented not only on process innovation in automotive, but also in other sectors like chemical and engineering. Now, this division counts for 50% of our turnover.

Additionally, the multinational companies pushed for the evolution and improvement of the public sector in the region. They bring world class knowledge and innovation and require the same from possible partners within the region, so this competitive pressure "forced" the public institutions to "catch up" in order to be able act as a partner of the foreign companies Several public institutions have been able to at least partly fulfill their requirements. This cooperation between all governmental levels and the higher amount of public sector organizations promotes the continuous improvement of innovation capabilities at the local level. For instance, leading technical university in Slovakia, STU in Bratislava, used EU structural funds for two projects related to automotive industry to improve its R&D capacities (Šipikal and Buček 2013). The orientation of towards innovations are for example towards green cars, weight reduction, intelligent vehicles or software components (Babeľová et al. 2010). STU has also good cooperation with automotive sector in the field of labour force education (Zamborsky 2012). As mentioned in the interview with university:

> If we want to improve our research qualities, we must concentrate on cooperation with private sector. Due to present division of labour in automotive sector—these companies are mainly interesting into cooperation in increasing the production effectiveness, so we concentrated our projects and research on these issues.

The improvement of public institutions is an important condition for a future upgrade of the region towards endogenous innovation pattern (Šipikal 2013). As mentioned in interviews:

> Foreign companies were not very interested in cooperation with us. We need to implemented several projects that improve our technology and tried to focus the projects on very specific issues that interested them. This improves our cooperation, but still we see a lot of space for our improvement. These projects are very difficult, because MNC are very demanding.

This cooperation is vital for regional public research institutions abilities to create and acquire new knowledge or innovation as key preconditions for shift in innovation pattern. As in previous upgrade, the critical mass is important, in this case not the FDI investment, but investment into specialised research in the public institutions (Šipikal and Buček 2013), probably connected to only certain fields as e.g. process innovation, which will allow region to perform research in these areas at the international level. This is necessary preconditions to foster cooperation with MNCs and embed existing ones in the region. This “second level of threshold” investment will be key to further upgrade of innovation pattern in the region.

The specific tacit knowledge necessary for process innovation in the automotive industry has been applied to generate new knowledge in other sectors, mainly through knowledge intensive business services (Šipikal and Buček 2013). Such spillovers are much more even more likely to occur outside the sector, specially due to the strong innovation performance of the automotive sector, which is significantly higher than for other industry sectors in the region. As one KIBS stated:

> We created a production process software support for automotive company in cooperation with this MNC. The knowledge we got during this cooperation led us to ability to successfully apply modification of this software in several non-rival sector in the region.

Without strong FDI, the KIBS will be never able to achieve that level of abilities themselves. The automotive FDI as one of most competing sectors push the local companies to the word class activities. This was one of the main differences when comparing other interviewed sectors. In them there was no such pressure from FDI, mainly because FDI were quite isolated in these sectors and domestic companies still play an important role. For example in wood processing sector, KIBS or universities cooperate mainly with domestic companies, but this cooperation lead only to incremental innovation activities compare to automotive sector, even both sides were more less satisfied with this cooperation.

However, the “embeddedness of FDI” is still much more in the way of “foreign to foreign” linkages and one of main future issues will be question if such type of embeddedness could survive possible “domino” effect if some of automotive companies will decide to leave the country or these linkages are strong enough to prevent them to do so in most of cases.

7 Conclusions

This case study investigated at the knowledge and innovation patterns that has been developed in the automotive industry in western part of Slovakia over last 15 years. Special attention was given to foreign direct investment. FDI proved to be the main channel of knowledge creation and acquisition and the one of main key factor of successful sectoral as well as regional innovation shift. Compare to some other studies (e.g. Simmie and Martin 2010), FDI play very positive role, so the crucial question is related to factors and specific context preconditions that can positively influence the role of FDI (Šipikal and Buček 2013).

We identify several main reasons for this successful upgrading innovation pattern. Firstly, FDI inflow was very much influence by human capital. At the beginning, it played decisive role in the ability of the region to attract new foreign companies. The labour force was very skilled and able to reach very good productivity comparable to costs. Human capital also influences regional ability to implement autonomously process innovations within companies. The role of process innovation, strengthening by production reduction or cancellation in the parent companies, became one of the main driving forces of the industry upgrade and lead to the clear division of tasks between the subsidiaries and parent companies and consequently, to increasing specialization in specific types of knowledge generation (Šipikal and Buček 2013). This is not only the case of Western Slovakia, similar orientation in the automotive sector was found in the Czech Republic (Pavlínek and Ženka 2010). The process innovation orientation could also help region to overcome economic crisis as importance of the efficiency of production increase during crisis. Another important factor was the achievement of a critical mass of FDI in the sector resulting in external economies of scale which improved the competitiveness of the industry. The aggressive government policies played important role in this process, especially in the beginning of whole transformation. The gradual institutionalisation of the innovation activities in all types of companies in the region, including MNCs and local suppliers, created a functioning systematic process of continuous improvement that led to sectoral and regional growth. To summarize, we showed that region used its own combination of different conditions and actions (e.g. adequate infrastructure, human capital, appropriate support policies to achieve critical mass of FDI and proximity to market) to achieve regional ability for knowledge creation and exploitation in specific part of innovation process.

This support the conceptual argument that regions like Western Slovakia could not have necessarily much worse innovative performance than Western European regions (Capello et al. 2012), as it looks when we compare traditional innovation indicators. Only because the innovation processes are divided according to the regions and sectors, they are just focused primarily on process innovation (Šipikal and Buček 2013).

Availability of universities and other public research centers, KIBS and specially extensive automotive supplier network could help to maintain the present FDI companies and sustain sector development in Western Slovakia for this moment, despite lack of developed domestic companies in the industry. However, according to the theory (Capello et al. 2012), it's only second stage and the new question arise—if the sector will able to move forward to endogenous innovation pattern. As some studies suggest (Pavlínek 2016), the conditions for this are not so favourable at this moment, especially quality and availability of skilled workforce in the field of research.

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The Influence of Financial Sourcing and Collaboration on Innovative Company Performance: A Comparison of Czech, Slovak, Estonian, Lithuanian, Romanian, Croatian, Slovenian, and Hungarian Case Studies

Viktor Prokop, Jan Stejskal, and Petr Hajek

Abstract Many authors emphasize that regions are key elements and political tools for economic growth and that regional competitiveness significantly shapes entrepreneurial behavior, and also say, that high-tech firms choose their location based on their assessment of regional competitiveness (productivity, innovations) and that highly innovative firms settle in highly competitive regions. Scholars analyze the knowledge spillovers and their impact on firms' productivity, demand and successful implementation of product and process innovations. Other scholars suggest that for economic growth promotion it is necessary to take actions to support the creation and dissemination of knowledge, to support research and development activities, investment in appropriate infrastructure and communication technology. Therefore, the significance of innovation is today more and more frequently emphasized as a key engine for regional growth, standard of living and international competitiveness. The goal of this chapter is to provide an analysis and evaluate the influence of selected drivers—determinants of the knowledge economy on the selected output—turnover from innovated production and provide some practical implications for policy makers not only in selected countries. The analysis will be conducted by using a multiple linear regression models constructed by the authors. Results show that determinants of innovation activities vary across countries and, separately, influence innovation activities less than in combination with each other. These findings confirm previous studies on the general shift towards a knowledge economy and the importance of factors such as knowledge, innovation and cooperation with different partners that allow the creation of synergies and spillover effects.

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1 Introduction

Currently, competitiveness is a topic that is frequently discussed and dealt with in economic analysis. This applies not only to individual companies or sectors but also to regions by whatever definition. Competitiveness is an entity's ability to be successful in a competitive environment so that its goals are achieved to the greatest possible extent (and in the most effective way). In fact, competitiveness is considered to be one of the most significant determinants of economic development; gradual increase of this determinant results to the fulfillment of objectives of regional policy and to the growth of welfare, quality of life and long-term economic development (Amin 1999; Prokop and Stejskal 2015b). Companies must respond dynamically to adapt to the situation on international markets. They must change production processes and find new resources for the needs of innovative production. These consist of valuable knowledge and skills that complement their own capabilities. Firms must dramatically change their innovative activities as well as company strategy and the company's access to innovations (Autio et al. 2014). Similarly, entrepreneurs must understand that firms are part of an innovative environment where individual entities affect others. This innovative environment plays an important role in the innovation process at the firm level (Stejskal and Hajek 2012). Knowledge, spillover effects, cooperation, and complex R&D have become the new production factors in this third phase. These factors, mainly cooperation activities with other firms or institutions, open up opportunities for accessing complementary technological resources (such as skill sharing), which can contribute to faster innovation development, improved market access, economies of scale and scope, cost sharing, and risk spreading (De Faria et al. 2010).

There are many methods of achieving maximum effectiveness. On one hand, they are dependent on the type of entity in question, but they are also influenced by the environment and the conditions of the economic system surrounding the competing entities. Sources of competitive advantage also continue to develop within the current globalized system; therefore, researchers also try to discover the most effective possible way to increase competitiveness both for economic entities and regions (and, thus, for the entire economy). Thanks to globalization and technological progress, methods of communication, the Internet and IT technology are important production factors that often play a key role in achieving competitiveness (Chen et al. 2004). More and more often, these results in progress towards a knowledge economy, in which knowledge represents an important national, regional or company asset that creates a source of competitive advantages (McAleer and Slottje 2005). Each entity's economic potential is determined by its ability to create, use and share knowledge (Malecki 2000).

Knowledge and the ability to transform it into innovation are becoming the foundation for individual regional and national economic systems. These often try to support the creation, acquisition and transfer of knowledge—both financially and non-financially. In this way, the economy often becomes dependent or based on knowledge. Regarding each government's limited financial possibilities, the question arises as to the effectiveness of such attempts (and support for such attempts) to create and develop a knowledge economy. There are no standard, generally recognized methods that are able to determine to what degree an economy is based on knowledge (Kitson et al. 2004). Various studies argue about whether economies' knowledge base is measurable or how to measure a knowledge economy's outputs, which are necessary for different types of economic analysis (Leydesdorff et al. 2006). That is why it can be very difficult to evaluate the effects of each driver (determinant) in innovation environment. Typical examples are the effects of the soft determinants—for example the level of cooperation. The second determinant what is difficult to evaluate, is the public support, i.e. financial resources to support collaboration and knowledge transfer, acquisition and application in practice. Very often the (mainly the support from the EU budget and national budgets are applied).

Therefore, the goal of this chapter is to provide an analysis and evaluate the influence of selected drivers—determinants of the knowledge economy on the selected output—turnover from innovated production and provide some practical implications for policy makers not only in selected countries. The analysis will be conducted by using a multiple linear regression models constructed by the authors.

The remainder of this chapter is divided in the following way. The first two sections are focused on the knowledge economy and the determinants of environment what lead to innovations. The third section describes the methodology, analysis and results. The last section comprises the research's concluding evaluations and provides practical implications for policy makers.

2 The Innovation Environment and the Drivers[1]

Economic development and the gradual improvement of the living conditions in a country and its regions is a basic long-term strategic goal (Safiullin et al. 2012; Pachura and Hájek 2013). Many authors emphasize that regions are key elements and political tools for economic growth and that regional competitiveness significantly shapes entrepreneurial behavior, and also say, that high-tech firms choose their location based on their assessment of regional competitiveness (productivity, innovations) and that highly innovative firms settle in highly competitive regions (Boschma 2004; Annoni and Kozovska 2010; Prokop and Stejskal 2015a). This leads to the attempt by regional governments to look for the most effective possible ways to increase their regional competitiveness—i.e., one of the main engines for the region's growth (Snieska and Bruneckienė 2009; Stejskal and Hajek 2012). A number of factors influence the success of these attempts.

One of these is knowledge, which has been an increasingly significant production factor as of the start of the twenty-first century (Malecki 2000). This fact is supported

[1] Adopted from Prokop et al. (2017)

by a number of studies investigating the connection between the increase in regional competitiveness and knowledge (Audretsch et al. 2012; Kwiek 2012; Sum and Jessop 2013; Camagni and Capello 2013). Knowledge undoubtedly represents a new source of economic growth; however, from the economic perspective, utilizing knowledge is not a new issue (Snieska and Bruneckienė 2009). Around 1911, Schumpeter had already come up with the idea of using knowledge and its combinations as a foundation for innovative activities and entrepreneurship and we can see a shift from material and capital inputs to the input information, respectively knowledge (Cooke and Leydesdorff 2006; Hajek and Stejskal 2015). The number of scholars analyzes the knowledge spillovers and their impact on firms' productivity, demand and successful implementation of product and process innovations. Other scholars suggest that for economic growth promotion it is necessary to take actions to support the creation and dissemination of knowledge, to support research and development activities, investment in appropriate infrastructure and communication technology. Therefore, the significance of innovation is today more and more frequently emphasized as a key engine for regional growth, standard of living and international competitiveness (Acs et al. 2002a). The role of knowledge and its ties to innovation and economic performance continues to be more frequently analyzed (Shapira et al. 2006). It is clear that it is no longer possible to attain economic growth in the same ways as in the past, i.e., by hiring an ever greater number of workers as an input resource or by increasing consumer demand (Pulic 1998; Chen et al. 2004). Therefore, individual economic entities must seek new ways of keeping up with the competition and coping with the tempo of quick changes (Stejskal and Hajek 2015). New, economically useful knowledge that leads to the creation of innovation (product or process) therefore plays a significant role in (i) achieving economic growth; (ii) international trade; and (iii) regional development (Acs et al. 2002b).

The efforts to save the resources during the innovation production (product, service and process or marketing innovations), the accelerating their entry into the market and the gaining a competitive advantage in a globalized economy, these all lead to massive use of the second determinant of the innovation environment. The cooperation is this second determinant (Lee et al. 2012; Fitjar and Rodríguez-Pose 2013). A common platform of cooperation is a variant of the (quadruple) triple helix (Leydesdorff 2012). It is proven in many studies that cooperation (in all its forms: cooperation only within the enterprise or business networks; collaboration with universities and research institutions, and broad platform for industry-university-government cooperation) contributes to the formation of innovations, it accelerates and cheapens the all processes (Lee et al. 2012; Fitjar and Rodríguez-Pose 2013; Schilling 2015). However, there has been intensive cooperation; many conditions in the economic environment must be fulfilled (e.g. generally positive business atmosphere, trust or creation of the appropriate incentives for development of cooperation at various levels). Due to globalization, it is not necessary to think about collaboration just on a regional level or platform (Conrad et al. 2014). On the other hand, studies point to the fact that the level of trust with the increasing distance of the cooperating entities is decreased (Connell et al. 2014).

Many studies highlight the fact that effective collaboration requires the creating of favorable business environment, adequate incentives to innovation processes and helpful attitude from the public sector (Kaihua and Mingting 2014; Wang et al. 2016). A common characteristic of the listed drivers is the public support, which can help to create the above mentioned environment, and initiate the cooperation on the (initially the mostly) regional level (De Blasio et al. 2015). The practice shows that public support providing to foster innovation is not very effective. Often, businesses are investing own funds in own R&D activities; respectively they invest the internal money to innovative collaboration (Bronzini and Iachini 2014). The second option is to purchase knowledge or whole innovation in the market by other economic subject, which is also financed from internal funds. Given the EU's interest to maximize the production of innovations and innovative products on its territory, there are many grants in this area and to various entities (including businesses, public sector organizations, knowledge-based sectors, as well as other support organizations and agencies). Condition for the disbursement of European funds is often the co-financing from national and internal funds. The evaluating the effectiveness of this public support is very problematic as evidenced by numerous studies (Zúñiga-Vicente et al. 2014; De Blasio et al. 2015). There are many obstacles for detailed analysis, for example missing micro data, very long period between using money and the innovation birth, missing output criterion and very of the un-measurable quality etc. (Czarnitzki and Lopes-Bento 2013). There are many studies that demonstrate the positive effects of public funding, but some authors are critical and the effectiveness of public subsidies is evaluated as inadequate (Antonioli et al. 2014).

Many mentioned studies show that in various countries the situation is different. Often the settings of financing terms, bureaucracy procedures or the existence of different legal barriers are different. Our previous research (e. g. Prokop and Stejskal 2016a, b) shows that many of the drivers of innovation environments operate independently and influence positively the outcome of the innovation process. On the other hand, the effects what are generated from the combination of different drivers were detected and analyzed. But there is no international comparative study that would analyze the combination of drivers and compared the situation internationally.

3 Data and Methodology

Data for the analyses were obtained from the Community Innovation Survey for 2010–2012. The Community Innovation Survey (CIS) is a harmonized questionnaire, which is part of the EU's science and technology statistics; it is carried out every 2 years by the EU member states and a number of ESS member countries. For our analysis, we created original multiple linear regression models that are commonly used for these kinds of analyses (e.g. Nieto and Quevedo 2005; Chen and Huang 2009; Bishop et al. 2011—logistic regression; Schneider and Spieth 2013—multiple linear regression) and therefore we suppose these models sufficient. We investigate the relationship between one dependent variable, represented by the % of turnover in new or improved products introduced during 2010–2012 (new to the market), and a number of selected independent variables (innovation activity determinants, see Table 1). In total, we analyzed 10,804 enterprises from 8 countries (see Table 2) from the manufacturing industries (NACE Categories 10–33).

Regression models take the general form as follows (Chatterjee and Hadi 2013):

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n + \varepsilon \tag{1}$$

where:

y is a dependent variable;
$x_1, x_2 \ldots x_n$ are independent variables;
ε is an error term that accounts for the variability in y that cannot be explained by the linear effect of the n independent variables;

Table 1 Independent variables

Financing	Cooperation	Innovation	Firm activities	Other
Public funding from local or regional authorities (FUNLOC)	Government or public research institutes (CO_GOV)	Introduced a new or significantly improved product into the market (INN_G)	Merge with or take over another enterprise (ENMRG)	The largest market in terms of turnover between 2010–2012 (LARMAR)
Public funding from the central government (FUNGMT)	Other enterprises within an enterprise group (CO_GP)	Introduced a new or significantly improved service into the market (INN_S)	Sell, close, or outsource some of the company's tasks or functions (ENOUT)	Participation in a group of enterprises (GP)
Public financial support from the EU (FUNEU)	Suppliers of equipment, materials, components, or software (CO_SUP)	Introduced a new or significantly improved process into the market: method of production; logistic, delivery, or distribution system; supporting activities (INN_P)	Establish new subsidiaries in [home country] or in other European countries (ENNWEUR)	
	Clients or customers (CO_CUS)		Establish new subsidiaries outside Europe (ENNWOTH)	
	Universities or other higher education institutions (CO_UNI)			

Legend: The % of total turnover in 2012 was used to determine expenditures

Table 2 Number of companies analyzed in selected countries

Country	Number of companies
Czech Republic	3110
Hungary	2799
Slovak Republic	870
Romania	3982
Croatia	1280
Slovenia	918
Estonia	921
Lithuania	906

Source: Authors' own calculations

$\beta_1, \beta_2 \ldots \beta_n$, called the regression parameters or coefficients, are unknown constants to be determined (estimated) from the data.

Verification of whether the data from the CIS were correlated was conducted using Spearman's test. Spearman's coefficient (r_s) measures the strength of the linear relationship between each two variables when the values of each variable are rank-ordered from 1 to N, where N represents the number of pairs of values (the N cases of each variable are assigned integer values from 1 to N inclusive, and no two cases share the same value). The difference between ranks for each case is represented by d_i. The general formula for Spearman's rank correlation coefficient takes the general form as follows (Weinberg and Abramowitz 2002; Borradaile 2013):

$$r_s = 1 - \frac{6 \sum d_i^2}{N^3 - N} \quad (2)$$

The values of Spearman's test rejected the hypothesis that the data are correlated with a level of significance at $p < 0.05$. Moreover, we also tested the collinearity among the independent variables by using Variance Inflation Factor (VIF) for each regression model (country). Multicollinearity was not observed in any of the models (VIF $<$ 5).

All calculations were made using the statistical software STATISTICA (StatSoft Inc. 2011). After fulfilling the first prerequisite (uncorrelated data) and the rejection of multicollinearity in the model, the analysis itself was conducted.

4 Drivers of Innovative Activities Analysis

For every country, we created 8 models (M1–M8) analyzing the influence of selected variables (Table 1) and the creation of spillover effects. Firstly, we analyzed the relationship between each of the independent variables (the determinants of innovative activities) and the target (dependent) variable (the growth of turnover from innovated products between 2010–2012). This is presented in model M1. Most of the determinants of innovation activities differ within countries and most of these determinants do not influence the innovation activities separately. There are number of studies that analyze the spatial distribution of innovative activities and the role of technological spillovers in the process of knowledge creation and diffusion across firms, regions, and countries (e.g., Moreno et al. 2005; Cabrer-Borras and Serrano-Domingo 2007; Lee et al. 2015). For example, Fritsch and Franke (2004) investigated the impact of knowledge spillovers and R&D cooperation on innovation activities in German regions; Andersson and Ejermo (2005) showed that there is a positive relationship between the innovativeness of a corporation and its accessibility to university researchers in Sweden; and Dahl (2002) and Engelstoft et al. (2006) analyzed knowledge flows within clusters in Denmark with respect to spillover effects as a positive technological externality.

Therefore, we subsequently analyzed how the addition of variables and their interactions could influence the strength of models. We created other advanced models (M2–M8) that analyzed influence of public funding and cooperation on dependent variable. We analyzed influence of combinations between public financing and cooperation within groups of companies (M2), cooperation with suppliers (M3), cooperation with customers (M4), cooperation with universities (M5), cooperation with government or public research institutes (M6). We also analyzed influence of combinations between cooperation with universities and other cooperation partners (M7) and influence of combinations between cooperation with government or public research institutes and other cooperation partners (M8). All results (for all selected countries) are shown in following Sects. 4.1–4.8.

4.1 Romania

In Romania, spillover effects rarely occurred because of a lack of innovative background and facilities. The results in Table 3 show that the majority of the research results are not significant. We assume that there are other factors that affect the output variable than those examined in this study. The most significant determinant of innovative activities in Romanian companies seems to be collaboration. It is apparent from the various models that the companies working together with their suppliers (on a regular supplier-customer base) positively influenced their innovation outcomes. Surprisingly, it was found that collaborating with customers did not lead to changes that would positively affect any subsequent levels of revenue from innovation. Romanian businesses also collaborated with public research organisations. Collaboration with them also positively influenced the innovation outputs and, consequently, innovation revenue.

Examining the combination of the effects of the selected variables does not yield any results. No form of public support acts sufficiently strongly on innovation activities and does not affect the output variable significantly. No significant (and positive) effect of collaboration or public funding of innovative activities was revealed.

Table 3 Romania

	M1	M2	M3	M4	M5	M6	M7	M8
Intercept	0.219	0.208*	0.157	0.165	0.224**	0.218**	0.197*	0.223**
GP	−0.012	−0.012	−0.013	−0.013	−0.012	−0.013	−0.012	−0.012
LARMAR	−0.010	−0.011	−0.012	−0.012	−0.010	−0.010	−0.011	−0.012
FUNLOC	−0.076	−0.075	−0.016	−0.020	−0.077	−0.072	−0.078	−0.074
FUNGMT	−0.014	−0.014	−0.015	−0.027	−0.010	−0.019	−0.016	−0.017
FUNEU	−0.033	−0.021	−0.029	−0.030	−0.036	−0.030	−0.034	−0.035
CO_GP	−0.008	0.003	−0.005	−0.010	−0.008	−0.007	−0.005	−0.014
CO_SUP	0.050	0.050**	0.164**	0.045*	0.051**	0.047	0.029	0.050**
CO_CUS	−0.066	−0.064***	−0.071***	0.022	−0.066***	−0.065	−0.084**	−0.077***
CO_UNI	0.001	−0.002	0.004	0.008	0.001	−0.006	0.021	0.003
CO_GOV	0.042	0.041*	0.043*	0.043*	0.043*	0.034	0.034	0.033
ENMRG	0.046	0.046	0.046	0.050	0.045	0.050	0.051	0.049
ENOUT	0.004	0.005	0.005	0.006	0.004	0.008	0.005	0.008
ENWEUR	0.046	0.046	0.047	0.045	0.046	0.038	0.036	0.023
ENNWOTH	0.074	0.074	0.072	0.069	0.073	0.065	0.067	0.079
INN_GOOD	−0.001	−0.001	−0.001	−0.001	−0.0001	0.001	−0.002	0.001
INN_SERV.	−0.022	−0.022	−0.023	−0.020	−0.022	−0.021	−0.019	−0.020
INN_PROC.	−0.006	−0.005	−0.006	−0.006	−0.006	−0.008	−0.009	−0.007
FUNLOC*CO_GP		0.000						
FUNGMT*CO_GP		0.001						
FUNEU*CO_GP		−0.015						
FUNLOC*CO_SUP			−0.120*					
FUNGMT*CO_SUP			0.004					
FUNEU*CO_SUP			0.001					
FUNLOC*CO_CUS				−0.114				

(continued)

Table 3 (continued)

	M1	M2	M3	M4	M5	M6	M7	M8
FUNGMT*CO_CUS				0.035				
FUNEU*CO_CUS				−0.001				
FUNLOC*CO_UNI					0.000			
FUNGMT*CO_UNI					−0.008			
FUNEU*CO_UNI					0.005			
FUNLOC*CO_GOV						0.000		
FUNGMT*CO_GOV						0.036		
FUNEU*CO_GOV						−0.008		
CO_UNI*CO_GP							−0.012	
CO_UNI*CO_CUS							0.028	
CO_UNI*CO_SUP							0.032	
CO_UNI*CO_GOV							0.014	
CO_GOV*CO_GP								0.013
CO_GOV*CO_CUS								0.029
CO_GOV*CO_SUP								−0.016
CO_GOV*CO_UNI								0.008
R2	0.081	0.081	0.090	0.097	0.081	0.088	0.094	0.088

***sig. at $p < 0.01$; **sig. at $p < 0.05$; *sig. at $p < 0.1$

Romania is a typical example of a country where there is an innovation paradox. In this country, a background for innovation is missing, and the country faces obstacles in elements of its environment (e.g., insufficient infrastructure). Therefore, determinants of innovative activities are not able to influence the growth of turnover from innovation even if they were provided with sufficient public funds. The country struggles with a lack of absorption capacity but may also be hampered by a lack of demand for innovation outputs (from both enterprises and research organizations). Therefore, we strongly suggest coordinating public policies, building sufficient infrastructure in the country, supporting the identification of innovative needs and the demand for innovation outputs, and helping promote trust among organizations.

4.2 Croatia

The results in Table 4 show that the determinants of innovative activities examined (acting alone) do not affect innovation outcomes and subsequent revenue from innovation in a significant way. The only positive result was revealed in the co-innovation of a group of companies (CO_GP). Here, in all examined models and variants of cross-determinants, positive results have appeared. Similarly, it is possible to say that Croatian companies are influenced by the market in which they operate and which is their target outlet. Even this determinant was able to influence the amount of revenue from innovative production.

Unfortunately, even in Croatia, no positive effects from the combinations and interactions of determinants (collaboration and financing) have been demonstrated. To a certain extent, this testifies to the development of the local knowledge sector and the innovative maturity of manufacturing companies.

In Croatia, the situation was initially similar to that in Romania and most of the determinants did not influence the growth of turnover from innovation on their own (see Table 4).

The results show that Croatian companies do not sufficiently cooperate with each other. This may indicate some type of lock-in problems. However, this approach is justifiable and often occurs in CEE countries. It results from an underdeveloped business environment where public sector institutions are unlikely to contribute to the removal of barriers to entrepreneurship. They also often do not contribute to the creation of innovation systems and do not sufficiently support the involvement and cooperation of various market and non-market entities in them. It is not possible then to create the spill-over effects of knowledge, or other positive externalities resulting from synergy. As a good basis, we can see the positive influence of cooperation in business networks and the willingness to influence the requirements of the target markets and their entities.

We would suggest strengthening cooperation with universities and public research institutes in addition to focusing on promoting cooperation with clients and customers—and with competitors, because these kinds of cooperation has not yet led to significant results. Collaboration with clients is an important element of

Table 4 Croatia

	M1	M2	M3	M4	M5	M6	M7	M8
Intercept	0.219**	0.195*	0.243**	0.210**	0.253***	0.203**	0.180**	0.181*
GP	0.054***	0.052***	0.056***	0.054***	0.057***	0.055***	0.054***	0.054***
LARMAR	0.042***	0.041***	0.043***	0.041***	0.043***	0.044***	0.040**	0.042***
FUNLOC	0.044	0.058	0.037	0.042	0.019	0.041	0.048	0.040
FUNGMT	0.018	0.001	0.017	0.014	0.006	0.006	0.019	0.017
FUNEU	0.001	0.002	−0.012	0.010	−0.010	0.010	0.007	0.006
CO_GP	0.010	−0.017	0.007	0.008	0.005	0.009	0.007	0.005
CO_SUP	−0.003	−0.009	−0.006	−0.004	−0.002	−0.007	−0.037	−0.033
CO_CUS	−0.017	−0.014	−0.017	−0.047	−0.014	−0.014	−0.025	−0.030
CO_UNI	−0.028	−0.029	−0.026	−0.025	−0.048	−0.030	0.012	−0.013
CO_GOV	0.036	0.041	0.034	0.037	0.034	−0.007	0.040	0.063
ENMRG	−0.003	−0.008	−0.003	−0.003	−0.008	−0.007	−0.001	−0.001
ENOUT	0.006	0.005	0.004	0.005	0.002	0.005	0.008	0.007
ENWEUR	−0.007	0.006	−0.007	−0.005	−0.001	0.001	−0.006	−0.015
ENNWOTH	0.004	0.003	0.005	0.004	0.009	0.006	0.001	0.014
INN_GOOD	−0.003	−0.002	−0.001	−0.001	0.002	−0.004	−0.006	−0.008
INN_SERV.	−0.009	−0.009	−0.009	−0.009	−0.007	−0.007	−0.007	−0.011
INN_PROC.	−0.037**	−0.040**	−0.038**	−0.038**	−0.039**	−0.040**	−0.036**	−0.036**
FUNLOC*CO_GP		−0.024						
FUNGMT*CO_GP		0.032*						
FUNEU*CO_GP		0.047						
FUNLOC*CO_SUP			0.025					
FUNGMT*CO_SUP			0.007					
FUNEU*CO_SUP			−0.022					
FUNLOC*CO_CUS				0.014				
FUNGMT*CO_CUS				0.012				

FUNEU*CO_CUS				0.014				
FUNLOC*CO_UNI					0.045			
FUNGMT*CO_UNI					0.024			
FUNEU*CO_UNI					−0.025			
FUNLOC*CO_GOV						0.002		
FUNGMT*CO_GOV						0.023		
FUNEU*CO_GOV						0.045		
CO_UNI*CO_GP							0.004	
CO_UNI*CO_CUS							0.010	
CO_UNI*CO_SUP							0.043	
CO_UNI*CO_GOV							−0.030	
CO_GOV*CO_GP								0.016
CO_GOV*CO_CUS								0.021
CO_GOV*CO_SUP								0.029
CO_GOV*CO_UNI								−0.030
R2	0.095	0.111	0.098	0.098	0.107	0.105	0.104	0.102

***sig. at $p < 0.01$; **sig. at $p < 0.05$; *sig. at $p < 0.1$

competitive advantage, as evidenced, for example, by the lead user theory, which states that user-centered innovation is a very powerful and general phenomenon that supports innovative activities (Von Hippel 1986, 2005). Also, cooperation with competitors can lead to significant results. Gnyawali and Park (2011) state that co-opetition (the simultaneous pursuit of collaboration and competition) is viewed as the sum of many different relationships, and the cooperative and competitive parts are divided between different actors. They also state that it occurs, evolves, and impacts the participating firms and the industry and that it plays an important role in enhancing common benefits as well as in gaining a proportionately larger share of the benefits. Co-opetition is a challenging yet very helpful way for firms to address major technological challenges, create benefits for partnering firms, and advance technological innovation. Moreover, co-opetition between giants causes subsequent collaboration among other firms and results in advanced technological development.

4.3 Slovenia

In Slovenia, interactions of determinants occurred rarely, even though firms effectively utilize the various determinants of innovation activities, and these determinants have strong influence on the growth of the firms' turnover from innovation in the manufacturing industry on their own. An interesting finding is the inability of Slovenian companies to use public funds from the central government effectively. Combination analyses give almost identical results (negative), which enhances the predictive power of these findings. The combination of FUNGMT * CO_GP also negatively affected the output variable. On the other hand, the use of EU resources supporting business networking has been positively evaluated. The development of a high-quality business sector (within the surveyed industry) is supported by the finding that the inclusion of the university and its research into these networks positively supports the turnover from innovative production (0.046***) (Table 5).

Companies in Slovenia are probably not forced to seek new sources of competitive advantage and change their current situation. Narula (2002) states that firms are by definition resistant to radical change, and firms will always to prefer to maintain the status quo if it does not endanger their competitiveness (firms are often slow in changing their dominant designs, because they are path dependent and technologically locked in). By their very nature, all innovation systems have some degree of inertia, and this may lead to lock-in. Moreover, while offering a veneer of protection to existing systems in the shorter term, innovation lock-in tends to create barriers to more sustainable innovation (Aylward 2006); this can lead to a country's decline in innovation performance as well as a decline in its competitive advantage and prosperity.

In Slovenia probably, the firms protect their know-how; there is no trust between firms or between firms and universities or public research institutes, which leads to a lack of cooperation and the lock-in effect. Narula (2002) states that this type of small country, for instance, simply does not have the resources to sustain world-class

Table 5 Slovenia

	M1	M2	M3	M4	M5	M6	M7	M8
Intercept	0.401***	0.407***	0.388***	0.407***	0.403***	0.395***	0.379***	0.395***
GP	−0.017	−0.017	−0.017	−0.017	−0.017	−0.018	−0.019	−0.017
LARMAR	−0.008	−0.008	−0.008	−0.008	−0.009	−0.008	−0.008	−0.008
FUNLOC	−0.019	−0.023	−0.018	−0.026	−0.022	−0.020	−0.015	−0.019
FUNGMT	−0.028*	−0.019	−0.030*	−0.027*	−0.027*	−0.027*	−0.027*	−0.028*
FUNEU	−0.003	−0.011	0.003	−0.004	−0.002	−0.001	−0.004	−0.003
CO_GP	0.003	−0.037	0.002	0.004	0.002	0.005	0.013	0.003
CO_SUP	0.013	0.010	0.055	0.013	0.012	0.012	0.003	0.014
CO_CUS	−0.010	−0.006	−0.010	−0.029	−0.009	−0.011	−0.013	−0.012
CO_UNI	−0.005	−0.007	−0.006	−0.005	0.007	−0.008	−0.015	−0.009
CO_GOV	0.017	0.020	0.018	0.017	0.018	0.001	0.021	0.020
ENMRG	−0.016	−0.016	−0.016	−0.016	−0.017	−0.017	−0.010	−0.015
ENOUT	−0.010	−0.009	−0.010	−0.011	−0.010	−0.011	−0.011	−0.010
ENWEUR	0.014	0.017	0.016	0.014	0.014	0.015	0.007	0.013
ENNWOTH	−0.059	−0.052	−0.055	−0.060	−0.057	−0.053	−0.059	−0.058
INN_GOOD	0.095**	0.100**	0.091**	0.094**	0.095**	0.100**	0.091**	0.097**
INN_SERV.	−0.014	−0.016	−0.017	−0.014	−0.014	−0.014	−0.017	−0.01
INN_PROC.	−0.017	−0.020	−0.018	−0.016	−0.017	−0.018	−0.015	−0.017
FUNLOC*CO_GP		0.021						
FUNGMT*CO_GP		−0.035**						
FUNEU*CO_GP		0.039**						
FUNLOC*CO_SUP			−0.052					
FUNGMT*CO_SUP			−0.012					
FUNEU*CO_SUP			0.015					
FUNLOC*CO_CUS				0.023				

(continued)

Table 5 (continued)

	M1	M2	M3	M4	M5	M6	M7	M8
FUNGMT*CO_CUS				0.006				
FUNEU*CO_CUS				−0.007				
FUNLOC*CO_UNI					−0.017			
FUNGMT*CO_UNI					−0.009			
FUNEU*CO_UNI					0.008			
FUNLOC*CO_GOV						0.005		
FUNGMT*CO_GOV						0.001		
FUNEU*CO_GOV						0.023		
CO_UNI*CO_GP							0.046***	
CO_UNI*CO_CUS							−0.016	
CO_UNI*CO_SUP							0.007	
CO_UNI*CO_GOV							−0.003	
CO_GOV*CO_GP								0.003
CO_GOV*CO_CUS								0.003
CO_GOV*CO_SUP								−0.004
CO_GOV*CO_UNI								0.006
R2	0.064	0.084	0.073	0.066	0.067	0.070	0.090	0.065

***sig. at $p < 0.01$; **sig. at $p < 0.05$; *sig. at $p < 0.1$

competences in as wide a variety of technologies as the economy may require. As such, the knowledge infrastructure may be unable to overcome lock-in as rapidly as firms need to sustain their competitiveness. Innovation lock-in, while offering a veneer of protection to existing systems in the shorter term, tends to create barriers to more sustainable innovation, and this could lead to a decline in a country's innovation performance as well as to a decline in its competitive advantage and prosperity. We therefore propose greater company openness and promoting trust and cooperation between firms as well as between firms and universities or public research institutes. In Slovenia, an open innovation approach is necessary to develop and promote to use of purposive inflows and outflows of knowledge to accelerate internal innovation and expand the markets for external use of innovation. This concept is based on different research trends and suggests that valuable ideas can come from inside or outside the company and can also go to market from inside or outside the company (Chesbrough 2006; Chesbrough and Appleyard 2007). Therefore, cooperation is seen as a crucial way to increase firms' growth of turnover and a country's competitiveness.

4.4 Czech Republic

In manufacturing industries in the Czech Republic, regression models in Table 6 showed more interesting results than in the previous countries. The analysis of the influence of the individual determinants on the dependent variable showed that the innovation activity of the Czech companies is influenced mainly by the choice of the target market. Independent financial determinants gave expected results. Funds from local, regional, or national sources do not significantly affect the turnover of innovative companies. EU budget funds affect them, but in all cases negatively. All models have shown that the independent impact of EU subsidies creates a hindrance for processing companies. This is due to an unclear and complicated system of applying for European subsidies, as well as very difficult accounting and a high risk of having to repay the subsidy in the event of violating the usage conditions. These results confirm the obstacles mentioned above in the form of a high degree of bureaucracy and the instability of the legal environment affecting the innovation activity of Czech companies.

As in other countries, no positive impact of collaboration has been demonstrated. Among Czech companies in the basic group, the impact of suppliers (in M3) and universities in the M5 model was confirmed. Collaboration of a business and a university, funded from a European project, resulted in the positive influence of the company's innovation turnover. Other types of funding did not have a significant positive influence on the dependent variable. Other combinations of collaborating entities and type of funding did not provide a significant result.

The results of the analysis show that there are also many important determinants of the innovation environment in the Czech Republic (as in other CEE countries), which are more effective in their ability to innovate. It was found that these

Table 6 Czech Republic

	M1	M2	M3	M4	M5	M6	M7	M8
Intercept	0.260***	0.250***	0.291***	0.256***	0.292***	0.267***	0.242***	0.249***
GP	−0.002	−0.003	−0.003	−0.002	−0.002	−0.002	−0.002	−0.002
LARMAR	0.0180**	0.017**	0.0178**	0.018**	0.019**	0.018**	0.018**	0.0172**
FUNLOC	−0.023	−0.006	−0.041*	−0.015	−0.029	−0.018	−0.023	−0.022
FUNGMT	−0.013	−0.010	−0.014	−0.011	−0.013	0.003	−0.015	−0.013
FUNEU	−0.021**	−0.021*	−0.019**	−0.021**	−0.019*	−0.021	−0.020**	−0.020**
CO_GP	0.001	0.040	0.0019	0.001	0.002	0.001	−0.001	0.003
CO_SUP	0.006	0.007	0.0710***	0.007	0.009	0.007	−0.001	0.007
CO_CUS	−0.010	−0.009	−0.010	0.028	−0.008	−0.009	−0.009	0.002
CO_UNI	0.011	0.012	0.0122	0.012	0.067***	0.013	0.005	−0.008
CO_GOV	−0.010	−0.013	−0.016	−0.013	−0.014	0.002	−0.001	−0.002
ENMRG	0.016	0.017	0.017	0.017	0.015	0.017	0.016	0.016
ENOUT	0.014	0.014	0.015	0.014	0.011	0.014	0.014	0.014
ENWEUR	0.010	0.008	0.008	0.012	0.010	0.008	0.010	0.009
ENNWOTH	0.008	0.004	0.005	0.003	−0.001	0.005	0.010	0.010
INN_GOOD	−0.013	−0.013	−0.011	−0.013	−0.013	−0.015	−0.013	−0.014
INN_SERV.	−0.021**	−0.021**	−0.021**	−0.020**	−0.021**	−0.021**	−0.0204**	−0.022**
INN_PROC.	−0.013	−0.013	−0.012	−0.013	−0.012	−0.012	−0.0137	−0.014
FUNLOC*CO_GP		−0.039						
FUNGMT*CO_GP		−0.010						
FUNEU*CO_GP		0.0026						
FUNLOC*CO_SUP			−0.058**					
FUNGMT*CO_SUP			−0.010					
FUNEU*CO_SUP			−0.010					
FUNLOC*CO_CUS				−0.038				
FUNGMT*CO_CUS				−0.009				

FUNEU*CO_CUS				0.002				
FUNLOC*CO_UNI					−0.054**			
FUNGMT*CO_UNI					−0.039***			
FUNEU*CO_UNI					0.0186*			
FUNLOC*CO_GOV						−0.018		
FUNGMT*CO_GOV						−0.023		
FUNEU*CO_GOV						0.001		
CO_UNI*CO_GP							−0.008	
CO_UNI*CO_CUS							0.004	
CO_UNI*CO_SUP							0.017	
CO_UNI*CO_GOV							0.013	
CO_GOV*CO_GP								−0.003
CO_GOV*CO_CUS								−0.016
CO_GOV*CO_SUP								−0.001
CO_GOV*CO_UNI								0.0232
R2	0.026	0.029	0.034	0.029	0.044	0.029	0.029	0.028

***sig. at $p < 0.01$; **sig. at $p < 0.05$; *sig. at $p < 0.1$

fundamentals are not actually a type of collaboration or financial support. To improve the situation, it is essential to improve the business environment; to encourage "bottom-up" cooperation. Regional innovation systems can be developed across the country to encourage greater collaboration between businesses, universities and other support organisations. Financial frameworks appear to be inadequately defined and targeted, and do not encouragie innovative cooperation. Similarly, it is necessary to eliminate the high degree of bureaucracy and formalism in the request for EU funding, which in practice in the Czech Republic appears to be a form of innovation paradox.

4.5 Slovakia

In Slovakia, regression models did not provide any significant results. The results obtained do not have sufficient information from any of the models presented (M1-M8). Without emphasis on significance, it can be argued that Slovak companies are not fundamentally influenced by the type of target market (whether domestic or international). Similarly, companies in Slovakia which collaborated with universities did not achieve a positive increase in innovation turnover. Collaboration with governmental research organisations did not appreciably affect the turnover of companies (but any influence detected was mostly positive) (Table 7).

The impact of public funds on company innovation has not been confirmed. Any public funds provided are rather inefficiently used. Similarly, the impact of collaboration has not been confirmed, even with public R&D organisations and universities.

We assume that weak results in Slovak manufacturing firms are due to the smaller sample of companies.

4.6 Hungary

In Hungary, proper market orientation, as well as in the Czech Republic, leads to creation of strong links influencing dependent variable (in all cases). The force of this determinant is evident from its invariant value in all regression models. Hungarian firms are also trying to establish new subsidiaries in Hungary or in other European countries (Table 8).

A very weak (but not significant) positive was the impact of collaboration with public research institutions and universities. Supplier inputs are also used, which have a positive effect on companies' turnover from innovation.

An interesting point was the fact that Hungarian firms seeking an innovative product or service, or process innovation, have failed to use these innovative incentives and effectively commercialise them. Significant negative effects on turnover from innovative production were identified. It can be assumed that this is a

Table 7 Slovakia

	M1	M2	M3	M4	M5	M6	M7	M8
Intercept	0.167	0.154	0.171	0.163	0.177	0.139	0.141	0.162
GP	0.029	0.032	0.030	0.033	0.032	0.031	0.025	0.026
LARMAR	−0.014	−0.015	−0.013	−0.012	−0.011	−0.013	−0.020	−0.014
FUNLOC	0.004	0.014	0.001	0.016	0.022	0.013	0.018	0.002
FUNGMT	0.039	0.045	0.036	0.045	0.057	0.080	0.045	0.039
FUNEU	0.047	0.043	0.046	0.025	0.027	−0.007	0.055	0.049
CO_GP	−0.060	−0.149	−0.061	−0.055	−0.057	−0.056	−0.058	−0.079
CO_SUP	−0.018	−0.028	−0.006	−0.022	−0.022	−0.021	0.014	−0.009
CO_CUS	0.043	0.055	0.042	−0.027	0.051	0.046	0.057	0.056
CO_UNI	−0.028	−0.033	−0.029	−0.029	0.107	−0.029	−0.109	−0.036
CO_GOV	0.001	0.004	−0.001	−0.002	−0.008	0.005	0.035	−0.005
ENMRG	0.053	0.053	0.055	0.064	0.062	0.065	0.052	0.053
ENOUT	0.053	0.056	0.051	0.051	0.046	0.050	0.053	0.052
ENWEUR	0.035	0.039	0.037	0.033	0.038	0.039	0.043	0.040
ENNWOTH	0.012	−0.003	0.017	0.018	0.005	0.031	0.023	0.012
INN_GOOD	0.009	0.012	0.010	0.012	0.015	0.009	0.020	0.008
INN_SERV.	0.045	0.052	0.043	0.041	0.039	0.043	0.053	0.043
INN_PROC.	−0.037	−0.040	−0.036	−0.035	−0.028	−0.036	−0.036	−0.036
FUNLOC*CO_GP		0.037						
FUNGMT*CO_GP		0.035						
FUNEU*CO_GP		0.035						
FUNLOC*CO_SUP			0.000					
FUNGMT*CO_SUP			−0.016					
FUNEU*CO_SUP			0.004					
FUNLOC*CO_CUS				0.039				

(continued)

Table 7 (continued)

	M1	M2	M3	M4	M5	M6	M7	M8
FUNGMT*CO_CUS				−0.016				
FUNEU*CO_CUS				0.060				
FUNLOC*CO_UNI					−0.123			
FUNGMT*CO_UNI					−0.065			
FUNEU*CO_UNI					0.037			
FUNLOC*CO_GOV						−0.012		
FUNGMT*CO_GOV						−0.066		
FUNEU*CO_GOV						0.074		
CO_UNI*CO_GP							0.006	
CO_UNI*CO_CUS							−0.049	
CO_UNI*CO_SUP							−0.028	
CO_UNI*CO_GOV							0.047	
CO_GOV*CO_GP								0.034
CO_GOV*CO_CUS								−0.021
CO_GOV*CO_SUP								−0.014
CO_GOV*CO_UNI								0.010
R2	0.063	0.073	0.063	0.073	0.084	0.074	0.077	0.067

***sig. at $p < 0.01$; **sig. at $p < 0.05$; *sig. at $p < 0.1$

Table 8 Hungary

	M1	M2	M3	M4	M5	M6	M7	M8
Intercept	0.168***	0.174***	0.172***	0.179***	0.184***	0.172***	0.146**	0.134**
GP	0.014	0.014	0.015	0.014	0.014	0.014	0.014	0.014
LARMAR	0.027***	0.027***	0.027***	0.027***	0.028***	0.027***	0.027***	0.028***
FUNLOC	−0.010	−0.015	−0.010	−0.021	−0.028	−0.020	−0.009	−0.009
FUNGMT	−0.012	−0.003	−0.005	−0.008	−0.008	0.025	−0.012	−0.012
FUNEU	−0.011	−0.013	−0.012	−0.009	−0.015	−0.048***	−0.011	−0.011
CO_GP	−0.001	−0.004	−0.001	0.001	−0.001	−0.002	0.001	−0.004
CO_SUP	0.013	0.013	0.011	0.012	0.013	0.012	0.011	0.005
CO_CUS	−0.015	−0.014	−0.016	−0.035	−0.013	−0.014	−0.014	−0.030
CO_UNI	0.001	0.001	0.002	0.001	−0.028	−0.001	−0.022	−0.014
CO_GOV	0.005	0.001	−0.003	0.001	0.003	−0.001	0.025	0.034
ENMRG	−0.020	−0.020	−0.020	−0.020	−0.019	−0.016	−0.019	−0.019
ENOUT	−0.013	−0.014	−0.013	−0.013	−0.012	−0.014	−0.013	−0.013
ENWEUR	0.015	0.014	0.015	0.017	0.014	0.017	0.012	0.013
ENNWOTH	0.030	0.029	0.029	0.027	0.033	0.035	0.031	0.032
INN_GOOD	−0.098***	−0.099***	−0.099***	−0.099***	−0.099***	−0.098***	−0.099***	−0.099***
INN_SERV.	−0.011	−0.011	−0.056***	−0.056***	−0.056***	−0.056***	−0.056***	−0.056***
INN_PROC.	−0.056***	−0.056***	−0.011	−0.012	−0.011	−0.009	−0.012	−0.012
FUNLOC*CO_GP		0.011						
FUNGMT*CO_GP		−0.018*						
FUNEU*CO_GP		0.003						
FUNLOC*CO_SUP			0.011					
FUNGMT*CO_SUP			−0.023**					
FUNEU*CO_SUP			0.004					
FUNLOC*CO_CUS				0.027				

(continued)

Table 8 (continued)

	M1	M2	M3	M4	M5	M6	M7	M8
FUNGMT*CO_CUS				−0.009				
FUNEU*CO_CUS				−0.004				
FUNLOC*CO_UNI					0.029			
FUNGMT*CO_UNI					−0.010			
FUNEU*CO_UNI					0.011			
FUNLOC*CO_GOV						0.006		
FUNGMT*CO_GOV						−0.044***		
FUNEU*CO_GOV						0.042***		
CO_UNI*CO_GP							−0.007	
CO_UNI*CO_CUS							0.006	
CO_UNI*CO_SUP							0.002	
CO_UNI*CO_GOV							0.024	
CO_GOV*CO_GP								0.004
CO_GOV*CO_CUS								0.018
CO_GOV*CO_SUP								0.005
CO_GOV*CO_UNI								0.014
R2	0.204	0.225	0.228	0.223	0.224	0.233	0.223	0.224

***sig. at $p < 0.01$; **sig. at $p < 0.05$; *sig. at $p < 0.1$

result of a time lag between the application of market innovation and its commercialisation.

Regression models have shown that, in the manufacturing industry, public funds provided by the central government act rather negatively, thus not affecting the innovation capability of these companies. They do not act positively even when they finance collaboration with public research institutions. However, this collaboration is supported in Hungary by European subsidies, which have been found to have a positive and significant result (0.042***).

The combinations analysed worsened the results of the regression models. On the basis of the results found, it is not possible to postulate any main conclusions, but rather to estimate the causes of these results. It may be true that in Hungary (as in other CEE countries), other factors such as the business environment, lack of openness, a high degree of bureaucracy, clientelism and corruption in public financing predominate.

4.7 Estonia

The results in Table 9 show the selected combination of variables in Estonia. Significant positive effects have been identified here on the turnover of innovation revenue (even at the lowest level of significance).

The analysis allows for positive effects when implementing product innovations (though not significant). Other types of innovation do not positively affect companies' innovation performance.

None of the analysed combinations of "cooperation and funding" provided significant results. Support from national sources does not work in practice in line with its objective (negative effects, however insignificant, have been found in all combinations). Any combination of cooperation and funding from the EU budget improves the impact of these funds. Individual models showed rather positive effects. Mutual combinations of different forms of cooperation also did not bring significant results.

We can conclude that public support does not always bring positive effects, especially if subsidies are not carefully targeted to the appropriate industry and to the target activity (totally clear type of innovation).

4.8 Lithuania

The results in Table 10 show that Lithuania has different situation regarding the impact of public finance as in Estonia. We found that the greatest influence on companies' innovation capabilities in Lithuania is the choice of the markets that firms are oriented towards. Almost identical effects were found in all models.

Table 9 Estonia

	M1	M2	M3	M4	M5	M6	M7	M8
Intercept	0.378**	0.369**	0.379**	0.378**	0.397***	0.414***	0.394**	0.382**
GP	0.043*	0.044*	0.043*	0.043*	0.043*	0.043*	0.043*	0.039
LARMAR	0.019	0.017	0.020	0.020	0.021	0.020	0.022	0.021
FUNLOC	−0.003	−0.002	−0.003	−0.004	−0.004	−0.004	−0.011	−0.005
FUNGMT	0.012	0.007	0.013	0.014	0.019	0.030	0.009	0.011
FUNEU	−0.016	−0.001	−0.018	−0.026	−0.039	−0.072	−0.015	−0.013
CO_GP	−0.040	−0.022	−0.040	−0.038	−0.041	−0.041	−0.023	−0.059
CO_SUP	0.009	0.011	0.004	0.009	0.009	0.008	0.013	0.010
CO_CUS	0.026	0.021	0.026	−0.020	0.027	0.029	−0.016	−0.024
CO_UNI	0.024	0.026	0.024	0.024	0.006	0.023	0.051	0.038
CO_GOV	0.016	0.016	0.015	0.020	0.015	−0.015	0.020	0.026
ENMRG	−0.010	−0.010	−0.010	−0.011	−0.009	−0.008	−0.014	−0.009
ENOUT	−0.029	−0.026	−0.031	−0.034	−0.034	−0.033	−0.021	−0.024
ENWEUR	0.022	0.017	0.022	0.025	0.025	0.017	0.020	0.0130
ENNWOTH	−0.070	−0.073	−0.073	−0.072	−0.083	−0.078	−0.098	−0.088
INN_GOOD	0.009	0.010	0.007	0.002	0.004	0.005	0.011	0.002
INN_SERV.	−0.025	−0.022	−0.026	−0.028	−0.030	−0.029	−0.022	−0.032
INN_PROC.	−0.004	−0.004	−0.003	−0.005	−0.003	−0.003	−0.005	−0.002
FUNLOC*CO_GP		0.000						
FUNGMT*CO_GP		0.009						
FUNEU*CO_GP		−0.031						
FUNLOC*CO_SUP			0.000					
FUNGMT*CO_SUP			−0.003					
FUNEU*CO_SUP			0.008					
FUNLOC*CO_CUS				0.031				
FUNGMT*CO_CUS				−0.002				

FUNEU*CO_CUS				0.023				
FUNLOC*CO_UNI					0.000			
FUNGMT*CO_UNI					−0.015			
FUNEU*CO_UNI					0.039			
FUNLOC*CO_GOV						0.000		
FUNGMT*CO_GOV						−0.022		
FUNEU*CO_GOV						0.067		
CO_UNI*CO_GP							−0.014	
CO_UNI*CO_CUS							0.061	
CO_UNI*CO_SUP							−0.008	
CO_UNI*CO_GOV							−0.027	
CO_GOV*CO_GP								0.024
CO_GOV*CO_CUS								0.056
CO_GOV*CO_SUP								−0.002
CO_GOV*CO_UNI								−0.019
R2	0.047	0.050	0.047	0.049	0.053	0.054	0.058	0.054

***sig. at $p < 0.01$; **sig. at $p < 0.05$; *sig. at $p < 0.1$

Table 10 Lithuania

	M1	M2	M3	M4	M5	M6	M7	M8
Intercept	0.204***	0.168*	0.203**	0.210***	0.145	0.189**	0.237***	0.262***
GP	−0.006	−0.006	−0.007	−0.008	−0.006	−0.007	−0.008	−0.009
LARMAR	0.042***	0.042***	0.042***	0.042***	0.045***	0.046***	0.040**	0.041***
FUNLOC	−0.057	−0.023	−0.055	−0.067	0.004	−0.046	−0.057	−0.052
FUNGMT	−0.011	−0.006	−0.010	−0.011	−0.001	0.007	−0.020	−0.021
FUNEU	0.034**	0.036*	0.032*	0.038**	0.049**	0.056**	0.036**	0.035**
CO_GP	0.038	0.095	0.038	0.041	0.037	0.035	0.044	0.057*
CO_SUP	−0.008	−0.008	0.004	−0.010	−0.006	−0.004	−0.032	−0.044
CO_CUS	−0.011	−0.010	−0.011	0.034	−0.010	−0.009	−0.025	−0.027
CO_UNI	0.047	0.043	0.048	0.045	0.129*	0.047	0.111***	0.114***
CO_GOV	−0.042	−0.041	−0.042	−0.041	−0.039	−0.024	−0.066	−0.062*
ENMRG	0.015	0.012	0.014	0.015	0.014	0.013	0.020	0.017
ENOUT	0.037	0.038	0.037	0.040	0.035	0.039	0.032	0.031
ENWEUR	−0.030	−0.027	−0.029	−0.031	−0.026	−0.030	−0.024	−0.024
ENNWOTH	0.047	0.046	0.047	0.048	0.057	0.057	0.043	0.044
INN_GOOD	−0.141***	−0.141***	−0.141***	−0.142***	−0.140***	−0.141***	−0.136***	−0.136***
INN_SERV.	−0.054***	−0.054***	−0.054***	−0.052***	−0.060***	−0.057***	−0.063***	−0.061***
INN_PROC.	0.003	0.002	0.003	0.001	0.001	0.001	0.003	0.002
FUNLOC*CO_GP		−0.051						
FUNGMT*CO_GP		−0.009						
FUNEU*CO_GP		−0.004						
FUNLOC*CO_SUP			−0.010					
FUNGMT*CO_SUP			−0.005					
FUNEU*CO_SUP			0.005					
FUNLOC*CO_CUS				−0.047				
FUNGMT*CO_CUS				0.001				

FUNEU*CO_CUS				−0.010				
FUNLOC*CO_UNI					−0.057			
FUNGMT*CO_UNI					−0.054**			
FUNEU*CO_UNI					−0.021			
FUNLOC*CO_GOV						0.000		
FUNGMT*CO_GOV						−0.045*		
FUNEU*CO_GOV						−0.028		
CO_UNI*CO_GP							−0.021	
CO_UNI*CO_CUS							0.027	
CO_UNI*CO_SUP							0.034	
CO_UNI*CO_GOV							−0.068**	
CO_GOV*CO_GP								−0.028
CO_GOV*CO_CUS								0.016
CO_GOV*CO_SUP								0.045
CO_GOV*CO_UNI								−0.095**
R2	0.318	0.320	0.319	0.321	0.337	0.331	0.339	0.336

***sig. at $p < 0.01$; ** sig. at $p < 0.05$; *sig. at $p < 0.1$

Public funding from EU funds positively affects corporate results. The results are almost unchanged in each model, which confirms the information capability. The impact of funds from public budgets has not been confirmed or was found to be insignificant, or negative. Innovative results of Lithuanian companies are also affected by collaboration with universities. Their importance is enhanced by collaboration with public research institutes.

Examination of individual combinations did not lead to any clear results in this country either. The impact of public finances on the development of collaboration has also not been confirmed in Lithuania. This is a result common to the CEE countries. For example, if a company collaborated with a university and used a subsidy from the national budget, it did not positively offset the revenues from innovative production. This result (though insignificant) is also supported by the results of the study of the impact of municipal and European public subsidies. This suggests that even Lithuanian companies will likely have to overcome the barriers to bureaucracy associated with the use of subsidies (which may be reflected in the fact that companies are more committed to fulfilling these claims than the innovation itself). Similarly, no positive impact of collaboration with universities or R&D organisations has been confirmed. Again, it can be assumed that the reason is the inflexibility and the completely dichotomous objective of these knowledge-based organisations which are incompatible with the objectives of business entities.

5 Conclusions

Nowadays, innovation plays an important role in the process of gaining competitive advantage and economic growth of firms or countries. However, finding the proper determinants of innovative activities represent a complex process lacking universal formula of which variables positively affect innovation creation. Therefore, the aim of this study was to fill the gap and find proper determinants of innovative activities—drivers of economic growth in twenty-first century, and make international comparison providing some practical implications not only for these countries. Results show that determinants of innovation activities vary across countries and, separately, influence innovation activities less than in combination with each other. These findings confirm previous studies on the general shift towards a knowledge economy and the importance of factors such as knowledge (Conceição et al. 1998; Wessel 2013), innovation (Aghion et al. 2013; Braha et al. 2015) and cooperation with different partners (Brink and Neville 2016; Vásquez-Urriago et al. 2016) that allow the creation of synergies and spillover effects.

An important implication arising from these results is that public policies to encourage the innovations creation should to be selective, and should be directed to selected sector. Cooperation in the creation of a specific innovation has to be the aim. In this case, it is possible to record even the existence of knowledge spill-over effects mostly in knowledge networks. Therefore, public support should be allocated wisely and only in selected areas of the industry. Individual projects must be clearly defined and measurable outputs of innovation and policy makers should carefully decide which projects and centers they will support (from national or European funds) and which not. The massive uncontrolled support should be mistaken for selective support focused on achieving the highest possible efficiency. The declaration of interest towards maximum efficiency should be incorporated into different strategies from national to the regional level. Public institutions and decision makers must use monitoring tools and methods using ex ante effectiveness evaluation (financial schemes must be prepared and “fit” to targeted applicants well because it is unable to apply the approach “all fits to all”). All these results should help to improve the strategic management of public sector organizations (also the regional governments) to prepare better strategies and various sectoral policies.

To increase efficiency, we recommend the clear definition of expected outputs, continuous monitoring and conditional funding. Likewise, we show that cooperation may have a greater positive effect if it occurs during the formation of a certain innovation and in combination with different entities, especially with universities and within groups of companies. These combinations significantly influence the growth of turnover from innovated products within different countries.

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Methodological Dichotomy in the Studies of Knowledge Spillovers: CEE Region Under Focus

Paula Puskarova

Abstract The recent years have witnessed increasing efforts to solve the puzzle around knowledge capital and externalities it appears to unfold. Clearly, the concept of prompting growth through acquiring knowledge for free is appealing. Still, there is no consensus on the significance and magnitude of the estimated impacts of knowledge externalities. The ambiguity might be caused by the lack of methodological unity. A large cohort of scientists advocate capturing knowledge spillovers alongside the movements of production or production factors—considered as channels of knowledge transfers—while others see true value of transferred knowledge in productivity increases registered at proximity to some knowledge production. In the latter case, distance matters more than mere transfer of a product and thus the approach might be quoted as spatial. In this chapter, we discuss major contributions to the field of knowledge spillover studies made while taken both approaches, point to some advantages and pitfalls attached, and address some directions how to steer the research of knowledge spillovers further.

1 Introduction

Knowledge spillovers have been subject to scrutiny for decades now. Conventionally, they are described as *"the benefits of knowledge to firms, industries or regions not responsible for the original investment in the creation of this knowledge (Fischer et al.* 2009*)"*. The idea to acquire knowledge without bearing costs of research demonstrates an appealing concept for profit-seeking companies as well as for scholars in the field of economic growth struggling to decompose the Solow residual. Scholarly work discerns between pecuniary and non-pecuniary externalities unfolded by knowledge capital. The pecuniary spillovers are denoted as those *"embodied in traded capital or intermediate goods and services (Puškárová and Piribauer* 2016*)"*, while the non-pecuniary externalities represent disembodied spillovers.

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The origins of the former kind might be traced back to American institutionalists. Veblen (1915) pointed to the transmission of technology embodied in traded machinery. Later, this hypothesis has been subject to more formalized empirical studies and led to conclusions that trade-operationalized transmission of knowledge might affect the productivity levels at destination to quite sizeable extent (McNeil and Fraumeni 2005; Puškárová 2015). Trade however does not appear to be solely responsible for knowledge transmissions. Among the most influential works on various channels of knowledge diffusion count those of Keller (1996, 1998).

The studies of the latter kind have always been intertwined with production and growth models. Solow model assumed global pool of knowledge that would allow all countries to grow at some constant exogenously determined rate of A (technology progress) once they reach the steady state. Scholars however found little evidence that countries converge in the long run. Global knowledge spillovers appear to be rather an environmental fallacy, and instead, local character of knowledge transmission presumably stands behind most of the cross-country growth and convergence differences (Keller 2002a; Puškárová and Piribauer 2016).

From methodological point of view, studies of pecuniary knowledge transmissions found a common approach over the years. Most usually, they estimate the impacts of transmitted knowledge as impacts of international flows such as trade and capital investments on local productivity. Clearly, international trade and foreign direct investments channel innovation and foster productivity changes within a company, within the community of its competitors (*horizontal knowledge transfers*) as well as within the community of their suppliers and customers (*vertical knowledge transfers*). However, to assume that all impact international flows do unfold on productivity changes is imputable to transfers of technology is a bit of a fallacy. For example, the entry of a foreign competitor or a foreign product to a local market might prompt local adjustments such as local competitors reorganizing their production, cutting their costs or expanding their supply. In the line with Rodriguez-Clare (1996) those cases would be erroneously regarded as knowledge transfers since no foreign knowledge per se facilitated the changes.

An alternative approach to study the impacts of knowledge transmission has been taken through the lens of spatial interactions. The logic here is that we focus on the effects at destination and care less how they happen or what processes channeled them. In the line with this approach, we identify N economic agents as spatial units, encode the distances between them into the form of a $N \times N$ matrix and introduce this matrix to a growth model. The estimated coefficients on the $N \times N$-multiplied knowledge capital are then seen as bilateral transfers of knowledge. This approach started to be gradually used as the discipline of spatial modeling progressed, spatial estimation packages got deployed and more scholars got trained in the field.

In the sections below, we walk you through the scholarly work that took the "channel" or "spatial" approach and highlight the progress that has been made in the both fields. Later, we discuss the advantages and disadvantages of both approaches and conclude with a list of recommendations what the pertaining thorny issues in the field are.

2 Theoretical and Empirical Background of Knowledge Spillovers

It is a conventional understanding that income differences are imputable to disparities in total factor productivity (TFP), for details see Klenow and Rodriguez-Clare (1997) and Easterly and Levine (2001). The first to highlight the role of technological progress as the main force standing behind the productivity gains and economic growth in the long run was Robert Solow. His model of transitional dynamics implied convergence of economies in the long run to the steady state. Still, numerous studies showed that real economy observations point rather to evolving divergence than convergence (Landes 1998; Islam 2003).

In an attempt to correct Solow model so that it matches real observations, few scholars provided explanations of growth based on endogenization of savings rate (Cass 1965; Koopmans 1965) thanks to explicit microfoundations of choice of consumption (Ramsey 1928). Others have attempted to empirically show that the impact of total factor productivity can be reduced (Denison 1962; Jorgenson and Griliches 1967; Madison 1987; Fagerberg 1994; De Loo and Soete 1999). Easterly and Levine (2001) provide extensive overview of these studies. Many have turned to exploration of factors that might stand behind the technology progress (Puškárová 2015; Puškárová and Piribauer 2016). Work by Griliches (1979), for example, use the stock of knowledge to extend the production model.

Before moving forward, we would like to make a comment that literature appears to reach a consensus how to model knowledge spillover impacts at least to certain point. The backbone of all knowledge spillover modeling is some production function and in most cases, the decomposition of Solow residual—the total factor productivity (Krammer 2014; Fischer et al. 2009). There are only few exceptions. Bottazzi and Peri (2003) for example detect impact of external sources of knowledge as residual elasticity of patent volumes on research and development investments. This approach however has been scarcely followed.

2.1 Pecuniary Flows of Knowledge: Empirical Evidence

Pecuniary knowledge transfers are commonly of twofold nature—either they are channeled by trade or by foreign direct investments. Both might at some point involve knowledge transmission that is *horizontal*—amongst suppliers and customers, or *vertical*—amongst competing companies. The latter might take an additional form of *forward* or *backward* spillover. The forward knowledge flow operates from suppliers of intermediary products towards producers of higher added-value while the backward one flows just in the opposite direction.

The argument that *trade may channel knowledge* rests upon the fact that today's production process employs vast variety of intermediary products of different technology level. As already indicated by Veblen (1915), traded goods contain innovative ideas that might get easily copied. International economic theory precludes that trade is highly correlated with productivity differences. Eaton and Kortum (2001, 2002) showed that classical Ricardian model as altered by Dornbusch et al. (1977) precludes access to foreign technology.

The question remains if in reality the access truly leads to learning process and knowledge spillovers since not all evidence proves that (Rodriguez and Rodrik 2001). As Keller (2010) mentions the success of technology transfer through trade appears to depend heavily on skills and technology congruence. While foreign direct investments create structures that enable daily interaction with knowledge transmitter and implicit facilitate successful knowledge spillover, trade does not provide for that. Scholarly work suggests that in an effort to engage in international trade corporations need to raise their competitiveness. Export-seeking companies face competition at foreign markets. They need to imitate foreign technologies and knowledge in order to be competitive. The rising productivity then translates into rising competitiveness also at local market. One of the first evidence on technology spillovers through export was provided using export-driven economic growth in Japan in 1960s (Rhee et al. 1984).

In 2000s other studies on export-driven growth in Asian economies, namely China, India and Southeast Asia (Hallward-Driemeier et al. 2002) emerged. However scholars have raised the concerns that these studies suggest only indirect technology spillovers since exporting firms engage in export only as a result of their increased productivity (Fagerberg et al. 2010). Other studies focused on differences in productivity between exporting and non-exporting companies and come to conclusions that the difference accounts for 0.8%. However, the rise in productivity across exporting companies might be attenuated by the fact that the study sample covered strictly US companies. US market however is one-of-its-kind given its demand size, high degree of diversification and competition what reduces differences in productivities. Moreover, US as a global top technology—and knowledge in general—producer do not depend on imports of knowledge from abroad and as such most of the export effects on productivity might be internalized (Keller 2010).

Clerides et al. (1998) studied firm-level data from Columbia, Morocco and Mexico using the dynamic discrete choice equation of average variable costs and sunk costs from export market participation. Autoregressive cost function estimates if past experience from export has any impact on current costs and implicit on the decision to pursue export activities further. They come to conclusions that on average the decision to export does not depend on prior-year experience on export. However, we shall interpret their conclusions with caution. As Keller (2010) points out they assume that export increases costs in time what is a complete contradiction with the economies of scale theorem. Besides that, the study does not consider heterogeneity of industries what may destroy the effects that occur in high-tech industries. Last but not least, as de Loecker (2007) suggests the technology gap between country of exporter and country of export destination matters: companies exporting to high-income countries appear to experience higher productivity gains than the companies exporting to lower-income countries.

Van Biesebroeck (2005) follows up on Clerides et al. (1998) and revises their idea by means of semi-parametric analysis and instrumental variables. Using a sample of nine African countries van Biesebroeck suggests that the gains from export need to be split between technology spillovers and scale effects. Since African companies export generally to countries of higher income and higher level of technology advancement the study points also to the role of technology gap.

Latest studies have advanced much on modeling the productivity gains from export. The distance decay parameters together with scale effects and role of skills have been introduced to models to account for most of the productivity variation across companies participating in exporting activities. Hu and Tan (2016) used a dataset of export firms from China, distinguishing the product-level and the country of destination. Using a gravity-type model estimated at firm-level, they find that: (1) *"export spillovers positively influence not only the decision of a nearby firm to start exporting, but also the volume of the exporting"* and that (2) *"the effect of export spillovers is stronger when it is product-destination-specific than that when it is either product or destination-specific alone, and also stronger than that is in general (Hu and Tan* 2016*)"*. Geographically, local export spillovers showed spatial decay in China. Specifically, the effect was stronger for firms located in the same city than that for firms outside the city. In addition, small and multi-product firms were more likely to be influenced by the local export spillovers (this effect was stronger for complex goods and easy-entry countries). Moreover, the export spillovers from private firms were reported to be the strongest, followed by foreign-invested firms and state-owned firms ranking last (Hu and Tan 2016).

Studies of knowledge transfers prompted by import has been led into two directions. One strand of research identifies knowledge spillovers arising with liberalization at firm-level (Pavcnik 2002; Amiti and Konings 2007). The other strand of literature focuses on sector-level gains from imports (Blalock and Veloso 2007; Coe and Helpman 1995; Acharya and Keller 2008).

Keller (1998) found no evidence of trade-driven knowledge spillovers at first, but few years later he revised his conclusions (Keller 2002a) by following up on Eaton and Kortum's (2001) argument that transport costs determine trade and thus shall lead to variation in knowledge transmission patterns. Coe and Helpman (1995) found evidence of trade-induced productivity gains by using trade-weighted R&D expenditures of importing companies. Acharya and Keller (2008) extend the literature and using a considerably larger panel data and instrumental analysis with control variables shed some light on causal link between separately trade and R&D expenditures, and productivity.

Current literature is still struggling to isolate the positive effects on productivity unfolded by import and those by export. In highly diversified economy, imports are accompanied with exports—just because the most trade is executed with intermediary products. An open economy barely stands at international markets as an exporter or importer—if so then only for a very limited time. Literature calls in this context for suitable instrumental analysis (Keller 2010).

Technology or *knowledge transmission through FDI* appears to be more complex than that fostered by trade. At one side, incoming FDI most commonly means increase in trade since FDI settlements are used foremost to produce intermediary products. At another side, FDI prompts mobility of skilled workers from abroad. Incoming FDI brings usually some managerial expats that supervise the establishment and the whole business following the internal culture of the multinational. The benefits of the FDI however rarely stay for the company alone. At some point, the transferred knowledge leaks. Fosfuri et al. (2001) described how training of workers in an FDI settlement prompts productivity increases amongst its local competitors. They conclude that the social benefits of knowledge transfers—increased productivity at country level—are reaped by all the consecutive employers who hire FDI-trained employees. The knowledge may be even transmitted to all the future coworkers of those employees and their future jobs.

In the light of the complexity of FDI-induced knowledge transfers the question emerges if the FDI impacts on productivity are higher than that of trade. The answer is not clear-cut. It might if the model did not control for trade flows but estimating simultaneous effects of trade and foreign direct investments on productivity points to the higher effects of trade, more than a double of the FDI impact estimate, to be exact (Krammer 2014; Puškárová 2015). An explanation might be found in the nature of FDI. As Griliches (1995) highlights, a foreign direct investment company is usually intended to produce intermediary products that are subsequently exported. The value of intermediary products is usually lower than that of final production. The impact of embodied knowledge thus is not fully accounted for as it is with trade. Even though the estimates appear to be robust it is necessary to bear in mind that both trade and foreign direct investments are measures in pecuniary terms. To identify what (and how large) part of the pecuniary flows is attributable to technology spillover is far from being resolved.

It comes as no surprise that many studies on knowledge transfers have been done on Asian countries. The emerging economies in Asia developed multi-level strategy to foster knowledge spillovers from abroad. The openness to FDI and trade, sponsored programs for young scholars to get top-notch education abroad and then to come back home: all that makes Asian countries a suitable case for studies of knowledge transmissions. The scholarly work agrees that the knowledge transfers in Asia appear to be sizeable, significant and robust (Hu and Tan 2016). The truth is that most Asian countries appear to receive technologies less through FDI and more so through trade. It may be imputable to the fact that their economies used to grow more through exports than through foreign investments. The tradition of large local corporations that control the production leaving less market share for foreign investors has shaped this trend.

2.2 Non-pecuniary Flows of Knowledge: Empirical Evidence

The microfoundations of non-pecuniary flows of knowledge are described in the Arrow's paper (1962) on learning-by-doing. An individual absorbs knowledge while interacting with colleagues. The returns on company's R&D investments are reduced by the gains collected by its competitors. Endogenous growth theory followed up by introducing scale effects into the Solow model. Romer (1986) showed that profit-seeking firms allocate part of their investments to research and development (R&D) activities, thus making perpetual returns to capital plausible. In a spirit of Mankiw–Romer–Weil model, the scale effects are buffered by an expanding stock of human capital. An increase in physical capital provokes investments in both physical and human capital. The coefficient on invoked savings (investment) rate might follow the diminishing returns to scale path, but the coefficient on the human capital is larger and works in the opposite direction, driving up the rate of return. As a result, we expect the net effect of relatively constant returns to physical capital. Aghion and Howitt (1998) provided a lucid exposition of the endogenous growth models and role of knowledge spillovers there. It is noteworthy that most of the studies assume sole existence of symmetric spillovers based on the Cournot-Nash oligopoly equilibrium. The estimations of the knowledge spillovers impacts however remain robust even once allowing for asymmetric spillovers (de Bondt and Henriques 1995; Atallah 2005; Vandekerckhove and de Bondt 2008).

It is noteworthy that the disembodied knowledge might be traded and as such be expressed in pecuniary terms as well. The institute of intellectual property law enables the original investor to commodify knowledge and collect royalties from commercial users at the technology market. However, such markets do fail in many cases. First of all, tacit nature of knowledge (Edquist 1994) restricts knowledge to be fully and duly commodified. A part of knowledge lives only with its social and physical context. The uncodified knowledge can easily leak to competition what gives less motivation for the buyers to pay for knowledge. Second of all, knowledge is a sophisticated product. Buyers usually have less comprehension of the knowledge as a product and depend on the information the supply gives them. The asymmetric information hinders the own judgment of buyers if and to what extent the solution might work for their company or production line. Third of all, the price of knowledge is not determined on its own market but is derived from the price of final production—added value of sold goods and services. The demand is sector-specific but also strongly time-specific. It is often the case that in crisis times the demand for knowledge rises tremendously while the supply stagnates. In times of economic expansion, companies tend to care less about innovating. The volatility of the demand is difficult to be predicted what scares the suppliers of knowledge off and leads to supply shrinkages. Fourth of all, the amortization of certain technology varies not just by sector and type of knowledge but even by time. Certain novelty might come at times when the competition is none or sleeping and that prolongs the amortization time of the technology. Fifth of all, technology market does not allow for filing a claim. Buyers have to bear the risk that in case the technology does not work the way they expected they can hardly get their money back.

By introducing spatial elements into the endogenous growth models, the researchers found reasonable way to start studying knowledge spillovers (Jaffe 1986; Feldman 1994; Audretsch and Feldman 1996). Distance or geography per se was considered the true exogenous factor of transmission. Since knowledge transmission success rises with frequency of personal contacts, absence of translation noise or cultural differences, we shall assume knowledge does not spread unrestricted and there are certain bounds beyond which the knowledge just does not go. This assumption precludes local spillovers.

Jaffe (1986) pioneered discerning between internalized and externalized effects of R&D stocks and finds that *"spillovers of R&D from several indicators of technological success on the productivity of R&D (Jaffe 1986)"*. The estimate of firm's R&D elasticity was 0.875. In addition, the estimated reached the value of 1.1 when considering the effect of other firms' R&D. Following Jaffe's logic, Branstetter (2001) estimates intranational and international knowledge spillovers on innovation and technological change. Previously unexploited panel data from the US and Japan were used at the firm level. Robust evidence was found that again intranational spillovers are stronger than international spillovers. Bottazzi and Peri (2003) re-estimate the impacts of disembodied knowledge spillovers on a sample of NUTS-2 European regions and their results adhere to the previous studies. Keller (2002a, b) estimates knowledge spillovers using exponential distance decay effects of research and development expenditures on total factor productivity. Even though he finds evidence of diminishing impacts of knowledge stocks with rising distance from their origin (for every 1200 km, the technology impacts on productivity diminish by 50%), he argues that globalization, integration and IT have reduced the transaction costs of knowledge transmission and that is why studies on pecuniary flows of knowledge find usually higher impacts of knowledge transmissions than studies on non-pecuniary flows. Irwin and Klenow (1994) run to the conclusions that "learning-by-doing" spillovers are global and not local but those might be spurious since they focus on the impacts on the growing market share and not on productivity levels.

Based on these theories, we discern between global and local spillovers (Grossman and Helpman 1991; Coe and Helpman 1995; Feenstra and Hanson 1996). Global spillovers support convergence and local divergence. Analogous results have been brought up by Krugman and Venables (1995), Fujita et al. (1999), and Baldwin and Forslid (2000). Eaton and Kortum (1996) support the thesis of local spillovers but once controlling for human capital, the spillover estimates drop. The same results were brought up recently by Puškárová and Piribauer (2016). Due to its large impact on knowledge spillovers we are going to explore the role of skills in more detail later in the text.

Local spillovers might arise due to several phenomena. Tacit nature of knowledge often restricts the informal flows of knowledge (Lundvall and Johnson 1994). Internal policies might restrict knowledge sharing as well. In case knowledge for whatever reasons cannot get protected by patent law or in case of company's know-how, internal security measures may slow down the learning processes happening within the company and thus restrict the leakage of knowledge to outside world (Tan et al. 2016). Behavioral studies also point in this context to the role of transport costs. Companies tend to localize their research and development activities to a single location in order to reap the benefits from agglomeration (Rauch 1993; Ellison et al. 2010). Marshall's (1920) benefits of agglomeration ultimately reflect gains that occur when proximity reduces transport costs, namely the costs of moving goods, people, and ideas. Knowledge is foremost a product of human capital (Jones 1995) and social capital (Puškárová 2015). By relocating of knowledge production factors and local reinforcing of their accumulation the companies usually force knowledge production lock-ins that ultimately result in increasing role of path dependency in knowledge production (Cohen and Levinthal 1990; Coombs and Hull 1998; Staber 2007).

The clustering of knowledge production appears to leave the rest locations at risk of losing the ability to catch up. In order to close the knowledge gap remote market players face the challenge to develop skills and social capital so that they at least can participate in knowledge transmission if not production. In case the market player does not know how to utilize the knowledge and does not have the appropriate network to check the correct utilization of knowledge, the knowledge transmission just cannot take an effect even if the knowledge reaches the market player (Fagerberg et al. 2007, 2010). The skill-intensive companies or regions grow faster leaving the skill-scarce companies or regions lag behind. This holds with fewer restrictions on movements of high-skilled labor. Similarly to income inequality measures, we may attempt to capture the inequality in knowledge production as the area lying between the Lorenz curve of cumulative knowledge production on cumulative shares of population and 45-degree line representing perfect equality. Due to the decisive role skills and human capital play on knowledge spillovers we are going to explore this factor a bit more in detail later in the text.

Empirical evidence suggests that global knowledge spillovers might occur only under rather exceptional circumstances. For example, some knowledge is relatively simple and does not require intensive or extensive learning. Gaspar and Glaeser (1996) call this general knowledge and discern it from specific skills that require face-to-face interactions to learn and use. Audretsch and Feldman (1996) suggest that local spillovers are bound to initial phase of production life cycle after which the technology diffuses more easily and gets more global. Glaeser et al. (1992) however point to the impact of local industry diversity on knowledge diffusion what is known also as Jacobs externalities (1969). Keller (2010) suggests that knowledge diffusion is restricted to certain area based on degree of its complexity. More complex technologies tend to stay local while the lower degrees of complexity—determined by the intermediary steps for its completion and application—allow technology to reach companies in larger distances.

One serious concern with estimation of non-pecuniary knowledge flows is the lack of validity of measures. Intangible assets such as knowledge or human capital cannot be easily approximated by mere patent volumes. Thus, they require careful consideration of control variables that can rule out the spurious effects.

2.3 Impact of Skills for Presence of Knowledge Spillovers

Decent amount of literature has highlighted the decisive role of certain characteristics for successful execution of knowledge spillovers. In theory, scholars define what these characteristics, also known as knowledge absorption capacity, are but within the lines of empirical studies, they appear to struggle how to capture these characteristics in a valid and exhaustive manner. Mancusi (2008) talks in this context about effectiveness in knowledge production and calculates knowledge productivity pointing to differences between innovation leaders and laggards.

The strand of literature that focused on exploration of certain "skills" for technology transmission has its roots with work of Abramovitz (1956). He introduced the term total factor productivity and pointed out the role of technology congruence and social capability for its level. While the role of technology congruence lays foremost with the similarities in market size or availability of production factors, the social skills entail enhancing education, entrepreneurial infrastructure, networking. Abramovitz suggests seeing social skills as of manifold nature. Among the most influential skills affecting the absorption of knowledge from abroad he names technical competency measured by education level of workers, previous experience from large corporation management, financial markets and institutions capable to mobilize capital at large scale, morality and trust, stability of government and effectiveness in norm introduction and growth support.

Rostow (1980) introduced similar concept of absorption capacity. He particularly highlights the impact of education and continuous training on absorption of new knowledge. Cohen and Levinthal (1990) followed up and conceptualized microeconomic principles of absorption capacity. They see it as *"firm's capability to recognize the value of new external information, assimilate and exploit it in own commercial activities"*. Cohen and Levinthal highlighted the role of cumulativeness in knowledge process—learning process shall never seize—and to the path dependency nature of a company. Moreover, they point to the barriers to cross-sector knowledge transmissions. Thus they recommend companies to stay diversified in technology specialization. Several authors challenged the conclusions of Cohen and Levinthal arguing that their study relies on rather large definition of absorption capacity. They see it as new technology, absorption of technology and commercial use of technology as well. The third facet of their concept is particularly questionable. Fagerberg et al. (2007) discern between technology competitiveness and capacity competitiveness. The former is imputable to technology advancement that motivates to obtain the knowledge while the latter is concerned solely with the exploitation of knowledge regardless if own or acquired.

Large amount of work on general skills of knowledge absorption has been done by Gerschenkron (1962). He was particularly focused on the role of technology gap in the transmission of knowledge and proposed list of general prerequisites of low-income countries to catch up with the technology advanced ones. Based on a case study of economic rise of Germany at the beginning of twentieth century he demonstrated the impact of technology imitations in the process. He controlled for other factors—such as path dependency, comparative advantages in certain sectors of production, historic conditions. He strongly supported the role of government support in the process of capacity building.

Gerkschenkron's work has been largely cited in the literature. Search for a "general recipe for convergence" took a form of "technology capability" and "social capability". Technology capability has been reported as the main driver of economic growth in Asia since late 1970s and in Central and Eastern European countries in

1990s (Fagerberg 1994). Social capability might be seen as "social capital". The role of trust and network as well as effective government for growth has been put under scrutiny only recently. Ishise and Sawada (2009) introduce social capital as an additional form of capital into the extended production model and find compelling evidence of productivity gains arisen from this form. Puskarova (2015) suggests to study social impacts on productivity through social globalization index and finds evidence of rather sizeable role of social networks for productivity variation across EU countries.

A line of studies attempt to escape the complexity of absorption capacity indices and focus on proxies of human capital instead. The knowledge production function can be written as follows (Jones 1995):

$$\Delta K_{it} = \delta_{it} K_{it-1}^{\gamma} H_{it}^{\beta} \exp(\omega_{it}) \quad (1)$$

where knowledge accrual denoted ΔK_{it} is a product of human capital H_{it} with some R&D productivity δ_{it}, and the knowledge capital stock in the previous period, $\exp(\omega_{it})$ denotes an error term, β and γ are elasticities related to the human and knowledge capital stock, respectively.

The equation implies that human capital is the primary factor behind the curtains of knowledge accumulation. More importantly, latest studies support the hypothesis that it might be a decisive factor also in the knowledge transmission process. Puškárová and Piribauer (2016) using the Spatial Durbin model on a dataset of NUTS-2 regions from EU-27 countries spanning 2000 through 2010 show that productivity responds more sensitively to human capital located in the neighborhood than to the human capital of that region. Few explanations might be considered. Either human capital captures some of the impacts of knowledge capital or it is subject to again weak proxies of knowledge and human capital. Either way, it is intriguing to conclude that once controlling for human capital, the knowledge capital impacts drop parlously. Puškárová and Piribauer (2016) suggest the revision of the knowledge production function into the following form:

$$\Delta K_{it} = \delta_{it} K_{it-1}^{\gamma_1} H_{it}^{\beta_1} \sum_{j \neq i}^{N} K_{jt-1}^{\gamma_2} \sum_{j \neq i}^{N} H_{jt}^{\beta_2} \exp(\omega_{it}) \quad (2)$$

where human capital can tap into both the knowledge and human capital of the others and add it to local knowledge stock. Human capital per se reflects not just abilities to create the knowledge but more importantly, to acquire and successfully utilize knowledge from other regions. The introduction of human capital thus captures both internal capacity to produce knowledge and to effectively absorb knowledge from the neighboring regions. Thus, it reflects regions' absorptive capacity. The central role of human capital for explaining differences in economic growth was reported in previous studies, see for example LeSage and Fischer (2008) and Fischer (2011), or some more recent studies such as Crespo Cuaresma and Feldkircher (2013) and Cuaresma et al. (2014). Previous research reported that empirical knowledge capital model can be severely biased as the result of omitted human capital variables due to highly correlated knowledge and human capital proxy variables.

Therefore, an important issue to be addressed is to distinguish between human capital and knowledge. On one hand, these factors of growth are straightforwardly included in the Cobb–Douglas production function (see Ishise and Sawada 2009). On the other hand, human capital is regarded as the factor of knowledge in knowledge production functions, see for example Jones (1995). However, human capital is also considered in the earnings-schooling function. Previous research has showed that investment into schooling pays off. Thus, education has been adopted as the first proxy for human capital. The effect of education on productivity is however still being studied. For example, about 20% of TFP growth can be attributed to human capital change according to Schultz (1960). Later, the robustness of this estimate using education attainment was verified by Jorgenson and Griliches (1967). Although later research proved this estimate to attenuate over the years, it is generally accepted that human capital is largely related to the education process. At the same time, the key role of human capital in knowledge producing and absorbing activities is also acknowledged. However, it can be concluded that to properly discern between human capital and knowledge is still challenging. This may be explained by the fact that a part of knowledge never takes a disembodied measurable form (a patent, for example). Moreover, *"some knowledge such as a productivity-enhancing organizational structure may be reflected only as the know-how of a company, possibly appearing in the records as expenses for the training of employees with respect to the new organizational structure (Puškárová and Piribauer* 2016*)*". Thus, the estimated effects of human capital might include some knowledge capital effects.

3 Knowledge Spillovers in the CEE Region: Empirical Evidence

In this section, we examine knowledge spillovers in the Central and Eastern European region by taking two approaches. First, we compare the changes in patent stocks and Total Factor Productivity (TFP) and later we estimate the impacts using Spatial Durbin model as per paper Puškárová and Piribauer (2016). In order to do so, we needed to construct TFP values and patent stock volumes.

TFP values were constructed using the Cobb–Douglas equation $\ln F_{it} = \ln Y_{it} - s_{it} \ln L_{it} - (1 - s_{it}) \ln C_{it}$. Conventionally, Y_{it} is stands for gross domestic product (GDP), L_{it} denotes the number of people employed and C_{it} are investments. This calculus however usually leads to robustness issues. Fischer et al. (2009) suggest revising the calculus in the following aspects. Firstly, gross value added (GVA) should be used instead of GDP. This is because the GVA is, similar to the TFP concept, more knowledge-centred. Secondly, due to imperfect factor shares, the labor input shares is better to be obtained from the labor costs rather than from its revenues. Thirdly, the C_{it} should be considered as a stock, rather than a flow. This is because it is difficult to measure the benefits unfolded by investments within a period. The stock of investments can then be calculated using gross investments I_{it}. As the depreciation rate of the stock of investments r is assumed not to vary significantly over the years, the perpetual inventory method can be used to calculate the stock of investments as follows $C_{it+1} = C_{it}\,(1 - r) + I_{it+1}$.

All the TFP input variables were collected from the Cambridge Econometrics Database. The GVA is represented in constant Euro prices of 2000 and deflated. The stock of investments are expressed in current Euro prices with depreciation rate $r = 0.12$ (Fischer et al. 2009). Labor costs are represented by wage remunerations in current Euro prices. The labor share is the share of labor costs in the sum of wage remunerations and investments. Hours worked were used to adjust the effect of different working time across the EU regions.

Figure 5 represents the resulted changes in log-transformed values of TFP. The results indicate that about the two third of the NUTS-2 regions have higher and about one third lower TFP levels than the average. The highest TFP values are registered traditionally in Luxembourg, Stockholm, Inner London, Groningen, and Brussels with the elasticities of GVA growth on changes in production factors higher than 1.6. Romanian and Bulgarian regions have the lowest TFP levels. In Puškárová and Piribauer (2016) we show also the TFP changes over the years in the region of Vienna–Bratislava–Budapest. The region might be regarded as the study case of West-East EU convergence. Figure 1 depicts the TFP levels for the area of large city regions located within the distances Vienna-Bratislava-Budapest. The results are compared with the average TFP regional level across the European Union.

Figure 1 shows that *"in terms of TFP Bratislava and Budapest did catch up with the Vienna region, especially after the EU accession of Slovakia and Hungary in 2004 (Puškárová and Piribauer 2016)"*. The Figure therefore supports the theorem

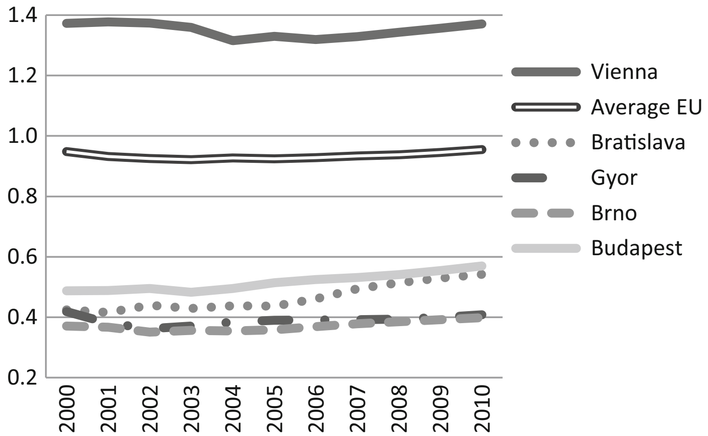

Fig. 1 TFP trajectory of selected regions. Source: Puškárová and Piribauer (2016)

that *“the selected area has been experiencing fast-growing knowledge spillovers, even though less tractable for the non-capital regions of Brno and Györ (Puškárová and Piribauer* 2016*)”*.

Patent stocks, or changes in patent stock for that matter, as depicted in the Fig. 3 in the Appendix were obtained using the perpetual inventory method as the number of patent applications to the European Patent Office (EPO) obtained from the Eurostat Regional Databases. Note that Greek regions were excluded due to missing data (Puškárová and Piribauer 2016). So the patent stock of region i at the end of period $(t + 1)$ can be expressed as $K_{it+1} = K_{it}\ (1 - r) + P_{it+1}$ where K_{it} denotes the stock of knowledge (EPO patent applications) at the end of period t and r represent the depreciation rate of that knowledge stock ($r = 0.12$ was adopted from Caballero and Jaffe 1993).

Comparing the Figs. 3, 4 and 5 in the Appendix we see that—first—the patenting intensity across the EU NUTS-2 regions is indeed localized. Second, TFP changes did not comply perfectly with patent stock changes in Central and Eastern European countries. Following the literature that sees knowledge spillovers as responsiveness of TFP on patent stock changes, we compared the Figs. 3 and 5 and came to following conclusions. As for Baltic states, we see a discrepancy in changes in patent stocks and changes in TFP: Patent stocks rose the most in Latvia but the TFP rose relatively largely only in Lithuania—the closest country to the Polish regions. We find one explanation in the fact that Lithuanian regions did benefit from their location to more innovating Polish regions. The Visegrad Four countries, namely Slovakia, Hungary, Czech Republic and Poland are another case. They appear to have increased both their patent stocks and TFP and the increase was the highest in both amongst the Central and Eastern European regions. That gives a strong argument for the role of geography and spatial knowledge spillovers. Croatians, on the other hand, increased their patent stocks relatively largely but what their geographical relative remoteness to other European Union countries presumably took its toll on their TFP only slowly moving upwards. Romanian and Bulgarian regions are another example of geographically disadvantageous regions. They have increased their patent stocks relatively sizably. Nevertheless, their TFP did not respond adequately. Here we see the impact of geography. Relatively remote location of Romania and Bulgaria from the knowledge intensive regions of Germany, Austria or England works against spatial knowledge spillovers.

A small note to the “old” European member states: Italy and Greece are the cases of low patent activity changes while their TFP relatively largely increased. On the other hand, Ireland and Swedish central and northern regions increased their patent stocks relatively sizably. However, their TFP did not respond adequately. Those are remote regions again what might support the argument of presence of spatial spillovers across European Union.

With the development of spatial econometrics, scientists have started to approach spillover effects unfolded by various economic activities as the estimated impact parameters of a model including a spatial matrix. Spatial matrix is conventionally a matrix of distances between spatial units. The spatial units shall be small enough in order to account for the spillover effects the closest to its origin. For that purpose, spatial units might be individuals, companies and also regions. The spatial weight matrix can be obtain using two neighborhood approaches—a common border concept or distance concept. In the common border concept, unity is assigned to a matrix element if the two regions share a common border, while zero is assigned otherwise. However, this concept neglects spillovers from island regions. The distance concept is based on the distances between regions and it is assumed that spillover effects decay with increasing distance. In that case, each element of the spatial weight matrix can be represented by $W_{ij} = {d_{ij}}^{-2}$ with no distance bound, and the elements on the main diagonal are set to zero, this is $W_{ii} = 0$. Usually, the distance d_{ij} is calculated as the distance between the i's region centroid and the j's region centroid. Overestimation problems were avoided by using the row-standardization of the spatial weight matrix, for details see Elhorst (2012) and Puškárová and Piribauer (2016).

Note that parameter estimates in conventional (non-spatial) linear models have a straightforward interpretation. However, the interpretation of the parameter estimates may lead to erroneous conclusions in spatial autoregressive models (LeSage and Pace 2009). This can be explained by the non-linear nature of models that involve a spatial lag in the output variable. Moreover, non-zero cross-partial derivatives are typical for spatial autoregressive models. These non-linear characteristics of the specifications of spatial autoregressive models have serious implications for the model used in this study. Specifically, the effect of a region's patent stock change is not only visible in the TFP of the same region (so-called direct effects), but it also affects the TFP of other regions (so-called indirect or spillover effect). Since the spillover effects can only be positive, spatial autoregressive models have to deal with N^2 partial derivatives for each explanatory variable. The $N \times N$ matrix of partial derivatives for the expected elasticity of TFP with respect to patent stocks K in a region $i = 1, \ldots, N$ can be defined as follows (for details see LeSage and Pace 2009):

$$\left[\frac{\partial \mathrm{E}(F)}{\partial K_1} \cdots \frac{\partial \mathrm{E}(F)}{\partial K_N}\right] = (I - \rho W)^{-1} \begin{bmatrix} \gamma_1 & W_{12}\gamma_2 & \ldots & W_{1N}\gamma_2 \\ W_{21}\gamma_2 & \gamma_1 & \ldots & W_{2N}\gamma_2 \\ \ldots & \ldots & \ldots & \ldots \\ W_{N1}\gamma_2 & W_{N2}\gamma_2 & \ldots & \gamma_1 \end{bmatrix} \tag{3}$$

where W_{ij} is the (i,j)th element of the matrix W. The problem of this matrix is the overwhelming quantity of information. To overcome this problem, several approaches have been proposed in related literature. For example, LeSage and Pace (2009) recommend reporting a summary metric specifically for the indirect effects (in this case spillover effects). To measure this metric, the mean value of either the row or the columns can be used that sums of the off-diagonal elements of the matrix. To measure the summary metric of the direct effects, the average can be calculated of diagonal elements of the spatial weight matrix. Puškárová and Piribauer (2016) come to the following conclusions (Table 1).

Depending on particular explanatory variable, the indirect (spillover) effects between two different regions are represented by a particular off-diagonal element of the impact matrix. The diagonal elements of this matrix represent the direct effect

Table 1 Local and spillover effects unfolded by knowledge and human capital across EU NUTS-2 regions, 2000–2010

Effects	Depreciation rate of $K = 5.5\%$	W for 4 nearest neighbors	W for 8 nearest neighbors	W for 5 nearest at travel distance
Direct (K)	0.104 (0.000)	0.095 (0.000)	0.093 (0.000)	0.108 (0.000)
Indirect (K)	0.186 (0.000)	0.210 (0.000)	0.224 (0.000)	0.204 (0.000)
Total (K)	0.291 (0.000)	0.305 (0.000)	0.317 (0.000)	0.312 (0.000)
Direct (H)	0.091 (0.003)	0.0607 (0.038)	0.064 (0.039)	0.076 (0.005)
Indirect (H)	0.436 (0.000)	0.492 (0.000)	0.437 (0.000)	0.478 (0.000)
Total (H)	0.527 (0.000)	0.553 (0.000)	0.501 (0.000)	0.554 (0.000)

Note: p-value are presented in parentheses, K denotes EPO patent applications (stock of knowledge); H denotes the share of working age population with ISCED 3–6 (i.e. at least secondary education), total effects is the sum of direct (local) and spillover (indirect) effects
Source: Puškárová and Piribauer (2016)

of a region. It is important to note that the maximum likelihood approach was applied to estimate the values of parameters. Therefore, these parameter estimates are represented by the average values of a normal distribution. However, note that the inference on direct and indirect effect estimates is complicated because the effect estimates are represented by non-linear functions.

Table 1 demonstrates that regardless the spatial matrix determination, indirect—spillover—effects dominate the productivity changes decomposition. The indirect effects from human capital are at the same time more decisive factor than knowledge capital—their impact accounts for more than a double of the patent stock impacts. For more explanation on the estimation please read Puškárová and Piribauer (2016).

In order to estimate the interregional spillovers we follow the approach of Puškárová and Piribauer (2016) again. If we draw D parameters from a normal distribution with its moments calculated as the maximum likelihood estimation output, D average effects (direct or indirect) can be obtained. If φ_{kd} represents the effect of the k-th variable (explanatory) of draw $d = 1, \ldots$, D, the mean $\overline{\varphi}_k$, variance v_k and the corresponding t-value τ of the D draws are given by:

$$\overline{\varphi}_k = \frac{1}{D}\sum_{d=1}^{D}\varphi_{kd} \tag{4a}$$

$$v_k = \frac{1}{D-1}\sum_{d=1}^{D}\left(\varphi_{kd} - \overline{\varphi}_k\right)^2 \tag{4b}$$

$$\tau = \overline{\varphi}_k / \sqrt{\frac{1}{D-1}\sum_{d=1}^{D}\left(\varphi_{kd} - \overline{\varphi}_k\right)^2} \tag{4c}$$

Thus, the (*i, j*)th elements of the partial derivative matrix matching the regions Budapest, Bratislava and Vienna in T subsequent years represent the bilateral sensitivity of productivity on knowledge and human capital located in both cities. As two explanatory variables are investigated, two matrices have to be constructed. Table 2 reports the mean (standard deviations) of the metrics of impact representing the human and knowledge capital stocks following Eqs. (4a) and (4b).

We report (also in Puškárová and Piribauer 2016) average annual direct and indirect effects in Table 2. These are compared with total indirect effects and interregional spillovers with other NUTS-2 regions located in the close neighborhood, including Jihovýchod (Brno region), Nyugat-Dunántúl (the Györ region), and Niederösterreich (Lower Austria). Table 2 reports that both domestic and foreign human capital and knowledge demonstrate significant effects on the TFP in the studied area. On one hand, domestic human capital seems to be slightly more important for TFP in Vienna when compared with those in the two other capital

Table 2 Estimates of direct and indirect (spillover) effects on TFP in capital regions' triangle Bratislava–Budapest–Vienna and other close regions

Effects	K in Vienna	H in Vienna	K in Budapest	H in Budapest	K in Bratislava	H in Bratislava
Direct	0.078 (0.003)	0.091 (0.030)	0.078 (0.003)	0.081 (0.029)	0.079 (0.003)	0.083 (0.029)
Indirect on Bratislava	0.005 (0.001)	0.025 (0.005)	0.002 (0.001)	−0.001 (0.000)	–	–
Indirect on Budapest	0.001 (0.000)	0.001 (0.007)	–	–	0.001 (0.001)	0.001 (0.000)
Indirect on Vienna	–	–	0.005 (0.000)	0.022 (0.001)	0.007 (0.0004)	0.022 (0.005)
Indirect on other close regions						
Indirect on Brno region	0.004 (0.000)	0.028 (0.007)	0.002 (0.000)	0.002 (0.000)	0.003 (0.000)	0.018 (0.005)
Indirect on Lower Austria	0.008 (0.000)	0.095 (0.028)	0.001 (0.000)	0.003 (0.001)	0.003 (0.000)	0.004 (0.001)
Indirect on Gyor region	0.002 (0.000)	0.001 (0.000)	0.004 (0.000)	0.035 (0.007)	0.003 (0.000)	0.016 (0.004)
Total indirect	0.113	0.035	0.075	0.102	0.096	0.003

Notes: standard deviations are presented in parentheses; K is the number of EPO patent applications (stock of knowledge); H is share of working age population with ISCED 3–6 (i.e. at least secondary education) regions. On the other hand, indirect effects from foreign human capital appear to be largest in Budapest. Regarding the stocks of patents, the direct effects seem to be similar in all three capital regions under investigation.

As Puškárová and Piribauer (2016) suggest Table 2 provides intriguing conclusions about the Central and Eastern European countries and knowledge spillovers within. Budapest appears to have large innovation potential. Indeed, it is the greatest beneficiary of the transfer of human capital within the investigated area. In addition, the domestic contribution of human capital is lower than the spillover effects from foreign human capital. This can be explained by the increasing involvement of Budapest in research networks, especially in those with international dimension. Budapest is the official seat of privately funded Central European University as well as of European Institute of Technology. These institutions attract human capital and promote international funding. Yet foreign capital in Budapest appears to be less driven by relocations from Vienna, at least less than by relocations from other EU regions. The effect of competition between the capital city regions might explain this result to some extent.

Table 2 also points that Vienna stands behind most productivity changes in the surrounding regions. This suggests that the human capital of Vienna promotes the growth of Bratislava and Lower Austria (the in-between lying region). The human capital of Vienna seems to be also important for the productivity changes in Brno region, yet less so for Hungarian regions. Considering the European average, knowledge spillovers from EU regions to Bratislava are lower when compared with Vienna or Budapest. This finding might clarify the strong impact of Vienna knowledge. Specifically, this impact is about 7.6-times stronger than the knowledge spillovers from remaining EU regions. This relatively small average effect of knowledge spillovers from EU regions may be attributable to the long-run flow of skilled workers from the capital city region Bratislava to other European Union countries (Ivancheva and Gourova 2011).

Last but not least, Table 2 reports that the effect of interregional human capital between the two capital city regions, Vienna and Bratislava, might be reciprocal. In other words, the human capital of Bratislava can also promote the TFP of Vienna. The accession of Slovakia to the European Union in May 2004 was a milestone for mutual cooperation and labor mobility. The wage gap—particularly for skilled labor—prompted the commuting practice of much of Slovak educated workforce to just 60-km-away city of Vienna. Since the working individuals commute, they do not lose their ties to Bratislava and that facilitates knowledge transfers locally in Bratislava. The existence of feedback effects can further boost the responsiveness Bratislava's TFP values to Vienna's human capital level. As Puškárová and Piribauer (2016) indicate their results are just first of its kind, and future empirical research should be conducted, with the focus on micro-studies investigating the mobility and better understanding of channels of knowledge transfer amongst the area of Central and Eastern European countries.

They further stress out that: *"knowledge spillovers are still somewhat restricted between the Western and Eastern EU (Puškárová and Piribauer* 2016*)"*. Bratislava might benefit a lot from Vienna, but the impacts of knowledge spillovers from more remote regions appear to be little. The Budapest region appears to succeed—they attract knowledge from abroad, yet very little from Vienna. This suggests that knowledge flows in the European Union: *"might not be fully restricted to the closest cities and that other factors may impact the geographically disadvantaged region (Puškárová and Piribauer* 2016*)"*. The role of path dependency might shed more light on the issue.

4 Bringing the Methodological Approaches to Knowledge Spillover Studies Together

The dichotomy of studies of knowledge transmission opens the room for discussion what the true impact of knowledge transmissions on productivity and growth might be. The coefficients generated by "channel" regressions suggest rather sizeable impacts. Spatial estimations, on the other hand, appear to be less optimistic about the magnitude of impacts. The only thing the both approaches agree on is that knowledge transmissions are present and significant for productivity gains at all spatial scales. In an effort to find the true value of knowledge spillover impacts we execute closer inspection into advantages and pitfalls of the two methods and suggest situations when one or the other might appear as a more reasonable option to employ.

One of the main arguments underpinning the results generated by the "channel" approach rests within the extensive work done in the field. The contribution of trade or foreign direct investments to total factor productivity has been put to empirical testing for various samples at different spatial scale and the results appear to be convincingly robust. Various studies find that up to 20% variation in Total Factor Productivity might be explained by international trade while the impacts of foreign direct investment account for about half of trade-driven impacts (Keller 2002a; Krammer 2014). These results hold particularly for European Union in the past two decades, the impacts across the US, however, do comply (Branstetter 2001).

The "channel approach", however, brings up serious validity concerns. First of them is that these flows might spark local activities that has little to do with incoming foreign knowledge. Rodriguez-Clare (1996) shows that in an effort to compete with the incoming foreign investor, local firms might engage in their own innovating activities: they reorganize their production, cut costs or generate efficiency gains through product innovation. In such a case it would be clearly misleading to see rising productivity as imputable to the technology brought in by the investor.

Another problem of the "channel" approach rests within the approximation of knowledge by pecuniary flows. Productivity gains arisen through trade or capital flows might be biased by *pecuniary effects arising with the flows*. It is far from being proven that the changes in pecuniary volumes of trade or foreign direct investments are proportional to the changes in knowledge transmitted through these channels. Some small amounts of foreign direct investments might be entirely consumed for productivity-enhancing activities of FDI-hired labor while some large-scale investments may be used up only to cover maintenance costs. Knowledge transmission is often a result of training, networking, or even informal talks within an FDI company and it would be beyond presumptuous to expect that variation in trade or foreign direct investments account for those factors.

In addition, trade and FDI are themselves subject to measurement error. The trade in intermediary products, for instance, reflects the prices set between affiliated companies or establishments sharing the same owner. In such a case, the knowledge-generated added value of the product may be fully accounted for only at the very last stage of the supply chain when the product is offered to the final consumer. The traded value of intermediary products are usually priced based on discounts and preferential regimes set up within affiliates.

Last but not least, "channel" studies rely heavily on the assumption that flows are coming from more technology advanced countries. In reality, countries trade with their geographical neighbors or preferential regime partners. That might distort the estimated role of trade-driven knowledge spillovers on the economy. One solution would be just to focus on mutual flows of trade and check the sensitivity of total factor productivity on trade with technology more advanced partners. Here we run into the problems of encoding the mutual flows of trade into the regression equation. Absence of bilateral ties and reliance on strong assumptions of the "channel" approach introduces little external validity of these results. Thus researchers might find it challenging to make forecasts based on these models.

On the other hand, spatial approach appears to provide less spurious results. The framework enables the researcher to control for the origin of knowledge flows through the spatial connectivity matrix and make strong convincing claims about the responsiveness of productivity to changes of cross-border knowledge. In case of a strictly exogenous matrix the spatial regression appears to unveil the true impacts of knowledge spillovers that are not distorted by bundling the knowledge to some other effects.

This approach however might underestimate the true value of knowledge spillovers. Why is that? First of all, it relies on the researcher's choice over the determination of the spatial connectivity matrix. The key prerequisite is that it needs to be determined exogenously in order the regression to work properly. In reality, it means to use geographical distance, travel distance or some other exogenously arisen measure of connectivity such as language. However, it is difficult to express connectivity in those limited terms—just by one variable. Furthermore, the connectivity matrix is usually determined based on the assumption that the effects vanish with the rising distance. This assumption might be seen also as rather too strong to hold. In a world where communication technologies transport information in a blink of an eye it is rather challenging to persuasively argue that knowledge might be restricted within some geographical area even if we account for the risks of long-distance misinterpretation or communication noise. In the end, the successful transfer of knowledge might be less subject to distance but more to the skills of the recipient to comprehend the true value of the knowledge and action he takes to efficiently utilize the knowledge in production.

Second of all, knowledge per se is rather challenging to be measured. Its intangible nature forces researchers to capture it through proxies. One of the most common approaches to find the proxies of knowledge is through the lens of knowledge generating process. There are two sides of the process involved—inputs and output. Conventionally, the inputs cover physical capital and labor. As per Eq. (1), knowledge accruals can be seen as a function of human capital and already existing knowledge—semi-endogenous growth models. Approximation of knowledge through the inputs into the production process might reflect all the efforts taken in order to produce new knowledge; however, it ignores the stochastic nature of knowledge generation process. Research and development is a risky process with unclear gains and often associated with time delays. Some investments never lead to productivity-enhancing results or if they do it is often difficult to identify the link between investments and productivity accruals within one period of time. Some scholars suggest working with private investments into research and development to circumvent the issue since private investments are usually associated with shorter returnability periods. Others suggest combining the input and output variables—for example, Branstetter (2001) employed R&D-weighted patent stocks. However, the risk of stochastic mismatch (ignorance) cannot be fully eliminated.

To approximate the level of human capital, various types of skills have to be captured, such as the socialization ability, personal work discipline, or the ability to create knowledge networks. Generally, the ability to gain the marketable knowledge and transfer it should be considered when constructing the measure of human capital. Usually, three milestones all through the education life are distinguished. The completion of elementary education is considered as the first one. The second one is represented by the completion of secondary education. A state examination is the result of the second milestone. The third one is related to university or college graduation. Life-long training represents an important part of educational process. However, it only further develops the skills obtained at the highest completed education level. As a result, it may not affect the estimates in this study significantly. On one hand, the quality of tertiary education facilities differs notably across the European Union (see for example the results of Financial Times Ranking or Shanghai University Ranking). On the other hand, the secondary education stage seems to be comparable in terms of research literacy, reading and maths according to PISA surveys. In other words, human capital in the European Union is similar in terms of secondary education level. Specifically, the PISA surveys have been carried out on the extensive sample of 15 year-old students. Therefore, Puškárová and Piribauer (2016) recommend filtering the lower educated population out and considering the population of working age primarily.

On the other hand, approximation of knowledge through the output of the knowledge generation process might fall short to capture all the productivity-enhancing effects generated throughout the process. Most usually, patents or patent applications are considered the true measure of knowledge process output. Indeed, they represent intangible assets of a company which need to be protected due to their undisputable market value. On the other hand, many of the existing patent applications are just upgrades of already existing patents and so that their true value cannot be fully attributed to the new patent application (Jaffe and Trajtenberg 2002). Second, and potentially even more serious problem associated with patents as approximation of knowledge is that a large pool of knowledge that works in favor of productivity gains never gets patented—either because it is strongly context-related or the whole process and fees of patent registrations are too costly (Griliches 1990).

To sum up, literature provides us with two approaches to estimate the externalities unfolded by knowledge—a “channel-driven” and spatial one. While the former employs flows of labor, capital or trade as proxies of knowledge what might lead to overestimated impacts, the latter focuses on spatial autocorrelation of knowledge and neglects impact of global vehicles of information such as internet. As a result, the results might be seen as underestimated. The choice over the approach to knowledge spillovers is first of all subject to reliable available data and second of all, to the spatial scale. Spatial approach falls short to unveil the impacts at higher spatial scale and is strictly bound to availability of data at the lowest spatial scale possible. Introducing trade or foreign direct investments as approximations of knowledge transmitted might lead to rather spurious results but at least it helps us to build a picture about the true impacts of these international flows in a particular economy. It might not be purely imputable to transferred knowledge but clearly to changes of productivity for whatever forces drive them within.

5 Recommendations for Future Research

5.1 Reducing Risks of Measurement Error

There is one general problem associated with estimations of knowledge spillover impacts. Regardless of the approach, scholars are struggling to find a consensus over the knowledge spillover regressions per se. Jaffe et al. (1993) and Jaffe and Trajtenberg (1999) suggest capturing spillovers as patent citations. In their work, the likelihood that any particular patent gets cited is determined by the combination of an exponential process by which knowledge diffuses and a second exponential process by which knowledge becomes obsolete.

An alternative—and we dare to say also more common—way is to just estimate the impact of trade or foreign direct investments on productivity, or knowledge proxies on productivity data. We have covered some problems the pecuniary flows demonstrate for knowledge spillover regressions. Without going too much into detail, we only reiterate that assuming that the impact of technology on productivity is proportionate to the impact of pecuniary flows is rather difficult to be justified. The local adjustments happening behind the scenes of trade and foreign investments might have little to do with foreign knowledge transfer (Fosfuri et al. 2001).

The common problem with the latter approach to estimation of knowledge spillovers relates to the measurement of Total Factor Productivity. The tricky issue here is that all productivity measures are only secondary variables and as such they are exposed to risk of measurement error. As showed by Katayama et al. (2009), the

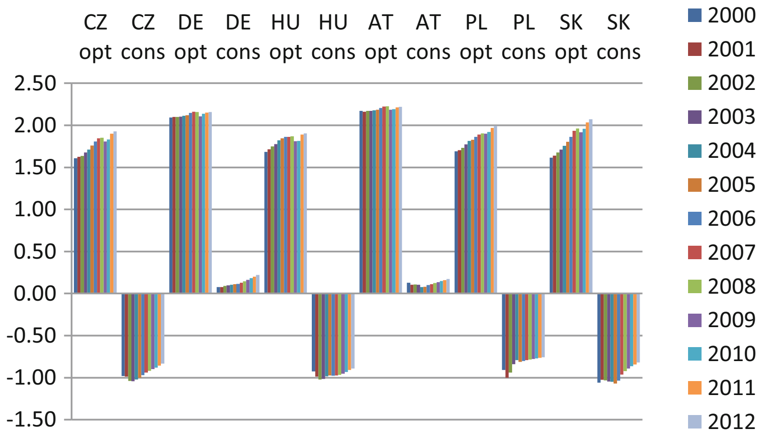

Fig. 2 Log-transformed TFP values in 2000–2012 in CEE, optimistic and conservative calculation approach compared. Note: opt is an acronym of optimistic, cons stands for conservative approach. Source: Author's calculation, data Eurostat, Cambridge Econometrics

manipulation with the primary (input) variables can largely increase the variation in the overall TFP. Usually, the values of TFP are calculated from the equation $\ln F_{it} = \ln Y_{it} - s_{it} \ln L_{it} - (1 - s_{it}) \ln C_{it}$. In previous studies, gross domestic product (GDP) is employed to represent Y_{it}, the number of people employed for L_{it} and C_{it} represents investments (Dujava 2012). This approach might be quoted as optimistic since residuals on GDP after accounting for changes in labor and capital might be quite sizeable. Latest studies (Fischer et al. 2009; Puškárová and Piribauer 2016) attempt to take a more conservative approach. Instead of GDP the studies employ gross value added and argue that residuals on GDP might quite erroneously encompass various non-productivity (for example pecuniary) effects. In addition, the latest studies suggest taking cost-based input share sit rather than revenue-based (note that this particularly true in the presence of imperfect factor shares) since cost-based appear to work more robustly throughout the estimations. Thirdly, the C_{it} should be regarded as a stock, rather than a mere flow. This is because positive benefits stemming from investments do not usually appear within a given period (within a year, in this case). Instead, the investments' stock can then be calculated using the perpetual inventory method applied on gross investments.

Figure 2 demonstrates the comparison of log-transformed TFP values when calculated using the "optimistic" approach of Dujava (2012) and the "conservative" approach of Puškárová and Piribauer (2016). As for the former, all the TFP input variables were collected from Eurostat databases with capital/labor input share s constant over the 2000–2010 of 0.65. As for the latter approach, the primary data were collected from the Cambridge Econometrics Database. The gross value added was in constant Euro prices of 2000 and it was deflated. Investments were in current Euro prices, and the depreciation rate of $r = 0.12$ was used in line with Fischer et al. (2009). Wage remunerations in current Euro prices were used for labor costs. As a result, the labor share was calculated as the share of labor costs in the total labor costs increased by investments. The adjustment by hours worked was employed to eliminate the effect of differences in working time across the regions in the European Union.

Following Fig. 2 it becomes clear that the log-transformed TFP values differ considerably when different calculation approaches are employed.

5.2 Call for New Variables and Models

Knowledge spillovers have certainly undergone large inspection over the past two decades. However, most of the studies do share certain drawbacks what might inspire scholars to look closer into them.

First of all, the need to find more accurate representatives of knowledge has become increasingly thorny. The solution here might not be only attempting to enhance the existing proxies. We might execute closer inspection into the factors of knowledge generation process and treat the inputs into the process as proxies of knowledge. Puškárová and Piribauer (2016) demonstrated that once human capital is included, the effects emanating from knowledge capital are significantly reduced. This justifies the assumption that vast amounts of knowledge do not remain in patents but in variables such as skills, experience, and education. In addition, we call for more exploration of social capital on productivity variations. The impacts on growth have been demonstrated by Ishise and Sawada (2009). Puskarova (2015) followed up and showed how the growth impacts of social capital channel through productivity increases. In our opinion, social networking and its products—trust, communication—all facets of social capital—might be the field to explore and explain knowledge spillovers further. Efficiency gains through concentration in space might always play certain role for diffusion of knowledge but with the general progress in information technologies, internet and global education market it would not be reasonable to assume that knowledge spillovers cannot reach even the furthest corners of the world. The only limits might then appear the demand for knowledge in those remote areas and the centrality, quantity and quality of the links within networks that any professional has. Nevertheless, both social and human capital as alternative proxies of knowledge remains poorly represented. Their intangible nature throw researchers back to the measurement problems. Large-scale surveys such as the Programme for the International Assessment of Adult Competencies (PIAAC) give us some promise that the progress has been made in this domain and more in-depth analysis of knowledge and its impacts through whatever channel on productivity will be feasible.

Second of all, there is a room to explore knowledge spillovers methodologically. General progress and deployment of estimation packages on spatial modeling enable larger pool of researchers to explore the spatial response of productivity to various proxies or factors of knowledge. Some work has been done already (Fischer et al. 2009). However, literature remains silent in terms of, for example, spatial time-series modeling of knowledge spillovers. Software codes for estimations of spatial VAR models are not particularly difficult to develop but researchers are restricted by the lack of time-series data on productivity and explanatory variables. Moreover, there is a room to explore knowledge spillovers through network analysis. The impact of centrality on knowledge gives us some perspective here but proper network modeling of the links is essential.

These problems are closely linked to finding the consensus across the studies what knowledge spillovers actually stand for. The studies focus on estimating the impacts but univocal theoretical explanation of knowledge spillovers and effective modes of transmissions have not been deployed so far.

5.3 Growing Knowledge Polarization: Impacts on Income Inequality

Knowledge inequality has not been just observed across the European Union but even more so all around the globe. In 1995 the share of the seven most developed countries on global knowledge resources accounted for 64%. In 2010, the share was up to 84% and after taking into account of the rapidly growing shares of China and India, only <10% of global knowledge was generated in the rest of the world. Theory finds explanation for the growing polarization of R&D and productivities within the realm of endogenous growth theory and international trade theory (Heckscher–Ohlin theorem, Stopler Samuelson theorem). We assume two countries—one skill-abundant and another skill scarce. Following knowledge accumulation function (Eq. 1), the skill-abundant country will accumulate the knowledge at a quicker pace since human capital works as an accelerator—it generates the knowledge and absorbs the knowledge from the foreign sources. In accordance with international trade theory (Heckscher–Ohlin theorem), the skill-abundant country is going to specialize in the production of high-skilled intensive production. Internationally mobile physical capital will relocate to the skill-abundant countries to maximize its returns. Internationally mobile high-skilled labor follows the capital for the same reasons.

Very little we know about the effects that knowledge transmissions may have on income inequality or redistribution of wealth and vice versa. In this part we are going to draw a very simplistic picture of the link between the two. We start from the decomposition of income. The decisive factors for income cover human capital and physical capital. Without access to money even the brightest mind cannot accrue wealth. Both affect the income positively. The pace of income accruals might however differ. Low skilled labor H_l is expected to be less challenged at work, less forced at workplace to learn newest technologies. High-skilled labor H_h on the other hand has to be up-to-date constantly and thus it spends significant portion of time learning in order to stay competitive with other high-skilled laborers. The level of starting knowledge does not affect only capability to bring own innovative solutions but also the capability to learn from the others—to absorb knowledge spillover. As a result, the knowledge inequality translates into income inequality *ceteris paribus*. We stress in this context, that human capital has to be supported by access to the physical capital. Then a very simplistic form of income inequality reads as:

$$\text{income inequality} = \frac{W_l}{W_h} = \frac{\delta_l H_l K_l}{\delta_h H_h K_h} \tag{5}$$

where K_l stands for physical capital for low skilled and K_h for high skilled labor. For productivities of low-skilled and high-skilled labor δ_l and δ_h the following proposition hold $\delta l < \delta h$.

Furthermore, as mentioned earlier in the text, knowledge spillovers remain mostly localized what affects the income inequality in a positive way too. The income inequalities show spatial autocorrelation in space. The spatial clustering of income inequalities have been demonstrated for many parts of the world (Chambers and Dhongde 2016). Literature attempted to theoretically justify the presence of income inequality in the growth model (Cingano 2014). Empirical studies argue that autocorrelation of income inequalities might be a relic of welfare regimes or cross-border sharing of redistribution preferences. This sharing gets the form of welfare regimes in the European Union (Esping-Andersen 1990). The three dominant regimes—socio-democratic distinguished by high degree of redistribution and low income inequality, conservative known for its still high degree of redistribution especially to families and liberal known for its mostly ambivalent position towards any redistribution. In a very generalized sumup, the size of public redistribution decreases when moving from the northern part of the European Union towards the south. An alternative explanation for spatial clustering of income inequalities is provided by studies of international factor movements. As Bachmann et al. (2016) suggest, mobility of labor changes the redistribution of income at the EU market. As barriers put up for intra-community mobility become less prevalent under the common strategies (Lisbon Agenda, Europe 2020) the high-skilled labor relocate to places where the demand and income for high skill labor is high. Furthermore, the mobility of physical capital leads to various clustering effects in income inequality as well (Roser and Cuaresma 2016). Few studies proved that foreign direct investment facilities boost wage spillovers across the sector or alongside the value chain (Maczulskij 2013; Lamo et al. 2013).

The gravity of knowledge creation that leads other knowledge in increase knowledge inequalities and implicit income inequalities may translate into observation of income inequality autocorrelation. The wage spillovers such as those explain in Maczulskij (2013) are intensified by redistribution autocorrelation. Redistribution autocorrelation emerges due to sharing the similar preferences within certain regions or countries. The autocorrelation of welfare preferences has led Esping-Andersen (1990) to develop his idea of four major welfare regimes present within the EU. Sharing social capital levels and knowledge capital level drives income inequality spillovers. Income inequality spillovers represent a situation when that the countries or regions with the high income inequality are surrounded by countries with the similar income inequality. The observation of income inequality spillovers is driven by the autocorrelation of skill premium within some distance as well as sharing of social capital and welfare preferences within some national or regional boundaries.

All that leads us to the conclusion that income inequality is highly correlated with the knowledge inequality. Unless regulated by the redistribution policy low-skilled labor cannot hope for higher earnings. The economy favors physical and human capital and those with lack of it are stuck in the low-level income trap when their earnings do not allow them to accumulate either kind. The role of welfare policy is highly underrepresented in growth accounting and knowledge spillover studies. However, the link is clear—redistribution might give extra money to those talented individuals who lack capital to accumulate knowledge and escape the low-income trap. Thus, scholars shall be encouraged to incorporate welfare redistribution variables into the models. The welfare redistribution might not be only in the form of social security but also in the form of mobility grants that enable young and bright to gain quality education and skills at top-notch places. The more knowledge country has and invest in the human capital, the gravity holds—the more it attracts from abroad. The reshuffling of production in the direction of higher-added value and skill-intensive sectors might let the real wages of the low-skilled stagnate increasing thus income inequality but reasonable level of redistribution can correct for that.

6 Conclusions

In the above, we provided an overview how the scholarly work on knowledge spillovers developed over the past decades and highlighted the dichotomy of methodological approach in this regard. While the "channel" approach might overestimate the impact of foreign knowledge on rising productivity through involving various knowledge-non-related pecuniary flows the spatial approach to knowledge spillovers might underestimate the true impact of imported knowledge since it assumes foremost knowledge transfers at proximity. The decision over the suitability of the approach depends on the data availability and spatial scale of the research design.

Apart from the methodological approach, studies of knowledge spillovers have so far failed to speak univocally in terms of impact estimates since there are pitfalls associated with both approaches. First of all, the risk of measurement error has not been fully mitigated. Second of all, scholars are struggling with the current use of knowledge and human capital measures and call for better representative of the nature of knowledge transfers and models that would capture these processes. Third of all, there is room to explore impacts of knowledge spillovers on income inequality.

Knowledge spillovers within the Central and Eastern European countries are present, yet not evenly distributed. Location appears to be one of the key drivers of knowledge spillovers what prompts positive productivity changes in Czech Republic, Slovakia and Hungary and works against Romania, Bulgaria or the Baltics. In line with this, one of the most promising areas to grow based on knowledge spillovers is the inter-city area of Bratislava–Vienna, with extension to Budapest.

Appendix

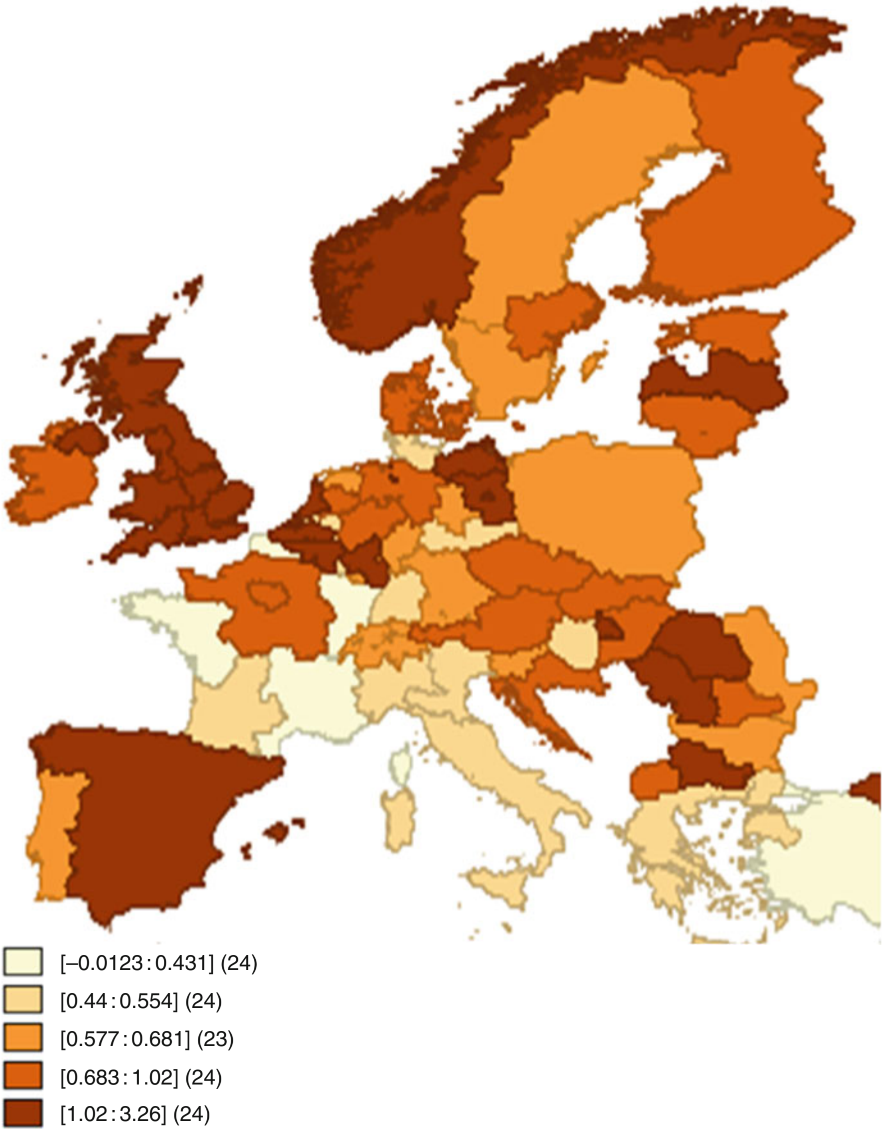

Fig. 3 Patent stock distribution [Patent stock calculated from the EPO patent applications using perpetual inventory method and depreciation following Caballero and Jaffe (1993)], NUTS-2 regions, % increase 2000–2010. Source: Author's calculations, GeoDa visualization

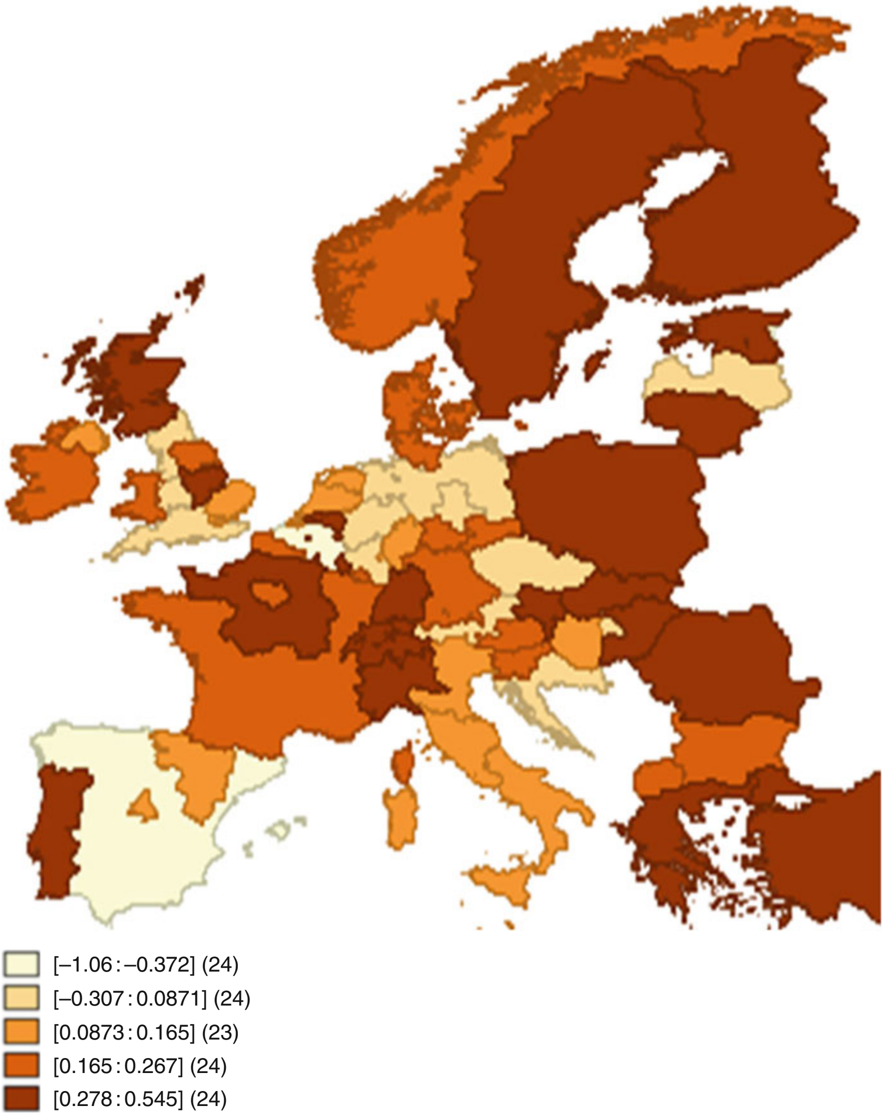

Fig. 4 Total factor productivity (TFP calculated following Fischer et al. (2009), data Cambridge Econometrics Database), NUTS-2 regions, mean % increase 2000–2010. Source: Author's calculations, GeoDa visualization

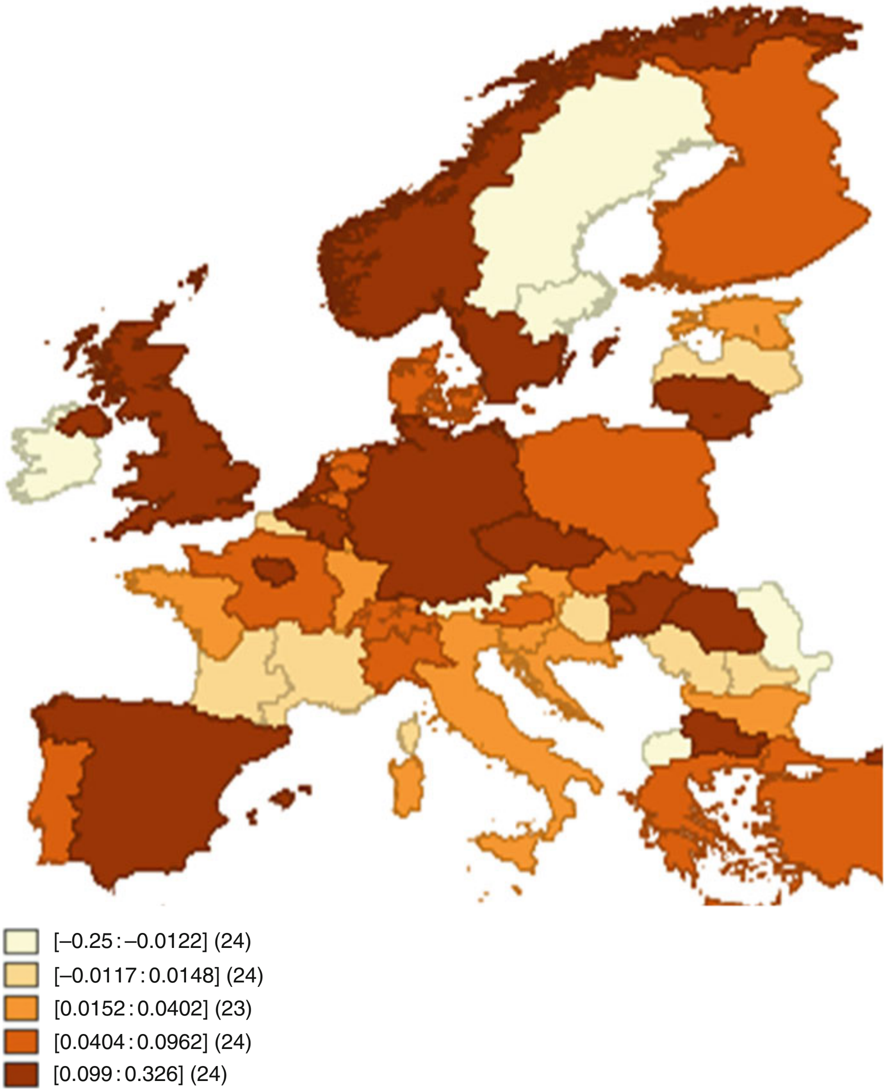

Fig. 5 Total factor productivity (TFP calculated following Fischer et al. (2009), data Cambridge Econometrics Database), NUTS-2 regions, % increase 2000–2010. Source: Author's calculations, GeoDa visualization

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