Innovation Environment in Europe—Efficiency Analysis Case Study

Viktor Prokop, Jan Stejskal, Petr Hájek, and Michaela Kotková Stříteská

Abstract Nowadays, measuring efficiency within countries' innovation environment seems to be incremental in the process of gaining competitive advantage. Therefore, this study is aimed to evaluate efficiency in patent creation within EU28 countries. We are using specialized tool for assessing the effectiveness, performance and productivity of comparable production units Data Envelopment Analysis and data from Eurostat. Moreover, we are analyzing countries' efficiency according to their innovation performance measured by European Commissions' European Innovation Scoreboard 2017. Results show that only 5 out of the 28 European countries are effectively using basic attributes of Innovation Environment (investment in science and research; human resources in science and technology; cooperation with external research and development firms). All of these countries belong to the group of Innovation Leaders. We also propose practical implications (for each country) on how to improve and how to change their inputs and outputs to become (more) efficient and provide information about countries that could be benchmark for less efficient countries.

Keywords Innovations · Entrepreneur environment · Efficiency analysis · Europe · Case study

---

V. Prokop · J. Stejskal (✉) · P. Hájek · M. Kotková Stříteská
Faculty of Economics and Administration, University of Pardubice, Pardubice, Czech Republic
e-mail: jan.stejskal@upce.cz

V. Prokop
e-mail: viktor.prokop@upce.cz

P. Hájek
e-mail: petr.hajek@upce.cz

M. Kotková Stříteská
e-mail: michaela.striteska@upce.cz

H. Pham (ed.), *Reliability and Statistical Computing*, Springer Series in Reliability Engineering, https://doi.org/10.1007/978-3-030-43412-0_4

1 Introduction

There are dynamic changes in each country's economy and society. These are the unintended changes that are the result of the development of society and its globalization in the world. But it is also about the intended changes that are the result of applied public policies. For many years, developed countries have supported the expansion of knowledge and technological progress (innovation is the result), which are perceived as the basic engine of economic development [16]. Some authors have been tantalizing for diffusion, which, in their views, is a major determinant of the economic or social impact of innovation [6, 54].

A plethora of studies has confirmed the importance of innovation. Many other scholars have also addressed the environment in which innovation is emerging. The subject of the study was both efficiency and research of determinants that make up an innovative background or environment. These determinants become an important part of the production functions, which in a modern concept contain not only basic production factors but also knowledge variables or other soft variables [33].

Many studies (for example Drucker [19]; Rao [46]; Vila [53]; Andersson [4]; Meissner [36] and others); also analyze the activity and role of different subjects in this innovation environment. The familiar concept of triple-helix [21] and also the well-known endogenous growth models [12] show that public sector (state) and public subjects are currently one of the important players in the innovation environment.

It is becoming increasingly important to explore the innovation environment, its determinants and the roles of individual significant regional actors [39]. The knowledge about processes, mutual relations and relations, but also ways of financing or other public support can help us to define the suitable conditions of the efficiency of this innovative structures [2]. Particularly important is the transfer of knowledge from various advanced environments, where more advanced economic systems can be perceived as an important benchmark for less advanced countries (or those where some of the important elements of the environment fail or are not yet created).

This chapter is organized as follows. First, theoretical background is provided on the determinants of the innovation environment. Second, research methodology and underlying data are described. The next section provides the results of your own DEA models. The final section concludes this chapter and discusses the results and political implications.

2 Theoretical Background

As mentioned above, the innovation environment is dependent on the creation and diffusion of new knowledge [35]. Many studies have shown that knowledge generation is influenced by a number of determinants [23]. They are primarily regional variables, creativity, innovation, but also openness, freedom, etc. In more detail, it has been found that the determinants of innovation need to be sought both in the microeconomic and macroeconomic environment of an innovative enterprise.

So many scientists have attempted to analyze the effectiveness of the innovation environment (in the region context) and regional innovation efficiency [39], as well as the performances of enterprises depending on the quality of the innovation environment (or selected determinants; [55]). They all agreed that it is necessary to perceive innovation in the context of the environment, to examine their effectiveness through the innovation approach system [1]. This is confirmed by the expanded concept of open innovation or open business models [49]. Nowadays, we can also capture transition from business ecosystem to innovation ecosystem that could be defined with different meanings and purposes (e.g. digital innovation ecosystem, hub ecosystems, open innovation ecosystem, platform-based ecosystem etc.) and which is understood as a set for the co-creation, or the jointly creation of value and innovation [17]. From these arguments there is a clear importance of innovation environment because of creating an open innovation environment that disclosure knowledge from the organizational to the inter-organizational level and opening up for external sources of knowledge flowing from the inter-organizational level to organizational level [45]. It allows environment and ecosystem stakeholders to assure the learning processes of the entire system.

For any efficiency analysis, as well as for the effectiveness of innovations or attributes of an innovative environment, we need to use the measurable indicators. Many studies (for example Hsu [30]; Ren [47] or Kim [32]) use innovation performance indicators such as patents, utility models, and sometimes revenue from innovative production. However, there are a number of critics, who do not perceive, for example, patent applications as sufficiently significant [9]. In practice, innovation takes place without their patenting, thanks to time considerations, financial demands and high dynamics in innovative change. Therefore, other ways to analyze innovative processes without these simplified indicators are being sought. Some come with their own indices, such as Innovation efficiency index by Guan and Chen [25].

In practice, qualitative studies based on empirical data are often used. They look for dependencies among the different variables that occur in the innovation environment and explore their impact on innovation performance. Similarly, these studies may only focus on selected industries or are suitable for macroeconomic studies [47]. Important frameworks for these researches are innovation systems, which in the regions represent the basis on which innovation activities are carried out between different actors. These are primarily regional innovation systems [11], sector innovation systems, or different types of innovation environment (milieu). These bases also allow you to analyze variables such as collaboration, the emergence and transfer of tacit knowledge or creativity [13, 52].

The core attributes of each innovation environment (see Fig. 1) operating altogether are:

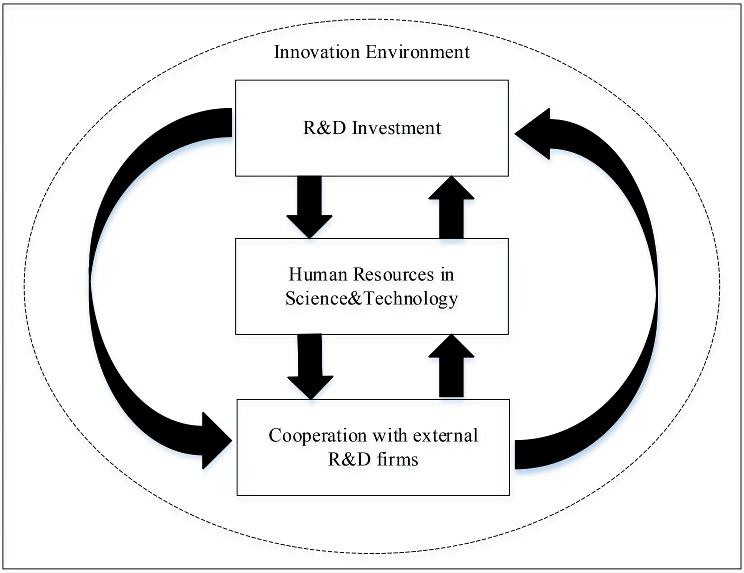

Fig. 1 Core attributes of innovation environment

- investments in science and research (including both private and public resources) for the acquisition of basic hard and soft infrastructure. There exists spatial dependence of R&D investments and efficiency while the regions with high efficiency of their R&D have spillover effect on the surrounding areas [29];
- HRST (human resources in science and technology)—internal knowledge resources—human capital, the holder of tacit and codified knowledge, innovation, creativity, etc. Innovation human resources represent the most dynamic resource among entrepreneurial enterprises (specifically high-tech) and play a very crucial role in the process of transforming innovation inputs into outputs within innovation environments [37];
- cooperation with external research and development firms—i.e. external knowledge sources) that could lead to higher innovation sales and more patents [51] and to creation of collaborative environment that increases the effects of abovementioned knowledge spillovers [26].

These attributes were also used in earlier publisher studies [10, 20, 28].

Even with these basic pillars of the innovation environment, it is possible to assume that there is no harmonious development in each country evenly. There is an innovation failure, a market failure, or a government failure to apply different public support policies. Moreover, these failures may give rise to adverse behavioral and relational consequences [34] and regularly endanger firms' overall competiveness (specifically in the case of new products and services failures [31]). Thus, macroeconomic efficiency analyzes are lacking, pointing to the different efficiency of creating an innovative environment. Therefore, the aim of this chapter is to analyze the effectiveness of the basic attributes of the innovation environment in the 28 countries of the European Union.

In this research, we assume that there is a difference in efficiency in the creation of the innovation environment of individual countries. Similarly, we expect the highest efficiency to be achieved by countries that are considered innovative leaders according to the European Innovation Scoreboard.

3 Data and Research Method

For our analyses, we used parametric approach Data Envelopment Analysis (DEA) which is commonly used as a model specialized tool for assessing the effectiveness, performance and productivity of comparable production units (homogeneous units, e.g. countries of EU 28) based on the size of inputs and outputs. These units convert multiple inputs into outputs, meaning a set of units that produce the same or equivalent effects that are referred as the outputs of these units [41].

The principle of DEA models is that when evaluating the efficiency of a production unit it maximizes its efficiency level, assuming that the efficiency rate of all other DMUs cannot be higher than 1 (100%). The weights of all inputs and outputs must be greater than zero so that all the considered characteristics in the model are included (to see more [27]). The model can be built on the assumption of constant returns to scale (one unit of input generates one unit of output), when all DMUs are operating at optimal scale (CCR model). Rather unrealistic condition is solved by introducing variable returns to scale (VRS) considering all types of returns: increasing, constant or decreasing (BCC model).

For our cross-country analyses within the EU 28 countries, we used input-oriented VRS model operating with variable returns to scale. As a data source, we are using data from Eurostat databases. Number of researchers (e.g. Wang and Huang [54]) analyzed the optimal time delay between input and output variables. Griliches [24] empirically proved that there is no time delay with significant impact on the results of analyses. In this study, we are using 3 years' time delay between inputs (2014) and outputs (2017). Input and output variables are described below. In the next section, we compare countries efficiency and distinguish selected countries according to their innovation performance in 2017 measured by European Commission (Innovation Leaders, Strong Innovators, Moderate Innovators, and Modest Innovators).

4 Results

In the following part (see Table 1), the results of input-oriented VRS DEA model are shown for 28 European countries (Romania results are not displayed, there is lack of data). European countries that efficiently used selected inputs (see previous

Table 1 DEA efficiency results

	Country	Efficiency	Benchmarks	Inputs (2014)						Output (2017)	
				R&D exp. (% of GDP)		HRST (% of active pop.)		Ext. R&D coop. (% of firms)		Patents (per mil. pop.)	
				Orig.	*Adjust.*	*Orig.*	*Adjust.*	*Orig.*	*Adjust.*	*Orig.*	*Adjust.*
Innovation leaders	Sweden	**1.00000**	–	3.14	3.14	55.10	55.10	26.90	26.90	283.46	283.46
	Denmark-DN	**1.00000**	–	2.91	2.91	54	54.00	15.10	15.10	246.61	246.61
	Finland	0.88075	DE	3.17	2.79	55.60	48.97	50.60	20.62	235.68	235.68
	Netherlands-NL	**1.00000**	–	1.98	1.98	52.80	52.80	41.10	41.10	203.59	203.59
	UK	**1.00000**	–	1.66	1.66	54.60	54.60	–	–	82.62	82.62
	Germany-DE	**1.00000**	–	2.87	2.87	47	47.00	17.60	17.60	228.81	228.81
Strong innovators	Austria	0.98088	DE	3.08	2.88	48.30	47.38	25.70	18.03	231.35	231.35
	Luxembourg	0.87005	NL	1.26	1.10	64.50	37.78	24.90	19.72	93.94	93.94
	Belgium	0.77866	DE	2.39	1.86	51.10	39.79	35.40	13.38	145.83	145.83
	Ireland	0.65398	NL	1.55	1.01	53.10	34.73	27.70	13.73	77.64	77.64
	France	0.80598	DE	2.23	1.80	49.10	39.57	31.20	13.43	141.85	141.85
	Slovenia	0.69575	DE	2.37	0.94	43.70	30.40	42.70	5.81	55.30	55.30
Moderate innovators	Czech Republic	0.74399	DE	2	0.70	38.10	28.35	24.90	4.35	33.78	33.78
	Portugal	0.80106	DE	1.29	0.48	33	26.43	20.90	2.99	13.80	13.80
	Estonia	0.56759	DE	1.43	0.63	48.90	27.75	39.80	3.93	27.60	27.60
	Lithuania	0.55568	DE	1.03	0.41	46.50	25.84	10.30	2.57	7.57	7.57
	Spain	0.67574	DE	1.24	0.72	42.20	28.52	19.30	4.47	35.56	35.56
	Malta	0.67328	DN	0.72	0.48	39.50	26.59	4.40	2.96	14.40	14.40
	Italy	0.90466	DE	1.34	1.09	35	31.66	11.30	6.71	68.46	68.46

(continued)

Table 1 (continued)

	Country	Efficiency	Benchmarks	Inputs (2014)						Output (2017)	
				R&D exp. (% of GDP)		HRST (% of active pop.)		Ext. R&D coop. (% of firms)		Patents (per mil. pop.)	
				Orig.	*Adjust.*	*Orig.*	*Adjust.*	*Orig.*	*Adjust.*	*Orig.*	*Adjust.*
	Cyprus	0.83281	NL	0.51	0.42	48.80	26.36	21.50	3.48	10.62	10.62
	Slovakia	0.79285	DE	0.88	0.44	32.90	26.08	15.20	2.74	10.14	10.14
	Greece	0.73211	DE	0.83	0.42	35.40	25.92	19.90	2.62	8.38	8.38
	Hungary	0.74478	DE	1.35	0.55	36.30	27.04	13.80	3.42	20.08	20.08
	Latvia	0.64504	DE	0.69	0.45	40.70	26.25	18	2.92	11.41	11.41
	Poland	0.66446	DE	0.94	0.52	40.40	26.84	21.40	3.28	18.08	18.08
	Croatia	0.72934	DE	0.78	0.38	35.10	25.60	23.70	2.40	4.80	5.07
Modest innovators	Bulgaria	0.72316	DE	0.79	0.38	35.40	25.60	7.80	2.40	4.13	5.07
	Romania	–	–	–	–	–	–	–	–	–	–

Source Own according to Eurostat data

part—the core attributes of each innovation environment) in the process of Patent creation (output variable—Patent applications to the European Patent Office per million inhabitants) reached the rate of effectiveness 1,000. Countries that did not reach the rate of effectiveness 1,000 were not considered effective—less rate of effectiveness means less efficiency of the country.

In total, 5 out of the 28 EU countries (18%) were effective. All of these countries belong to the group of Innovation Leaders according to the European Commissions' European Innovation Scoreboard 2017. Only Finland was not efficient within the group of Innovation Leaders. On the other hand, countries that belong to the other groups according to their innovation performance were not efficient. Lithuania was evaluated as the least efficient country within analyzed EU 28 countries. Svagzdiene and Kuklyte [50] state that Lithuania, in comparison with the other EU 28 countries, payed minimum expenditure in the business sector and in the promotion of the economic policy did not consider innovation progress in a key priority for the driven agricultural sector and other industries.

The advantage of the DEA model is that it provides practical implications (for each country) on how to improve and how to change inputs and outputs to become (more) efficient [39]. Input-oriented models propose changes focusing primarily on input variables (or even minor changes on the output side). Table 1 therefore shows both original values (that each country reached) and adjusted values (provided by DEA) that show how the input (output) variables should be reduced/increased. Moreover, DEA also provide the information about countries that could be benchmark for other inefficient countries. Germany was proposed as benchmark country for other countries in 18 cases (66%). Germany represent the group of countries that are able to develop their innovation potential and create sufficient innovation environment and one of the global leaders in innovation and competitiveness, also in the context of the knowledge economy [42–44].

The results unambiguously confirm that there are significant differences in the innovation environment between innovation leaders and followers (in all categories). Almost all countries regarded as innovative leaders achieve maximum efficiency in creating a knowledge-based innovation environment. It is clear from the results that these countries achieve the optimal values of the individual variables and, even after the time delay, they have maximum efficiency. These results are in accordance e.g. with Prajogo [39] which pointed that dynamic efficient innovation environments strengthen the effect of innovation (specifically product innovation) on business performance. The significant role of core attributes within business environments and ecosystems (e.g. in terms of dynamism, innovation creation, growth and competitiveness) is indisputable. We can therefore see that our selected inputs represent contingency factors which affect the effectiveness of countries innovations (patent creation) in delivering countries performance. Moreover, Blazsek and Escribano [7] show that these countries (R&D and innovation leaders) have sustained future profitability and earn significant future excess returns, while followers only earn average returns. This could lead to the creation of dynamic (multiplier) spillover effects which may ultimately affect also following countries (R&D and innovation followers).

In the case of strong innovators, a lower level of effectiveness was found. In this category, it is possible to perceive differences between original and adjusted values and appropriate measures near the recommended benchmark. The result is that the smallest differences between the actual and the recommended value are in the number of patents. On the other hand, at microeconomic level, Prokop and Stejskal [40] show that firms from countries belonging to the group of strong innovators are able to effectively utilize the various determinants of innovation activities (e.g. financing from the EU, cooperation with clients or customers, cooperation with public research institutes, and expenditures in extramural R&D), to influence their innovation turnover. Therefore, there is a need to identify positive benchmarks for these countries (Germany and Netherlands) and follow these countries at macroeconomic level.

The worst results were found in the moderate and modest innovators group. It shows that there are almost three times less R&D expenditures in these countries. Important is that there has been a high level of cooperation and large numbers of HRSTs in these countries. However, given the results, it can be concluded that these elements do not have the required quality. R&D staff can not produce outputs that can be patented and do not represent significant global or at least European innovation. Ponsiglione et al. [38] also stated that innovation environments with similar industrial structures and characteristics can strongly differ from each other even in terms of innovation and competitive performance while this gap is more evident in the case of the so-called lagging regions (characterized by moderate and modest level of innovativeness). These lagging regions lacked solid interactions, network coordination, competences and skills as well [3]. This is, in our view, the cause of the low efficiency of innovation systems in these countries that are not able to increase their effectiveness and to reduce waste of innovation efforts. It could be also caused by a lack of exploiting new ideas by the firms and inertia caused by local systems [15].

5 Conclusions

An innovative environment is a vital complex element that affects most of the innovation processes in different organizations (both private and public). The state and its institutions or public organizations have the task of regulating the behavior of individuals and companies with the help of public policies. Their aim is, among other things, to create support schemes or financial schemes. Practice shows that there are significant differences between countries, namely in the quality of ensuring the basic attributes of the innovation environment.

The aim of this chapter was to analyze the effectiveness of the basic attributes of the innovation environment in EU countries 28. The basic attributes of the innovation environment were defined as inputs; the output variable was the number of patents. This was mainly a quantitative analysis.

The results are confirmed by the European Innovation Scoreboard, issued by the European Commission for the EU Member States. The countries that are considered to be the European innovation leaders achieve the highest efficiency. Our analysis also showed the optimal values of individual indicators (input variables) that countries should achieve if they want to increase their efficiency.

These results can be used to define country-specific recommendations and their public policies. An essential recommendation for all countries with less efficiency is to ensure the basic attributes of the innovation environment—above all a skilled workforce with a strong knowledge base. Inefficient countries also should follow leaders' behavior which positively influences the ability of organizations to develop successful innovations (e.g. thanks to radical innovation, willingness to change, open innovation etc., [18]. However, these countries must take into account whether they have sufficient absorption capacity. Therefore, it is necessary to start from the bottom (e.g. changes in the education system, building a knowledge base, trust, etc.). Without these changes, innovation paradox or NIH and NSH (Not-Invented-Here, Not-Sold-Here) syndromes could occur. The latter syndromes (NIH, NSH) represent problems that can be rooted in corporate innovation culture and do not allow the company to adapt open innovation logic. It is connected with protective attitude towards external knowledge exploitation when employees affected by these syndromes feel that if the knowledge or technology cannot by exploited in own products/services, it should not be exploited at all by anyone else [14]. Frishammar et al. [22] state that understanding the firm's innovation culture is one of the most critical aspects to grasp when changing from a closed to a more open model of innovation and to mitigate these syndromes.

Ponsiglione et al. [38] state that the exploration capacity, the propensity to cooperation, and the endowed competencies of actors could be considered as key aspects in affecting innovation performance (specifically at regional level). Therefore, another recommendation is to increase attention to the results of co-operative links between subjects, to be dissatisfied with poor quality or low quality results. As the results of innovative followers show, some countries do not give a significant weight to quality. They report results (quantitatively high), but qualitatively these results do not contribute to the growth of the output variable (in this case the number of patents). Therefore, we propose implementing quality-orientated management (quality improvement methods—QIMs) that together with innovation represents central strategies for firms and poses significant managerial, organizational and technical challenges in the highly competitive international business world [8].

Thirdly, it is necessary to point the link between the quality of government and its components (e.g. rule of law, control of corruption, government effectiveness and government accountability) and the capacity of regions to innovate and to shape patenting [48] that play a key role mostly in countries suffering low innovative ability. It leads to the wide recognance that institutional factors influence innovative performances (specifically at regional and local level). Therefore, according to Arbolino et al. [5], we propose considering qualitative (socio-political aspects) and quantitative factors (managerial, policymaking and expenditure abilities). Zeng et al. [56] also state that firms should devote continuous efforts to maintain a solid quality system in place integrating a set of quality management (QM) practices (e.g. hard QM that pertains to the technical aspects of QM and soft QM that relates to the social/behavioral attributes) and corresponding performance measures.

The limitation of this study is the quality of the primary data entering the analysis and, of course, a certain limitation of the selected input indicators. Future research should be aimed at identifying the reasons for inefficiency of selected indicators of the innovation environment in individual European countries.

Acknowledgements This work was supported by a grant provided by the scientific research project of the Czech Sciences Foundation Grant No. 17-11795S.

References

1. Acs ZJ, Audretsch DB, Lehmann EE, Licht G (2017) National systems of innovation. J Technol Transf 42(5):997–1008
2. Adams R, Jeanrenaud S, Bessant J, Denyer D, Overy P (2016) Sustainability-oriented innovation: a systematic review. Int J Manage Rev 18(2):180–205
3. Anderson HJ, Stejskal J (2019) Diffusion efficiency of innovation among EU member states: a data envelopment analysis. Economies 7(2):34
4. Andersson U, Dasí À, Mudambi R, Pedersen T (2016) Technology, innovation and knowledge: the importance of ideas and international connectivity. J World Bus 51(1):153–162
5. Arbolino R, Boffardi R, De Simone L (2018) Which are the factors influencing innovation performances? Evidence from Italian Cohesion Policy. Social Indicators Research, pp 1–27
6. Berry FS, Berry WD (2018) Innovation and diffusion models in policy research. In: Theories of the policy process. Routledge, pp 263–308
7. Blazsek S, Escribano A (2016) Patent propensity, R&D and market competition: dynamic spillovers of innovation leaders and followers. J Econometrics 191(1):145–163
8. Bourke J, Roper S (2017) Innovation, quality management and learning: short-term and longer-term effects. Res Policy 46(8):1505–1518
9. Brem A, Nylund PA, Schuster G (2016) Innovation and de facto standardization: the influence of dominant design on innovative performance, radical innovation, and process innovation. Technovation 50:79–88
10. Caragliu A, Nijkamp P (2012) The impact of regional absorptive capacity on spatial knowledge spillovers: the Cohen and Levinthal model revisited. Appl Econ 44(11):1363–1374
11. Cooke P, Uranga MG, Etxebarria G (1997) Regional innovation systems: institutional and organisational dimensions. Res Policy 26(4–5):475–491
12. Cozzi G (2017) Endogenous growth, semi-endogenous growth… or both? A simple hybrid model. Econ Lett 154:28–30
13. Cumbers A, Mackinnon D, Chapman K (2003) Innovation, collaboration, and learning in regional clusters: a study of SMEs in the Aberdeen oil complex. Environ Plann A 35(9):1689–1706
14. Dąbrowska J, Teplov R, Podmetina D, Albats E, Lopez-Vega H (2017) Ready or not? Organizational capabilities of open innovation adopters and non-adopters. In: ISPIM conference proceedings. The International Society for Professional Innovation Management (ISPIM), pp 1–21
15. Das P, Verburg R, Verbraeck A, Bonebakker L (2018) Barriers to innovation within large financial services firms: an in-depth study into disruptive and radical innovation projects at a bank. Eur J Innov Manage 21(1):96–112
16. David PA (1992) Knowledge, property, and the system dynamics of technological change. World Bank Econ Rev 6(suppl_1):215–248
17. de Vasconcelos Gomes LA, Facin ALF, Salerno MS, Ikenami RK (2018) Unpacking the innovation ecosystem construct: evolution, gaps and trends. Technol Forecast Soc Chang 136:30–48

18. Domínguez-Escrig E, Mallén-Broch FF, Lapiedra-Alcamí R, Chiva-Gómez R (2018) The influence of leaders' stewardship behavior on innovation success: the mediating effect of radical innovation. J Bus Ethics 1–14
19. Drucker PF (1985) The discipline of innovation. Harvard Bus Rev 63(3):67–72
20. Erken H, Kleijn M (2010) Location factors of international R&D activities: an econometric approach. Econ Innov New Technol 19(3):203–232
21. Etzkowitz H, Ranga M (2015) Triple Helix systems: an analytical framework for innovation policy and practice in the Knowledge Society. In: Entrepreneurship and knowledge exchange. Routledge, pp 117–158
22. Frishammar J, Richtnér A, Brattström A, Magnusson M, Björk J (2019) Opportunities and challenges in the new innovation landscape: implications for innovation auditing and innovation management. Eur Manag J 37(2):151–164
23. González-Pernía JL, Kuechle G, Peña-Legazkue I (2013) An assessment of the determinants of university technology transfer. Econ Dev Q 27(1):6–17
24. Griliches Z (1998) Patent statistics as economic indicators: a survey. In: R&D and productivity: the econometric evidence. University of Chicago Press, pp 287–343
25. Guan J, Chen K (2010) Measuring the innovation production process: a cross-region empirical study of China's high-tech innovations. Technovation 30(5–6):348–358
26. Hajek P, Stejskal J (2018) R&D cooperation and knowledge spillover effects for sustainable business innovation in the chemical industry. Sustainability 10(4):1064
27. Halaskova M, Halaskova R, Prokop V (2018) Evaluation of efficiency in selected areas of public services in European union countries. Sustainability 10(12):4592
28. Hazır CS, LeSage J, Autant-Bernard C (2018) The role of R&D collaboration networks on regional knowledge creation: evidence from information and communication technologies. Pap Reg Sci 97(3):549–567
29. He B, Wang J, Wang J, Wang K (2018) The impact of government competition on regional R&D efficiency: does legal environment matter in China's innovation system? Sustainability 10(12):4401
30. Hsu CW, Lien YC, Chen H (2015) R&D internationalization and innovation performance. Int Bus Rev 24(2):187–195
31. Joachim V, Spieth P, Heidenreich S (2018) Active innovation resistance: an empirical study on functional and psychological barriers to innovation adoption in different contexts. Ind Mark Manage 71:95–107
32. Kim B, Kim E, Miller DJ, Mahoney JT (2016) The impact of the timing of patents on innovation performance. Res Policy 45(4):914–928
33. Klímová V, Žítek V, Králová M (2019) How public R&D support affects research activity of enterprises: evidence from the Czech Republic. J Knowl Econ. https://doi.org/10.1007/s13132-019-0580-2
34. Liao S, Chou CY, Lin TH (2015) Adverse behavioral and relational consequences of service innovation failure. J Bus Res 68(4):834–839
35. Maskell P (2001) Knowledge creation and diffusion in geographic clusters. Int J Innov Manag 5(02):213–237
36. Meissner D, Polt W, Vonortas NS (2017) Towards a broad understanding of innovation and its importance for innovation policy. J Technol Transf 42(5):1184–1211
37. Pan X, Zhang J, Song M, Ai B (2018) Innovation resources integration pattern in high-tech entrepreneurial enterprises. Int Entrepreneurship Manage J 14(1):51–66
38. Ponsiglione C, Quinto I, Zollo G (2018) Regional innovation systems as complex adaptive systems: the case of lagging European regions. Sustainability 10(8):2862
39. Prajogo DI (2016) The strategic fit between innovation strategies and business environment in delivering business performance. Int J Prod Econ 171:241–249
40. Prokop V, Stejskal J (2017) Different approaches to managing innovation activities: an analysis of strong, moderate, and modest innovators. Inžinerine Ekonomika/Eng Econ 28(1)
41. Prokop V, Stejskal J (2017) Effectiveness of knowledge economy determinants: case of selected EU members. In: European conference on knowledge management. Academic Conferences International Limited, pp 825–832

42. Prokop V, Stejskal J (2019) Different influence of cooperation and public funding on innovation activities within German industries. J Bus Econ Manage 20(2):384–397
43. Prokop V, Stejskal J, Hudec O (2019) Collaboration for innovation in small CEE countries. E + M Ekonomie a Management 22(1):130–144
44. Prokop V, Stejskal J, Hajek P (2018) Effectiveness of selected knowledge-based determinants in macroeconomics development of EU 28 economies. In: Finance and economics readings. Springer, Singapore, pp. 69–83
45. Radziwon A, Bogers M (2019) Open innovation in SMEs: exploring inter-organizational relationships in an ecosystem. Technol Forecast Soc Chang 146:573–587
46. Rao S, Ahmad A, Horsman W, Kaptein-Russell P (2001) The importance of innovation for productivity. Int Prod Monit 2(spring):11–18
47. Ren S, Eisingerich AB, Tsai HT (2015) Search scope and innovation performance of emerging-market firms. J Bus Res 68(1):102–108
48. Rodríguez-Pose A, Di Cataldo M (2014) Quality of government and innovative performance in the regions of Europe. J Econ Geogr 15(4):673–706
49. Stejskal J, Mikušová Meričková B, Prokop V (2016) The cooperation between enterprises: significant part of the innovation process: a case study of the czech machinery industry. E + M Ekonomie a Management 19(3):110–122
50. Svagzdiene B, Kuklyte J (2016) The analysis of factors which have impact for summary innovation index in Germany, Estonia and Lithuania. Transform Bus Econ 15
51. Szücs F (2018) Research subsidies, industry–university cooperation and innovation. Res Policy 47(7):1256–1266
52. Tucci CL, Chesbrough H, Piller F, West J (2016) When do firms undertake open, collaborative activities? Introduction to the special section on open innovation and open business models. Ind Corp Change 25(2):283–288
53. Vila N, Kuster I (2007) The importance of innovation in international textile firms. Eur J Mark 41(1/2):17–36
54. Wang EC, Huang W (2007) Relative efficiency of R&D activities: a cross-country study accounting for environmental factors in the DEA approach. Res Policy 36(2):260–273
55. Zanello G, Fu X, Mohnen P, Ventresca M (2016) The creation and diffusion of innovation in developing countries: a systematic literature review. J Econ Surv 30(5):884–912
56. Zeng J, Phan CA, Matsui Y (2015) The impact of hard and soft quality management on quality and innovation performance: an empirical study. Int J Prod Econ 162:216–226

Viktor Prokop is a professor assistant at Institute of Economics Sciences, Faculty of Economics and Administration, University of Pardubice. The author is co-researcher of the grant project: modelling knowledge spill-over effects in the context of regional and local development; and explores the issue of measuring the knowledge economy in his dissertation.

Jan Stejskal is an associate professor with the Institute of Economics, Faculty of Economics and Administration, University of Pardubice, Czech Republic. His domain is connection of the public economy in the regional scope and view. Especially, he analyses regional policy, tools of the local and regional economic development, and public services.

Petr Hájek is an associate professor with the Institute of System Engineering and Informatics, Faculty of Economics and Administration, University of Pardubice, Czech Republic. He deals with the modelling of economic processes (especially in the field of public economics and public finance).

Michaela Kotkova Striteska is a professor assistant at Institute of Business Economics and Management, Faculty of Economics and Administration, University of Pardubice. She is specialist in BSC and strategic management field. She is a member of the research team titled Modelling knowledge spill-over effects in the context of regional and local development.