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Efficiency of innovation system in the Czech Republic: Comparison with other European countries

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Abstract

This paper examines the efficiency of the innovation system in the Czech Republic compared to other European Union countries. The analysis is based on a data envelopment method using a model containing innovation drivers, knowledge creation and indicators of innovation and entrepreneurship as inputs, and intellectual property and application assets producing outputs of the national innovation systems of selected European countries. The data envelopment analysis method focuses on non-parametric linear programming, examining the relative performance and efficiency of particular units under a constant return to scale, converting inputs into outputs as variables of modelling. The measured technical efficiency indicates a difference in performance of innovation systems of selected countries of the European Union and compares an obtained score in efficiency evaluated in the model. The Czech Republic belongs to the moderate group in terms of innovation performance; its national innovation system is characterised by weaknesses in intellectual assets and research.

Keywords: Innovation, national innovation system, DEA modelling, technical efficiency.

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1. Introduction

The functional national innovation system (NIS) can be considered as one of the most important factors influencing economic performance and helps to create conditions for a driver of economic growth—innovation. Innovation is a result of the combined impact of particular elements of the national system supporting the economy based on knowledge, creativity and technology, and forming conditions for innovation activities. The national innovation system can be described as that set of national institutions contributing to the generation and diffusion of new technologies and providing the framework within which government and firms negotiate policies to influence the innovation process (Metcalfe, 1997). The system of innovative entrepreneurship in the Czech Republic consists of four components: managing institutes, the education system, funding (including venture capital, seed capital and risk capital) and subjects of innovative entrepreneurship (Urad vlady, 2004). The NIS network include institutes that participate in innovation processes, including government institutes, parliament, ministries, R&D institutes, universities, banks and funding institutes and partners in research and development in the private and public sectors. The national innovation strategy of the Czech Republic defines the innovation policy as the sharing of new technologies and knowledge, the creation of a functional education system, an effective government policy supporting innovation and an environment and companies' research and development to produce high technology and superior products (Urad vlady, 2011). There is no single definition of the national system of innovation, there are variations in definition by various researchers and authors.

Measuring relative national innovation system efficiency is based on the transformation of innovation inputs into outputs. The innovation union scoreboard (IUS) is one study provided by the European Commission, focusing on the innovation performance of European Union countries and trends in innovation development in the EU.

This paper focuses on the efficiency measurement of innovation performance of the Czech Republic associated with data envelopment analysis calculated for input dimensions. The study works with the IUS report, which was the basis for analysis by Hollanders and Celikel-Esser (2007), who examined the efficiency of European Union countries.

The paper is organised as follows. Following this introduction, Section 2 offers the theoretical background and a literature review. Section 3 specifies the research framework, methodology and data sources used. The main results are presented and discussed in Section 4. Finally, the last section summarises and concludes the paper.

2. Literature review

2.1. The national innovation system and performance

Hollanders and Celikel-Esser (2007) focused on the national innovation systems of European countries. The study emerged from the European Innovation Scoreboard as a basic document measuring innovation performance using data for 25 innovation indicators. The calculations in this study were based on a constant return to scale output-oriented data envelopment analysis model in combination with the three input and three output dimensions. The analyses were performed for the most and the least innovative countries. Matei and Aldea (2012) also adopted a non-parametric frontier model, data envelopment analysis and used the IUS indicators to calculate efficiency scores for the European Union countries. Carayannis, Grigoroudis and Goletsis (2016) evaluated the efficiency of the innovation system based on data envelopment analysis (DEA) modelling, its main characteristic being its ability to handle different inputs and outputs at different levels. They applied this approach to a set of 23 European countries and their 185 corresponding regions. The results showed differences regarding the efficiency scores at national and regional levels in the countries presented in the study.

2.2. DEA measuring of innovative efficiency

Measuring of efficiency is based on several methods. Farrell (1957) described technical efficiency as a production function, being the output that a perfectly efficient company could obtain from any given combination of inputs, under constant returns to scale. This method of measuring efficiency works with a hypothetical company that is constructed as a weighted average of two observed firms, in the sense that each of its inputs and outputs is the same weighted average of those of the observed companies, the weights being chosen to give the desired factor proportions. The methods measuring efficiency can be split into parametric and non-parametric methods. Kotsemir (2013) defined non-parametric methods as a tool calculating the scores of efficiency on the basis of an empirical efficiency frontier built on observed objects of analysis. Parametric methods stochastically estimate the efficiency scores. The DEA was used for the purpose of efficiency measuring in this paper is a non-parametric method minimising inputs at a given level of output or maximising outputs at a given level of input (Vincova, 2005). We applied DEA as developed by Charnes, Cooper and Rhodes (1978). The principle of DEA modelling is to calculate efficiency within a sample group and compare its efficiency with each other unit. The basic DEA idea is to measure relative efficiency across defined decision making units (DMU) and calculate the efficient frontier for the sample objects. Bielicki and Lesniak (2016) interpreted efficient DMUs as those located on the frontier, whose efficiency ratio takes the value of 1. Any country not on the frontier is considered inefficient. A numerical coefficient is given to each object defining its relative efficiency, efficiency taking a value from the interval [0–1]. The difference in value relative to 1 specifies the size of the inefficiency of a single object.

The national innovation system production we understand is when a DMU unit consumes inputs to produce outputs. There are *n* productive DMUs (DMU1, DMU2, DMU3, …, and DMUn), which convert *m* number of inputs (x1, x2, x3, …, xm) into *s* number of outputs (y1, y2, y3, …, ys). The objective of each DMU unit is to minimise the inputs consumed within a system to produce the output on a constant returns on scale level. A constant return on scale (CRR) model is output-oriented with the purpose of maximising the value of efficiency; the principle is to increase the output rather than decrease the inputs.

The primary CCR output-oriented model is defined as:

$$\text{Minimise} \qquad g = \sum_{j}^{m} v_j x_{jq}, \tag{1}$$

$$\text{subject to} \qquad \sum_{i}^{r} u_i y_{ik} \le \sum_{j}^{m} v_j x_{jk}, \quad k = 1, 2, \ldots, n,$$

$$\sum_{i}^{r} u_i y_{iq} = 1,$$

$$u_i \ge \varepsilon, \quad i = 1, 2, \ldots, r,$$

$$v_j \ge \varepsilon, \quad j = 1, 2, \ldots, m.$$

Here, x_{ij} and y_{ij} are the inputs and outputs of the DMU_n and u_i and v_j are weights assigned to the *j* th input and *I* th output.

The dual model to this can be stated as follows:

$$\text{Maximise} \qquad g = \phi_q + \varepsilon(e^T S^+ + e^T S^-), \tag{2}$$

$$\text{subject to} \qquad X\lambda + S^+ = x_q,$$

$$Y\lambda - S^- = \phi_q y_q,$$

$$\lambda, S^{+}, S^{-} \geq 0.$$

DEA models are used not only to measure efficiency, but also to calculate target values for inputs and outputs for the inefficient unit.

3. Variables of the study and data used

The study deals with the fact that the output will change by the same proportion as the inputs are changed. The CCR output-oriented model determines the inputs required to be effective in outputs and assumes constant returns to scale.

The variables used in this study characterise the innovation activity of the DMUs and are based on the Innovation Union Scoreboard. The research emerged from within a moderate group of innovators defined by UIS, including Croatia, Cyprus, the Czech Republic, Estonia, Greece, Hungary, Italy, Latvia, Lithuania, Malta, Poland, Portugal, Slovakia and Spain. The innovation performance of this country group is below that of the EU average.

The following data serve as inputs for the DEA modelling for the year 2015:

- The number of researchers (full-time equivalent that corresponds to one year's work by one person, residents and non-residents);
- R&D expenditure of particular countries in all sectors of the economy (in million €).
- The inventive output in the year 2015 is covered by:
- Number of granted patents;
- Gross domestic product (in million €).

These inputs/output variables were selected as key factors influencing the innovation process and the results were compared across countries with similar innovation performance published in the UIS 2016 report. The data were obtained from Eurostat and the World Intellectual Property Organization in 2015.

The chosen criteria for the DEA analysis of innovation efficiency and input–output data are displayed in Table 1.

Table 1. Input and output variables in the year 2015

Country	Researchers in R&D in all sectors	R&D expenditures in all sectors	Patent grants	GDP
Croatia	6,367	375	51	43,847
Cyprus	860	80	14	17,637
Czech Republic	38,081	3,250	823	166,964
Estonia	4,186	303	34	20,252
Greece	35,069	1,684	284	175,697
Hungary	25,316	1,511	403	109,674
Italy	120,677	21,892	9,629	1,645,439
Latvia	3,613	152	155	24,368
Lithuania	8,124	387	144	37,331
Malta	817	68	29	9,276
Poland	96,692	4,317	2,722	429,794
Portugal	39,580	2,289	122	179,540
Slovakia	14,406	927	93	78,686
Spain	122,437	13,172	3,074	1,075,639

Data envelopment analysis online software was used for the calculation, which is available on DEAOS websites.

4. Results and discussion

Based on the dataset, the efficiency of the countries belonging to the group of moderate countries was calculated. First, we calculated the correlation between the variables using the dataset covering the year 2015. The results are presented in Table 2.

Table 2. Correlation between input and output variables

Name	Researchers in R&D in all sectors	R&D expenditures in all sectors	Patent grants	GDP
Researchers in R&D in all sectors	1.0000	0.8774	0.8141	0.9023
R&D expenditures in all sectors	0.8774	1.0000	0.9582	0.9961
Patent grants	0.8141	0.9582	1.0000	0.9526
GDP	0.9023	0.9961	0.9526	1.0000

The correlation between factors shows the dependency for further calculations of efficiency across the units.

Table 3 presents the results of DEA analysis. The table is divided into two parts: the calculated efficiency scores within the DMUs, and improvements of variables measured by the output-oriented CRS model. As mentioned above, the output-oriented CRS model focuses on outputs with contracted inputs. The calculations in Table 3 enable suggestions to be made for improvements of inputs to be effective with the same output levels. The recommendations are based on the variables relating to the most efficient DMUs within the sample.

Table 3. Efficiency scores and improvements

2015		Improvements			
Country	CCR	Researchers in R&D in all sectors	R&D expenditures in all sectors	Patent grants	GDP
Croatia	54.4%	4,466–6,367	375–375	51–94	43,847–80,666
Cyprus	100.0%	860–860	80–80	14–14	17,637–17,637
Czech Republic	43.3%	38,081–38,081	3,250–3,250	823–1,901	166,964–385,678
Estonia	32.1%	4,071–4,186	303–303	34–106	20,252–63,040
Greece	49.9%	22,324–35,069	1,684–1,684	284–569	175,697–351,758
Hungary	42.0%	25,316–25,316	1,511–1,511	403–960	109,674–261,246
Italy	100.0%	120,677–120,677	21,892–21,892	9,629–9,629	1,645,439–1,645,439
Latvia	100.0%	3,613–3,613	152–152	155–155	24,368–24,368
Lithuania	52.8%	7,321–8,124	387–387	144–273	37,331–70,718
Malta	89.3%	817–817	68–68	29–33	9,276–10,390
Poland	64.6%	96 692–96 692	4,317–4,317	2,722–4,212	429,794–665,058

Portugal	35.6%	24,607–39,580	2,289–2,289	122–401	179 540–504 639
Slovakia	39.5%	11,093–14,406	927–927	93–236	78,686–199,159
Spain	58.9%	122,437–122,437	13,172–13,172	3,074–5,221	1,075,639–1,826,724

As we know from the model principle theory, the efficiency of countries is defined by a level higher than one. This means that we consider a country with an efficiency score of 100%–to be efficient. The CCR analysis indicates that Cyprus, Italy and Latvia are efficient countries that use resources effectively. The CCR scores also show the inefficiency of countries. Estonia is the most inefficient unit in the sample, with the lowest efficiency score of 32.1%. The CCR score confirmed Cyprus' leading position in innovation performance for the group of moderate innovators. In contrast, Estonia is the most inefficient country in our analysis but the UIS presents this country in second position in innovation performance. The efficiency result for Estonia should be further examined with analysis of further input and output variables entering the innovation system. The technical efficiency score of the Czech Republic presents this country as inefficient within the sample group with a value of 43.3%. The Czech Republic confirmed its position in this group of European moderate innovators following Cyprus, Estonia and Malta. The other observation focused on proposed improvements in factors influencing the national innovation systems. The selected countries are not effective in utilising researchers in research and development. Inefficiency was also measured in terms of the number of granted patents, which should be higher, on the same level of the entering factors.

The Czech Republic innovation performance score is below the average of the European Union, published in the UIS. The Czech national innovation system is characterised by weaknesses in intellectual assets and an open and excellent research system. This fact was confirmed by the results of the DEA analysis. The UIS considers the Czech system strong in human resources and finance and support; the efficiency was calculated in variables measuring the number of researchers in R&D in all sectors. In comparison with other countries in the moderate group, the Czech Republic follows Malta with weakness in venture capital investments and strong improvements in intellectual assets, namely in patents granted in our study. In the case of the Czech Republic, there is no significant number of granted patents, which should be higher in an efficient system with invested expenditure and the numbers of researchers working in the system. The data show that the countries do not use sources adequately–to support innovation.

5. Conclusions

The aim of this article was– to examine the technical efficiency of the moderate group of European Union countries as defined by the Union Innovation Scoreboard and edited by the European Commission. Data envelopment analysis was implemented in the form of an output-oriented constant returns to –scale model. This model works with the quantity of inputs consumed in the innovation process– to produce outputs, based on the constant returns to –scale. The results present efficiency in countries such as Cyprus, Latvia and Italy within the sample group, and the analysis pointed out differences in the indicators used in the study. Based on the results obtained, we conclude that the most efficient country in the group, Cyprus, confirmed the position defined in the Union Innovation Scoreboard, followed by Estonia and Malta. The Czech Republic was shown to –be an inefficient country with weaknesses in intellectual assets and the utilization of innovation as drivers of economy. The limitation of the study is in the input and output indicators entering the system, which should be analysed in detail and combined for the calculation of values.

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