The Impact of Soft Knowledge Infrastructure and HRST on Economic Development

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***Abstract*—Globalizing changes in society are able to influence changes in the economies of individual countries. Individual economic entities from various sectors attempt to achieve high economic performance and development. They do this within the conditions that are possible at that time; if there are favorable conditions for their development, this will result in creating innovative production and its subsequent commercialization. Not only private companies but also organizations from the public sector and individual governments are involved in creating this type of environment. However, the effectiveness of the individual steps taken towards an innovative environment or its determinants is not unequivocally positive. This paper's goal is to analyze the impact of soft knowledge infrastructure and HRST on the economic development of EU 28 economies in 2012 and within CEE countries between 2002-2012. DEA models will be used for analysis with the input being knowledge stock and inflows, patent cooperation and activities, and the output being gross domestic product and value added. The results indicate that CEE countries were less effective than the rest of EU 28 countries in the processes of using selected determinants.**

Keywords-soft knowledge infrastructure; economic development; DEA method; government; environment

I. INTRODUCTION

Currently, innovation is perhaps the most frequently discussed concept in the field of economics. It is being dealt with at different levels: the influence of innovation on company efficiency and performance has been frequently investigated and many studies have investigated innovation's influence from the macroeconomic perspective. However, all of these have something in common. They all prove that implementing innovation positively influences the economic performance of individual entities (companies, regions, and overall economies). Likewise, certain authors link innovation with production exhibiting higher added value [6] and posit conclusions recommending that individual levels of government should support innovation and create conditions favorable to it – conditions under which innovation can emerge and be implemented practically [22]. It can be stated that, over the past 20 years, many advanced countries (including the EU) have begun to extensively support research and development that focuses on creating the conditions for a favorable business environment, and they have focused their public policies on making innovative processes more effective [20]. In recent years, what has been emphasized in particular are policies that can tagged with the label "knowledge," i.e., which motivate individual economic players towards producing, communicating, sharing, or transferring information and knowledge [1]. That's why the concept HRST (Human Resources in Science and Technology) was created. OECD defined in 1995 HRST as individuals who fulfill one or the other of the following conditions (a) they have successfully completed education at the tertiary level in an science and technology field of study; (b) they are not formally qualified as above, but are employed in an science and technology occupation where the above qualifications and (c)are normally required.

How effective individual measures are is a frequent topic of discussion and investigation. Individual studies further point to the inefficiency – or ineffectiveness – of individual processes [31]. This often results in a specific form of the innovation paradox, where the expected results of the public sector's extensive support for innovation do not appear [17]. Likewise, there are studies that talk about the ineffectiveness of public aid and point to the crowding out effect. This results in the crowding out of private investment by the public funding that has been provided [16, 37]. It is indisputable that there has been an increase in inter-regional differences on account of variation in the effectiveness of individual innovation (or information-based or knowledge-based) policies. Paradoxically, this is also true within the European Union itself. Despite its regional policy, there are varying rates of practical use for information, ICT, and various types of knowledge, which negatively influences economic development [33]. The countries of Central and Eastern Europe (CEEC) are a typical example of this; they have been conspicuously lagging behind [32]. Therefore, it is necessary to investigate the impact of the selected innovation process determinants and use this as a basis for positing conclusions aimed at modifying or reforming the innovation environment in individual regions or economies [21].

The remainder of this paper is structured as follows. In the next section, we present the theoretical background for the determinants of innovation activities and the main research questions. Section 3 provides the characteristics of the dataset and the research methodology. Section 4 lists the experimental results. In Section 5, we discuss the results that were obtained and conclude the paper with suggestions for future research.

II. THEORETICAL BACKGROUND

The theoretical framework for this paper is founded on the endogenous growth theory. It assumes a positive correlational relationship between innovation and economic performance [26]. The growth theory states that economic growth is also determined by the level of the technologies that can be used to implement innovation which are available. It is important to note that, in the same way as the previously mentioned technologies, innovation is seen here as an input into the production process [5]. Growth theories also assume the existence of a positive business (innovation) environment, which makes it possible for the owners of specific production factors (primarily information, knowledge, patents, know-how, etc.) to enter the market and use them for commercial purposes [35]. This model alters the traditional model that had often been used in the past, which assumed that innovation has only a temporary effect and influences a company's output only until the competition replicates this innovation. However, there is a vast amount of evidence showing that some firms in different industries and different institutional settings remain superior to their rivals for a considerable period of time, irrespective of the measure of firm performance used [15]. Schumpeter and his concept of innovation brought an important conceptual change. According to Schumpeter's thesis of creative destruction, any type of innovative change reflected in production, the environment, the markets, the forms an organization takes, etc. leads to fundamental reform of the existing economic structures and the emergence of new ones. Originally, he assumed that the influence of entrepreneurs on their own was the driving force of change; later, he named large firms operating in concentrated industries as the source of innovative activities [27]. Therefore, various approaches and models can be encountered in practice, often including combinations of that which has been listed above. However, all of these agree that innovation is an important means to improve company output in order to achieve successful market commercialization and business goals [2]. Likewise, they consider both the behavior of companies on their own as well as the environment a company is situated in to be important.

There are also special models that analyze the behavior of companies in the market environment. A well-known one is the multi-stage model of company behavior. It outlines the clear conclusion that a company must try to differentiate its products from the competition's and that they must do this using various innovation determinants. Primarily, these are science and development, a qualified work force, cooperation, information, and ICT infrastructure [well known as HRST; 30]. The next generation of endogenous models is the non-scale endogenous growth models. They removed the scale effect by replacing the human capital variable in the innovation function with the ratio of human capital to total labor force or with the GDP share of R&D investment (R&D intensity). They argue that, as the numbers of new products and sectors increase over time, the R&D investment has to increase just to keep the innovation rate constant for each sector [15, 23]. It is also possible to encounter other models that are primarily microeconomic in nature. On the other hand, studies focusing on macroeconomic effects are still lacking and cover only a small number of OECD countries. For example, refs. [11, 36] examine the relationship between total factor productivity and R&D intensity using data from OECD countries and find a positive relationship between these variables [34].

The determinants of innovation activities also have an indisputable influence on innovation performance [3]. There are many studies that independently define different ranges of determinants. Their nature tends to be determined by economy type. The most frequent determinants for emerging economies are (a) size and age, (b) education level, (c) export intensity, (d) market structure, (e) R&D, (f) partnership, and (g) technology transfer. Ref. [14] lists an overview of these studies. They also state that the inconclusive results justify the inclusion of many control variables in order to obtain robust results on the effect of size and competition on the innovation capacity of the firms. Such is the case of the average education level of production workers, export intensity, and market structure. There are also studies that point to the fact that the availability of information, knowledge, and knowledge sharing between skilled co-workers has at least an indirect effect on firms' performance (e.g., [4, 25, 28]). Therefore, the goal of this paper is to analyze the impact of soft knowledge infrastructure and HRST on the economic development of selected economies.

III. Data and Methods

For our analyses, Data Envelopment Analysis (DEA) was conducted by using data from Eurostat (available at http://ec.europa.eu/eurostat/data/database) and OECD (available at http://stats.oecd.org) databases. DEA is a parametric approach used as a model specialized tool for assessing the effectiveness, performance and productivity of comparable production units (homogeneous units – 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 [29].

The mathematical formulation of DEA models considers the existence of a set of homogeneous production units $U_1, U_2, \ldots, U_n$, wherein each of the units produces r outputs and subsequently using m inputs [19]. Then, $X = \{x_{ij}, i = 1, 2, \ldots, m, j = 1, 2, ..., n\}$ is considered as input matrix and $Y = \{y_{ij}, i = 1, 2, \ldots, r, j = 1, 2, ..., n\}$ is considered as output matrix. Efficiency rate of U_q unit is generally expressed as weighted sum of inputs/weighted sum of outputs [10]. The principle of DEA models is that when evaluating the efficiency of a production unit U_q 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 [10].

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).

TABLE I. VARIABLES INVOLVED IN THE MODEL

Input variables (2011)			Output variable (2015)	
Determinant	**Variable**	**Description**	**Variable**	**Description**
Inflows into HRST	First and second stage of tertiary education	Eurostat indicators on real and potential inflows into the stocks of HRST	Gross domestic product	Gross domestic product (GDP) and its growth represent one of the most frequently used indicators of economic growth [7, 12]
Stock of HRST	Persons employed in science and technology	Eurostat indicators on stocks of HRST	Value Added	The value added is another possible determinant of economic growth and identifier of the growth of commercial gain [13, 18]
Patents	Patents granted by the USPTO	Patent information is based on the priority year and is made available after the date of publication of the application. This statistical unit is the innovative activity within a country's borders that result in patent granted by the USPTO.		
Cooperation	Patent cooperation with foreign co-inventor(s)	Knowledge and information creation and share could be efficiently supported through patent (innovation) cooperation within various economic entities (e.g. countries, firms, universities)		

Note: HRST = Human Resources in Science and Technology; First stage of tertiary education not leading directly to an advanced research qualification, Second stage of tertiary education leading to an advanced research qualification; USPTO = United States Patent and Trademark Office

Source: own based on Eurostat and OECD databases

For our cross-country analyses within the EU 28 countries (focused on CEE countries), we used input-oriented VRS model operating with variable returns to scale. Selected inputs and outputs are shown in Table 1.

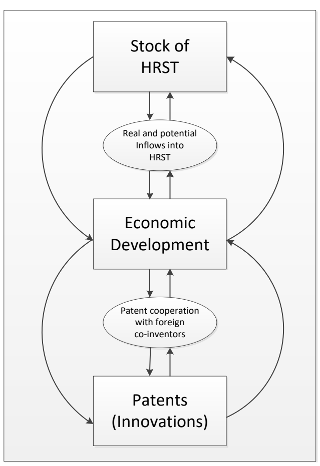

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Figure 1. Knowledge and information sharing processes within economic development.

We chose 4 input variables that were grouped in the Science, Technology and Patents themes that could be expected as main determinants of the knowledge economy that could help to efficient creation, dissemination and share of knowledge and information [8-9] and two output variables representing countries´ economic development. Process of the knowledge and information sharing is shown at Fig. 1. We expect synergies and ties between selected variables that both - independently and together - allow flows (sharing) of knowledge and information and influence countries´ economic development.

Firstly, we compare countries efficiency, both within the EU 28 and within CEE countries in 2012 (Table 2). We clarify whether the economies of the EU 28 use effectively the selected determinants of the knowledge economy and identify the economies with low efficiency. For low-efficient economies, the DEA software proposes some inputs and outputs reductions that will help them to become more efficient . Secondly, we created DEA models between 2002-2012 and compare efficiency of CEE countries within EU 28 (see Fig. 2-4).

IV. RESULTS

Results of input-oriented VRS model are shown in Table 2. Countries that efficiently used selected determinants reached the rate of effectiveness 1,000, other countries were not considered effective (less rate of effectiveness means less efficiency of the country).

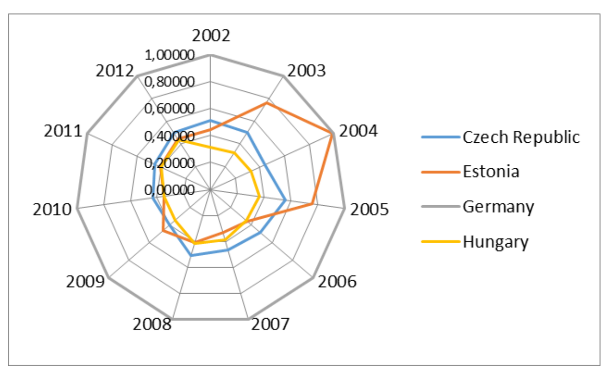

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Figure 2. Efficiency of selected CEE countries between 2002-2012.

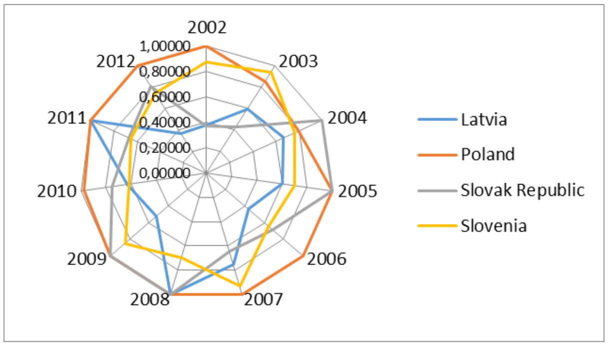

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Figure 3. Efficiency of selected CEE countries between 2002-2012.

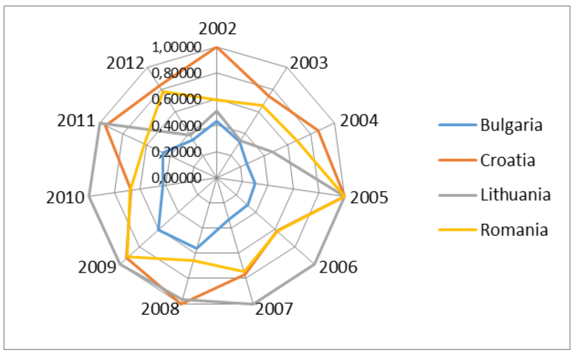

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Figure 4. Efficiency of selected CEE countries between 2002-2012.

Results show that 11 countries of the EU 28 (39 %) were effective. Only 2 from 12 (16 %) CEE countries – Germany and Poland – were considered effective. The rest of CEE countries (84 %) did not efficiently used selected determinants and did not fully exploit their potential to share knowledge and information to affect their economic development. Moreover, Latvia and Bulgaria were less efficient countries within these processes in comparison with other CEE and EU 28 countries in 2012.

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. Input-oriented models propose changes focusing primarily on input variables (or even minor changes on the output side). Table 2 therefore shows both original values (obtained from the Eurostat databases) and adjusted values (provided by DEA). Adjusted values are counted by DEA software and show how the input (output) variables should be reduced/increased to improve countries´ efficiency. For example, Czech Republic cooperated in 117 cases (data from Eurostat) however the output was not such efficient in comparison with other efficient countries, therefore, DEA proposed decrease in this kind of cooperation (adjusted value = 68). This result indicates that Czech Republic should focus on the efficiency of cooperation to reach better outputs in the future.

TABLE II. RESULTS OF INPUT-ORIENTED VRS MODEL IN 2012

			Input Variables								Output Variables			
	Country	Rate of Efficiency	Inflows into HRST (in thousands)		Stock of HRST (in thousands)		Patents (no. of units)		Cooperation (no. of units)		GDP (in millions Euro)		Value Added (in millions Euro)	
			Orig.	Adjust.	Orig.	Adjust.	Orig.	Adjust.	Orig.	Adjust.	Orig.	Adjust.	Orig.	Adjust.
CEE Countries	Czech Republic	0.49741	107,773	53,607	90	23,303	334	166	177	68	161434,3	164006,4	145075,8	145075,8
	Estonia	0.44579	11,497	5,125	20,1	6,931	45	16	23	10	17934,9	17934,9	15676	15904,43
	Germany	**1.00000**	554,215	554,215	1292,6	1292,600	21075	21075	4561	4561	2758260	2758260,0	2478596	2478596
	Hungary	0.43482	69,917	30,401	53,2	15,654	251	109	112	49	99085,6	99085,6	83217,7	87750,15
	Latvia	0.36977	21,472	7,780	27,6	8,083	22	8	12	4	22058,4	22184,7	19639,5	19639,5
	Poland	**1.00000**	638,957	638,957	222	222,000	416	416	171	171	389368,9	389368,9	344976,7	344976,7
	Slovak Republic	0.80964	72,374	39,450	33,5	25,483	62	50	41	15	72703,5	75726,8	66410,3	66410,3
	Slovenia	0.74044	20,596	11,274	12	8,885	63	27	17	13	36002,5	36002,5	31225,6	31890,95
	Bulgaria	0.34002	64,091	13,565	28,4	9,656	93	31	39	13	41947,2	41947,2	36296,5	37137,14
	Croatia	0.82925	39,82	18,557	16,1	13,351	32	27	16	9	43933,7	43933,7	37266,1	38723,45
	Lithuania	0.38263	42,379	14,907	33,2	11,999	46	18	17	6	33348,2	34233,9	30164,9	30164,9
	Romania	0.77892	200,106	73,790	61,6	44,351	123	96	70	27	133511,4	133784,0	117125,1	117125,1
Other EU28 Countries	Austria	0.86726	69,385	60,175	146,5	77,856	1792	1554	655	454	317117	317117,0	281955,7	282612,3
	Belgium	0.75335	110,419	83,185	94,4	71,117	1951	1049	1024	301	387500	387500,0	346698	347229,6
	Denmark	0.81917	58,667	48,058	74,8	61,274	1391	1105	399	327	254578	254578,0	219794,7	227516,8
	Finland	0.67974	53,296	36,227	62,1	42,212	2194	789	488	256	199793	199793,0	172417	178417,6
	France	**1.00000**	697,193	697,193	604,6	604,600	8718	8718	2218	2218	2086929	2086929,0	1873450	1873450
	Greece	**1.00000**	66,333	66,333	27,3	27,300	167	167	59	59	191203,9	191203,9	168979	168979
	Ireland	0.77466	60,022	46,496	34,4	26,648	885	284	475	107	175752,5	175752,5	9734	156456,7
	Italy	**1.00000**	383,332	383,332	281	281,000	3468	3468	799	799	1613265	1613265,0	1448021	1448021
	Luxembourg	**1.00000**	1,289	1,289	5,2	5,200	127	127	93	93	44112,1	44112,1	39386,4	39386,4
	Netherlands	0.89227	152,049	135,668	264,9	158,758	3377	3013	1162	815	645164	654468,1	583832	583832
	Portugal	**1.00000**	94,264	94,264	55,6	55,600	123	123	34	34	168398	168398,0	147361,6	147361,6
	Spain	**1.00000**	391,956	391,956	190,3	190,300	1392	1392	412	412	1039758	1039758,0	954026	954026
	Sweden	**1.00000**	69,14	69,140	151,5	151,500	3665	3665	1033	1033	423340,7	423340,7	373843,9	373843,9
	United Kingdom	0.93996	780,606	683,151	915	590,122	9025	8483	3071	2155	2065737	2065736,8	1844409	1854416
	Cyprus	**1.00000**	6,173	6,173	7,2	7,200	6	6	3	3	19467	19467,0	17265,5	17265,5
	Malta	**1.00000**	3,463	3,463	6,7	6,700	11	11	7	7	7155,7	7155,7	6268,9	6268,9

Source: own

In our analyses, we consequently created DEA models between 2002-2012 to analyze efficiency of CEE countries (in comparison with EU 28 countries). Results are divided into three figures (see Fig. 2-4) and show the evolution of countries efficiency. Germany was only one country that efficiently used selected determinants – knowledge stock and inflows, patent activities and cooperation – to influence their economic development and exploit its potential to support creation and dissemination of new knowledge and shared information (similar results are also in [24]).

V. CONCLUSIONS

Results of our cross-country efficiency analyses showed that most of EU 28 countries did not efficiently used selected determinants of economic development in 2012. Moreover, only 2 out of 12 CEE countries were considered efficient and only Germany has been able to effectively use knowledge stocks and inflows into HRST, cooperate with foreign co-inventors and use patents. For these reasons, we propose some practical implications for policy makers within CEE and other EU 28 countries. They should create sufficient environment for cooperation and networking (between all economic actors) and support firms´ localization, research and development (e.g. through tax benefits, after-care) that will help to increase efficiency of knowledge and information flows and sharing. It is necessary to change government's policies on tertiary education (promotion of science and technology, language skills, higher mathematical literacy, which will increase the innovation potential). We also propose supporting relationship with practice, as done in Germany through vocational education and training system, which is aimed at promoting cooperation between firms, universities and public research centers. Finally, we recommend finding the common interests of individual economic actors (specifically universities and firms that have different interests in most cases) at micro and macroeconomic level. For the future research, we plan to analyze microeconomic environment within CEE countries and the issues of cooperation between firms and universities and consequences of knowledge and information sharing within individual economic actors.

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