Regional knowledge production in Central and East European countries: R&D factor productivity and changes in performances

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Abstract

In this paper, we analysed regional R&D productivities of Central and Eastern European (CEE) Countries. The regional knowledge production framework is utilized for a total of 52 NUTS-2 regions for the 2001-2012 period. Patent applications to the European Patent Office (EPO) are taken as the main output of R&D activities while input variables are total expenditure on R&D and total R&D personal and researchers. Applied productivity analysis based on Malmquist Index shows that total factor productivity (TFP) of knowledge production increased from 2001 to 2012 in all regions. Considering the whole period, although TFP has partially decreased partially after the 2008 crisis, the regions experienced capacity expansion. The main sources of the increase in TFP are found to be technological change and capacity expansion. Efficiency change, in contrast, is found to be negative in the majority of regions. Detailed performances are also illustrated with geographical information maps.

Keywords: factor productivity, knowledge production, innovation paradox, Malmquist TFP Index, Central and East European Countries

Introduction

The regional concentration of economic activities due to local networks, sectoral clusters and knowledge spillovers have made regions the main unit of analysis of policy-making in the European Union (EU) (Cantwell and Iammarino, 2003; Committee of the Regions, 2013; McCann and Ortega-Argiles, 2015; Schrempf *et al*., 2013). Considering the current economic disparities between European regions, one can count numerous explanations for regional agglomeration of innovative activities in specific territories in the EU. Navarro *et al*. (2009), for

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instance, identify eight groups of regions in EU-25 according to innovative capacity typologies ranging from advanced and highly specialized regions to peripheral and lagging regions (Heidenreich, 1998). Policy design and performance evaluation should comply with the attributes of these region typologies (Tödtling and Trippl, 2005; Zenka *et al*., 2014). Central and East European (CEE) regions in general, like other peripheral and/or lagging regions in this sense, need a special focus due to the structural differences compared to the advanced EU regions.

This study aims to assess CEE regions' TFP performance of knowledge production for the 2001-2012 period. Comprising pre-accession, accession and the 2008 crisis sub-periods, the study evaluates the performance of regional knowledge production in CEE countries by using Malmquist TFP Index methodology. The results are expected to answer two questions. The first one is about the efficiency of R&D inputs in knowledge production. Efficiency gains, if they exist, will show governance and management achievements of R&D activities at the regional level. The other question is related to innovative capacity building. Positive TFP achievements in CEE regions are thought to contribute to the capacity building in the regions. As Malmquist method generates two main categories of factor productivity, namely efficiency change and technological change, an increment in either of the two components will mean a positive contribution to the innovative capacity building goal of CEE regions.

The paper is organized as follows. The first section briefly summarizes the background of the study. Section two and three convey literature review and methodology-data parts, respectively. While section four presents empirical results of the analysis, the conclusion section sums up findings and implications.

1. Background

CEE countries have experienced serious political and economic transformations since the fall of the planned economies. Beginning in the early 1990s, CEE countries started on to accomplish the so-called „post-socialist transition", i.e. restructuring of economies, opening up national markets and integration with European and world production networks. The period until EU accession was mainly shaped by the PHARE Programme (European Commission, 1999). Related to the R&D capacity of the regions, state economic enterprises and local administrative institutions became two main areas of reform Reforms were aimed to privatize existing state economic enterprises and to build administrative institutions which were in compliance with European standards as stated by Copenhagen Criteria. While CEE countries accomplished regional administrative reforms, i.e. regional development agencies, to get pre-accession assistance and to make use of structural funds afterwards, the achievements of reforms on capacity-building are thought to be questionable (Bailey and De Prophis, 2004).

During this period, privatized industries lost their R&D facilities which were sustained in the 1980s. The innovative capacity in the pre-accession period was mostly shaped by global FDI flows to these countries (Holland and Pain, 1998; Kattel *et al*., 2009). However, new coming foreign firms' impact on innovation infrastructure of CEE countries was limited (Radosevic, 1999).

With the enlargement of the EU in 2004 and 2007, CEE countries began to integrate with the developed countries of the union. The EU Regional Policy was aimed to ease the gap between EU regions with regard to economic, social and territorial inequalities by being targeted at the "lagging regions" among these new members. Following the innovation system perspective for regional units at NUTS-2 level, Cohesion Policy targeted CEE regions to increase competitiveness through innovation supports and smart specialization strategies. A new period of regional policy was started in CEE countries in view of the effect of the Cohesion Policy on local start-ups and SMEs. European Regional Development Fund (ERDF) became the main source of R&D and innovation themed supports[1] in less developed regions. As illustrated by Table 1, the outputs of ERDF projects contributed to regional economies in terms of employment, innovative capacity building and supports for SMEs. By authorizing regional institutions, Cohesion Policy led to regional thinking in CEE countries. During the first years of enlargement, CEE regions developed interregional collaborations and supported local network organizations between the private sector, research institutions and regional development agencies.

Table 1. Selected indicators from ERDF projects, 2007-2013 total

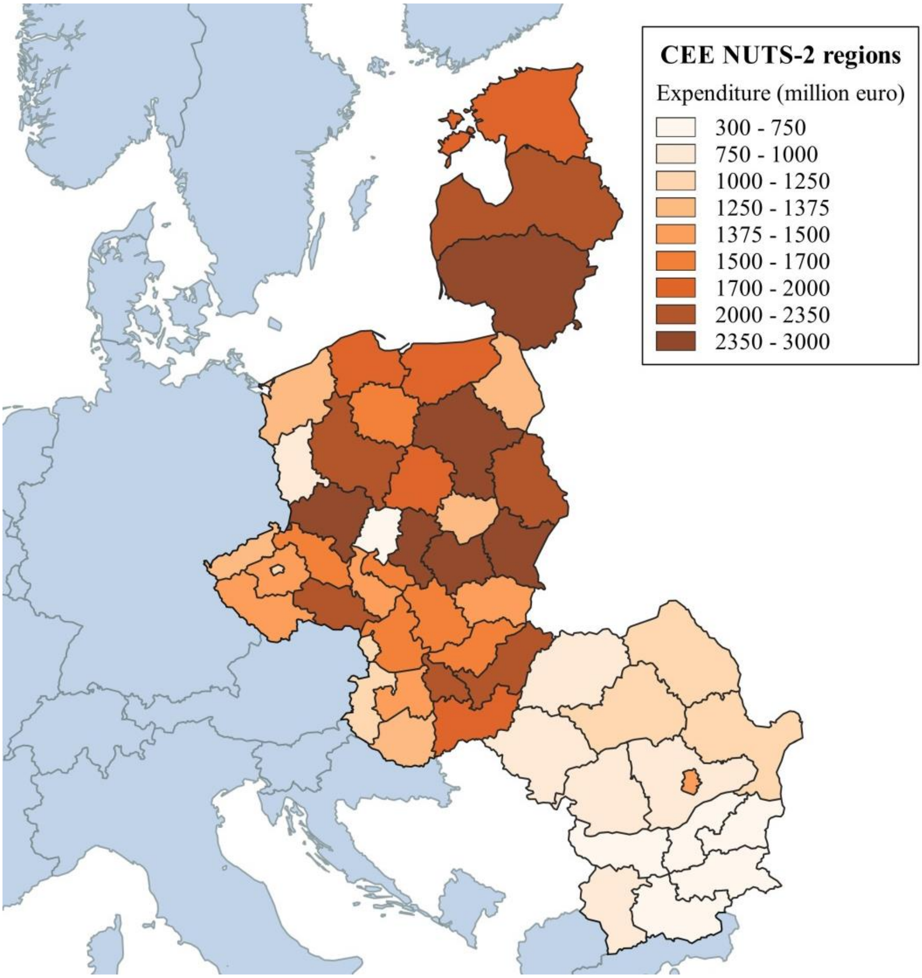
	BG	CZ	EE	HU	LT	LV	PL	RO	SK
Aggregate Jobs (fte)	23039	132770	52237	427451	29530	12002	385241	126619	23242
Research Jobs (fte)	1190	14387	NA	16529	3441	984	18660	4764	234
Research and Tech. Development Projects	566	5409	5140	50028	3057	579	5783	2028	1875
Firm-Research Institution Cooperation Projects	119	989	NA	2293	113	164	4367	165	1051
Direct Investment Aid Projects to SMEs	NA	18856	NA	151739	5540	456	53651	10272	6611

Source: European Commission (2018).

[1] For the 2012-2020 planning period, 94.1 percent of the total ERDF supports are related with these themes (European Commission, 2018).

Becoming eligible[2] for funding since accession, CEE regions have resorted ERDF projects particularly for SMEs and capacity building in R&D activities. Figure 1 shows total expenditures from the ERDF 2007-2013 planning budget by NUTS-2 regions in the CEE area. Due to late accession to the EU, the regions of Romania and Bulgaria have lower expenditure levels compared to 2004 enlargement regions.

Figure 1. ERDF expenditure by NUTS-2 regions, 2007-2013 total



Source: European Commission (2018).

[2] ERDF, Cohesion Fund and European Social Fund are aimed at less developed countries according to European Commission legislation (European Commission, 2018).

CEE regions' position in innovative activities among other European regions separates negatively. According to Regional Innovation Scoreboard, which reports on regional innovation performance by using an index of indicators, CEE regions are classified as „lagging behind" compared to the EU average (European Commission, 2017). The regions are either modest (below 50%) or moderate innovators (between 50% and 90%), meaning that they have scores below the average of all EU NUTS-2 regions. Only Prague and Bratislava are strong innovators (99% and 104%, respectively). Although to some extent similar, CEE regions fall well behind the EU average on patent applications to the EPO. In order to reduce the absolute gap and sustain convergence, CEE regions need to increase R&D capacities and innovative outputs.

Considering the relation with the Cohesion Policy rationale of competitive regions and the impact on income generation, knowledge production itself has become one of the areas to be studied (O'Huallachain and Leslie, 2007). In view of that, we consider specifically the performance of regional knowledge production in CEE regions with reference to changes in TFP.

2. Literature review

Knowledge production in the form of a functional relationship between R&D inputs and patent output is first defined and discussed by Griliches (1979). In the context of measuring the effect of TFP on economic growth and cross-country differences in income, Griliches highlighted issues related with the measurement of R&D capital and problems with aggregated, i.e. industry level, data. TFP is viewed as the source of long run economic growth and is explained in the context of the "knowledge economy" framework (Romer, 1986; Comin, 2017). This framework takes the effect of TFP on gross domestic output as endogenous by linking the increases in economy-wide TFP to innovation and knowledge production. In essence, TFP measures variations in returns to factors, i.e. labour and capital, used in production in a particular industry. As related with knowledge production in CEE regions, four main research objectives emerge in the literature.

Some studies assess the performance of CEE regions from the perspective of regional innovation systems. With the rise of systems of innovation perspective, growing numbers of studies have adopted regions as a unit of analysis to investigate knowledge production in regions (Buesa *et al*., 2006; Vogel, 2015). This approach relies on the fact that innovative firms are spatially concentrated within specific regions and benefit from knowledge spillovers in those regions. The network of research institutions, universities, and other local dynamics determine the success of regions and hence, the productivity of knowledge production. Fritsch and Slavtchev (2011), for instance, in their analysis of European regional innovation systems, find that the efficiencies of regions are closely related with agglomeration of specific industries as well as the spillovers from the university-private sector collaborations.

The second area in the literature focuses on the convergence issue. It is noticeable that existing disparities in terms of income and regional competitiveness within EU-15 has surged with the accession of the CEE countries (Hadjimichalis and Hudson, 2014; Rosati, 2004). The CEE regions' performance is analyzed for deciding absolute and conditional convergence. As an example of such studies, Archibugi and Filippetti (2011) evaluate the impact of the 2008 crisis on innovative performance and convergence in the EU. The study shows that R&D investments are affected mostly in the developing part of the EU. Although innovative outputs were converging in the years 2004-2008, the crisis reversed the situation.

The examination of the impacts and effectiveness of EU regional policies is the third area of research on CEE regions. In this field, support programs and policy implications constitute the focal point of various studies. As an example of this kind, Radosevic (2002) points out the need for a regional policy design for CEE regions that target network organizers and collaboration. By reviewing pre-accession aid programs which target social capital and locally bounded industries, the study asserts the ineffectiveness of support policy and proposes an alternative.

The fourth and last field of research is regional knowledge production itself. Several studies point out the "path dependent" nature of knowledge production (Fritsch, 2002, p. 90; Rodriguez-Pose and Crescenzi, 2008). Taking into account the loss of knowledge production capacity in the mid-1990s and the ongoing efforts to restore and boost productivity in the last three decades, this characteristic is more apparent in CEE regions. Due to a paradigmatic transformation from planned economy to market orientation, it is not a straightforward task to sustain technological change continuously by a private sector-led economic system. Old cultural institutions, which were once effective in innovative production in CEE regions, are not changing at the same rate as policiesdo. Kravtsova and Radosevic (2012), in their country-level study of R&D productivity in Eastern Europe, compare knowledge production with reference to the socialist era and a control group of countries. They highlight the differences in several sectors and the degree of technology generation in knowledge production. The study provides evidence that Eastern European countries produce lower levels of innovation outputs relative to human capital employment in R&D sector. The low level of productivity in knowledge output generation is thought to be related to the weak absorptive capacity of these countries.

Capacity problems sourcing from a low private sector engagement in R&D activities and a low initial level of knowledge production in CEE regions were noticeable before the enlargement. Related to this fact, the innovation support regime in these regions has been criticized for being linear and paying little attention to the demand-side factors of knowledge production (Suurna and Kattel, 2010; Rodriguez-Pose and Wilkie, 2017). According to Crescenzi and Rodriguez-Pose (2011), Cohesion Policy has encouraged R&D investments in regions where region-specific institutions were not yet organized. The result has been inefficient factor employment for firms and for the regions. In the literature, this situation is called "innovation paradox" (Oughton *et al*., 2002; Muscio *et al.*, 2015). Dachin and Postoiu (2015) exemplify the state of innovation paradox in Romanian NUTS-3 regions. Although developed regions of Romania possess a large pool of trained human capital and invest heavily in R&D, regional knowledge productivity is still far from the European average.

The reasons that lead to low absorptive capacity in CEE regions are examined by a number of studies. Capello and Lenzi (2015) review innovation modes across European regions with scientific and non-scientific bases of R&D activity. Their findings show that EU-12 regions[3] benefit mostly from a non-scientific base of knowledge production. Hence, investments in scientific knowledge base and related factor endowments do not yield productive results compared to the regions with higher scientific knowledge capability. They propose that R&D support policies should match the region-specific themes and regional modes of innovation. A similar study by Varga *et al*. (2014) measures R&D productivity for 189 EU regions including the CEE area. They show that two types of knowledge production are statistically significant in the regions, i.e. the Edison-type with clear economic benefits and the "pre-competitive" Pasteur-type with scientific base (Varga *et al*., 2014, p. 233). Their analysis shows that the Pasteur-type knowledge production productivity is spread unevenly vis-a-vis the Edison-type. Only some capital regions in the CEE area have comparable Edison-type knowledge productivity due to agglomeration of industrial production in these regions. For the rest of CEE regions, both types of knowledge productivity are below the average.

Considering the literature on knowledge production performance of CEE regions, some points step forward. To begin with, very few papers focus exclusively on CEE regions. A great amount draws conclusions from the similarities/dissimilarities framework with the other EU regions. Such line of reasoning produces relative conjunctures and fails to grasp the specificity of CEE regions. Although some admit the fallacy of "one size fits all" approach (Tödtling and Trippl, 2005), their policy propositions are far away from practicality. Another point is the so called innovation paradox and its relevance to CEE regions. The paradox, whether directly or not, is highlighted by the majority of studies. The key division between these studies is the interpretation of outcomes from monetary investments in R&D activities. By using countable patent numbers and related indicators, this kind of studies can only provide a partial explanation. Long-term and infrastructural effects can go unnoticed. Consequently, when commenting on the impacts of support policy towards CEE regions, analyses of short-term input-output relationship will lead to a myopic perspective on the innovation paradox.

[3] These are the regions of enlargement countries Bulgaria, Cyprus, Czech Republic, Hungary, Estonia, Latvia, Lithuania, Malta, Poland, Romania, Slovakia and Slovenia.

3. Methodology and data

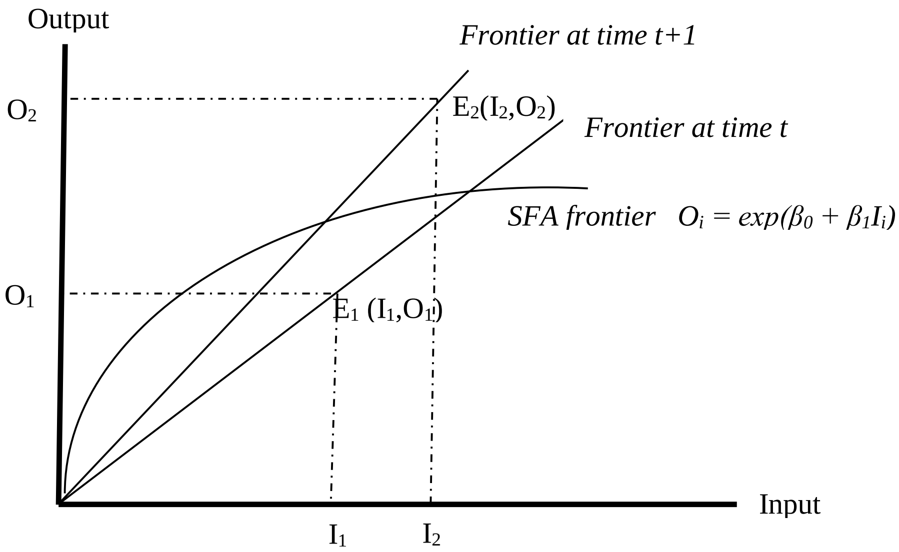
3.1. Methodology

One of the commonly used criteria for measuring the production performance of a group of units (firm, industry, region or country) is based on comparing their efficiencies and productivities. Although partial and static examination yields a relative understanding, the analysis of changes in TFP over time gives information about unit performances on issues like competitive power, technological advancement, decision-making and policy-making. In order to assess knowledge production TFP performance of CEE regions, we employed Malmquist index method with classical inputs (human capital and R&D expenditures) defined by Griliches (1979). The method stands out among other methods for measuring TFP with its comparative advantages in data needs and assumptions behind. One should keep in mind that TFP performance does not necessarily show relative significance of the regions in knowledge production but the use of resources.

The measurement of TFP change has been a much-debated concern especially in economic growth literature. Two main methods of TFP measurement have been growth-accounting and indexing approaches (Carlaw and Lipsey, 2003). While the growth-accounting method requires an *a priori* determined production function about the input-output relationship, the indexing method requires a functional association in the construction of input and output indexes like the Laspeyr' and Paasche. When dealing with more than one output as it is in economy-wide TFP measurement, the aggregation of inputs and outputs into a scalar becomes challenging in these two methods. Moreover, both assume the production function to be identical across units and stable over time, which is a highly challenging assumption.

Alternative to these two methods is the frontier approach developed with reference to the Swedish statistician Sten Malmquist's distance functions (Caves *et al.*, 1982). The idea behind this approach is the representation of input and output points on a coordinate space and the calculation or estimation of distances to a specific frontier (see Figure 2). The frontier approach has two versions depending on the determination of frontier. Parametric and non-parametric methods use econometric regression and data envelopment analysis (DEA) techniques, respectively. The parametric method, known as stochastic frontier analysis (SFA), is based on the estimation of the frontier production function with maximum likelihood and other estimators and has assumptions about the distribution of error (inefficiency) terms (Battese and Coelli, 1995). Since SFA is based on an econometric estimation, one can perform tests of hypothesis based on economic theory.

Figure 2. Malmquist DEA frontiers and stochastic production frontier



Source: developed from Lien *et al*. (2007).

On the other hand, the non-parametric method is developed by Charnes *et al*. (1978) and it is easier to apply. In contrast to SFA, no functional form is needed and no diagnostics checking is required[4]. The non-parametric Malmquist method employs distance calculations via the linear programming (LP) technique of DEA. Production frontier is determined by the most efficient unit (points E_1 and E_2 in figure 2) so that all the other units lie below the frontier. The units' efficiency is calculated as distances to the frontier.

Decision making units in Malmquist DEA method have to be equivalent to firms, regions or countries so that a meaningful evaluation can be conducted (Charnes *et al*., 1978). When comparing units in multiple periods, the analysis of changes in TFP and its components serves as a benchmark. By definition, TFP changes can be sourced from efficiency changes and/or technological change (Coelli, 1996). Malmquist DEA method has the ability to decompose TFP change into (technical) „efficiency change" and „technological change". While efficiency change provides an idea about the "catching-up" effect, technological change is identified as a technological expansion of the production capacity (Bjurek, 1996, p. 303). Efficiency change shows an efficient use of inputs to achieve higher levels of output with a given year's technology. Technological change, on the other side, is

[4] Interested readers are recommended to refer to Kalirajan and Shand (1999) for a discussion of the main efficiency measurement methods in a comparative and non-mathematical style.

revealed with the expansion of the production frontier (the rotation of the frontier from *t* to *t+1* in figure 2).

The Malmquist TFP index is calculated by the following equation:

$$m_0(i_{t+1}, o_{t+1}, i_t, o_t | \, CS) = \left[\frac{d_0^t(i_{t+1}, \ o_{t+1})}{d_0^t(i_t, \ o_t)} \cdot \frac{d_0^{t+1}(i_{t+1}, \ o_{t+1})}{d_0^{t+1}(i_t, \ o_t)}\right]^{1/2}$$

Respectively, *i* and *o* represent input and output vectors where inputs and outputs can be more than one. The TFP index is calculated by solving the distance functions (d_0^t and d_0^{t+1}) for two consecutive period technologies. The first term in the brackets gives efficiency change and the other gives technological change from period *t* to *t+1* for units. The LP solution can be conducted either input-based or output-based. Cullinane *et al.* (2005) and Foddi and Usai (2013) clarify the distinction according to the production objective of the units and time horizon. The input-based solution is thought to be fitting to short-term goals and units aiming operational efficiency within certain financial and human capital limitations. The output-based solution, in contrast, is more appropriate to units with long-term objectives and output maximization[5].

For our purposes, we adopted the output-based Malmquist TFP index method. The choice of the output-based version relies on the nature of regional knowledge production. EU policy-makers and local authorities perceive regional knowledge output to be maximized, invest in human capital and in the innovative private sector. Considering the intense determination of R&D capacity enhancement of EU policy in CEE regions, our analysis is focused on medium to long term TFP changes in regional knowledge production. Comprising both pre-accession and accession to the EU periods, the results will show a comparative performance evaluation in knowledge production.

3.2. Data

Contrary to some recent studies, we addressed CEE regions separately from the EU sample (Ezcurra *et al.,* 2009; Foddi and Usai, 2013). Considering historical coverage and the official definition of CEE countries by OECD, we included 52 NUTS-2 regions from 2004 and 2007 enlargement countries[6]. We excluded Albania and Croatia due to missing data. The 7th Cohesion Policy Report classifies seven out of nine countries in our study as less developed (GDP per capita below 75% of EU average) and two as moderately developed (between 75-90% of EU average) (EC,

[5] Technically, input and output based Malmquist TFP indexes give identical values for TFP change. The difference arises from the fractions of EC and TECHC (Fare *et al.*, 1994).

[6] Included countries are Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania and Slovakia. See Annex 1 for the list of regions.

2017). Although, within the sample, disparities in these 52 regions exist, CEE regions generally go through similar developmental processes and have a common background. This situation makes CEE regions as a whole comparable for our purpose.

The main source of data used in this study is the *Regional Statistics* section of Eurostat Database. We employed several science and technology statistics by NUTS-2 classification for the 2001-2012 period. Input variables are constructed in accordance with standard Solow-type capital and labour inputs. For the output variable, patent applications are preferred to patent registration number considering the time lag problem in the latter. Since patent applications can end in up to five years, the year in which R&D expenditure and human capital employment was realized will differ from patent registration.

Table 2. Variable definitions and summary statistics

variable	Definition	mean	st. dev.	min.	max.
human capital	R&D personnel and researches; all sectors; full-time equivalent	4567.58	5299.67	190	27483
R&D expenditure	All sectors; euro per inhabitant	59.40	95.22	1.8	790.6
patent application	Application to EPO; per million inhabitants	6.94	8.11	0.018	49.03

Source: own calculations.

Table 2 shows a description and summary statistics for the variables. Some regions from Romania and Bulgaria have very low levels of both patent applications and inputs. Regions from Central Europe like Prague, Eesti, Severovychod, Közep-Magyarorszag and Bratislavsky Kraj hold upper positions, on the other hand. In order to avoid heavy reliance on data accuracy, we used a three-year means instead of yearly values (i.e. 2001-03, 2004-06, 2007-09, 2010-12). By this, we also partitioned the 2001-2012 period into sub-periods in accordance with macro changes like EU accession and the crisis. The 2001-03 sub-period constitutes the base term for a general performance comparison, as being the pre-accession phase for all regions in the sample.

4. Empirical results

The measurement of knowledge production productivity for the regions is calculated by using the DEAP program developed by Coelli (1996). The program provides yearly values for efficiency change, technological change and TFP change for each region. It also decomposes efficiency change into „pure efficiency" and „scale efficiency" (See Annex 1). In section 4.1., we will evaluate the region means for the total period and leave out yearly performances. For the overall performance evaluation in section 4.2., we will elaborate on sub-period means for all regions.

4.1. Regional performances

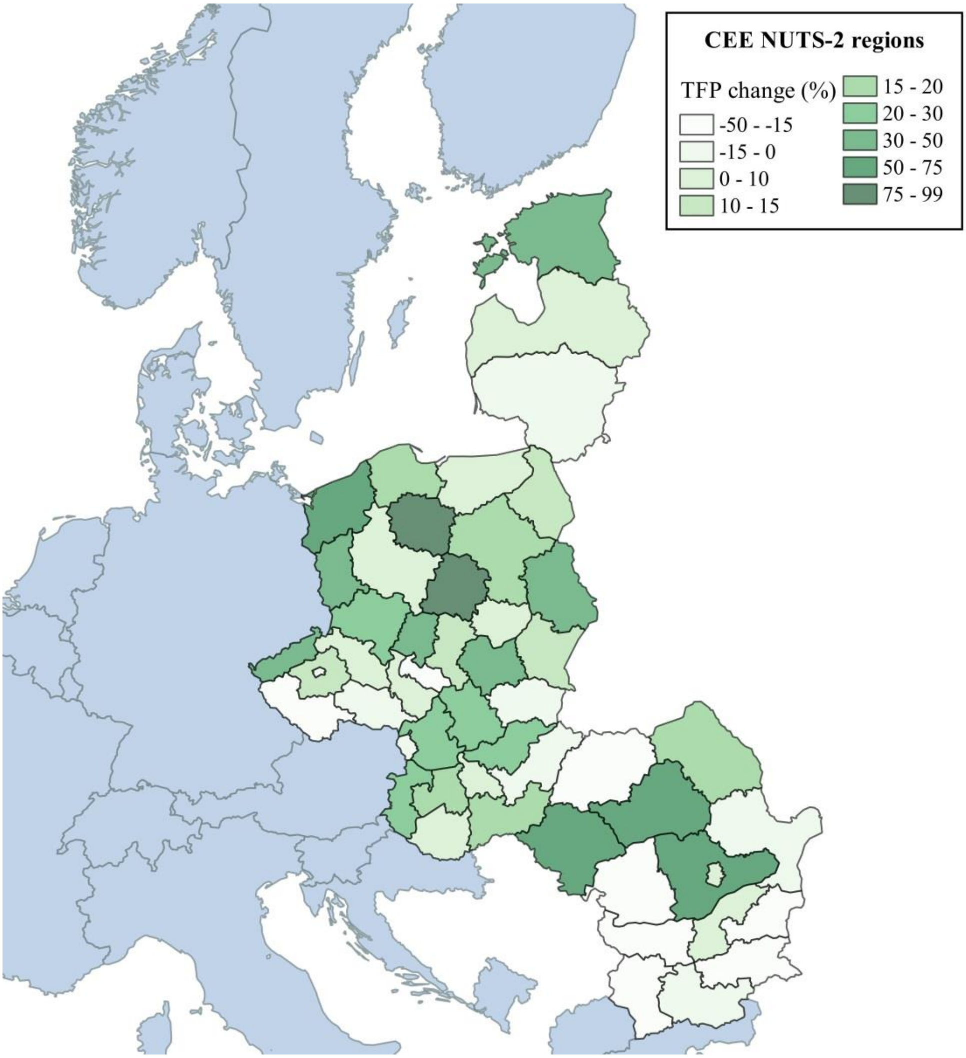
The Malmquist TFP index results for the regions are shown in Annex 1. The source of increase in TFP in these regions varies according to gains from efficiency change and/or technological change. During the 2001-2012 period, all regions have experienced positive technological change and increased their knowledge production by exploiting capacity returns. R&D investments and knowledge output increased simultaneously in all CEE area. This finding is represented by frontier expansion in the Malmquist framework. Nevertheless, positive efficiency change was limited to 10 regions (see Annex 1). Regions possessing efficiency gains and hence, „catching-up" effect, are Lodzkie (PL11), Malopolskie (PL21), Lubelskie (PL31), Z. Pomorskie (PL42), K. Pomorskie (PL61), Centru (RO12), Sud-Montenia (RO31) and Vest (RO42). Excluding PL11 and PL21, these regions benefit from a low initial-level of knowledge production and enjoy increasing returns to scale through capacity expansion during the period.

For the rest of the regions, the decrease in technical efficiency indicates that the regions' decision-making performance on R&D investments and/or scale choices are not optimizing. Others compensate efficiency losses by capacity (frontier) expansion (higher levels of knowledge output while still inefficient input use in 42 regions). In brief, even though R&D investments increased, patent output did not accompany them proportionally in 80 percent of the CEE regions (only 10 regions out of 52).

For these 42 regions that have efficiency losses while expanding production frontier, R&D expenditures can be considered as infrastructural investments. Taking into account the large amount of ERDF supports and incentives towards CEE regions, the period can be deemed as a capacity building phase. The period may not be long enough to allow these regions to gain efficiency.

With regard to TFP change, 36 regions (70% of the sample) experience a positive TFP change. Other 16 regions' TFP change is negative (see Figure 3). These regions' TFP losses are based on negative efficiency change. This means that some of the regions expand capacity but cannot reach a sufficient level of efficiency due to an ineffective input allocation. According to these results, regions that have diminishing TFP are faced with input misallocation and organization problems related to R&D investments. Henceforth, they need a large time horizon to solve these problems.

Figure 3. TFP Change in Regional Knowledge Production, 2001-2012



Source: own representation.

4.2. Overall performance

From 2001 to 2012, the overall TFP of knowledge production in CEE regions increased by 10.1 percent. As shown in Table 3, the main source of the TFP increase is found to be knowledge production capacity improvement (41.7%) in the regions due to technological development. Efficiency change was negative (-22.3%).

Although managerial inefficiency (pure efficiency) is tolerable at -7 percent, scale choices of R&D capacity expansion led to inefficient and disproportionate input use by -26.4 percent for the entire period.

Table 3. Overall Productivity Changes for CEE NUTS-2 Regions

Period	Efficiency Change	Technological Change	Pure Efficiency	Scale Efficiency	TFP Change
2004-2006	0.601	**2.067**	0.829	0.726	**1.243**
2007-2009	**1.235**	0.834	**1.197**	**1.032**	**1.031**
2010-2012	0.632	**1.648**	0.811	0.780	**1.042**
Mean	0.777	**1.417**	0.930	0.836	**1.101**

Source: own calculations.

With regard to sub-periods, the crisis years' period distinguishes itself from others by a positive efficiency change (23.5%) and a contraction of production capacity. Both human capital and R&D expenditures decreased by absolute terms. This can be seen as the decline in technological change by 16.6 percent. These two components in total result in a 3.1 percent increase in TFP in 2007-09 with respect to the previous sub-period. The impact of the crisis on CEE regions was a „forced" efficiency in terms of R&D management (19.7%) and scale optimization (3.2%). The negative impact of the crisis on the production capacity seems to be recovered during 2010-12 with a 64.8 percent technological change and, in consequence, 4.2 percent increase in TFP.

CEE regions experienced the highest knowledge production capacity expansion during the sub-period 2004-06 by 106.7 percent. These years correspond to the first three years of EU membership for seven countries in CEE and to the heyday of FDI flows towards developing countries.

Conclusions

Comprising the pre-accession and accession periods along with the 2008 crisis, our analysis on the performance of regional knowledge production in CEE countries indicates a definite capacity expansion in 52 regions during the 2001-2012 period. By using the Malmquist DEA Index methodology, we found that productivities of R&D expenditure and human capital as knowledge production inputs increased by 10.1 percent in the CEE area. TFP increases are mainly sourced from technological change induced expansion in patent production capacity. Except the crisis period, all regions experienced a capacity expansion with higher input uses and output levels. These findings confirm the existence of progress in CEE regions towards innovative capacity building rationale of the Cohesion Policy.

The efficiency of both financial and human resource uses did not follow the advances in capacity expansion in CEE regions. Our analysis detected efficiency gains in only 10 regions. Bearing in mind the low initial level of innovative activities in the CEE area and accessibility of EU funds, one can easily infer that the regions gave priority to capacity building rather than to efficiency achievements. The achievement of efficiency and the reversal of capacity expansion during the crisis period also confirm this finding.

Regional innovation capacity construction is one of the determinants of competitiveness. With the aim of achieving competitive regions and self-sustaining regional development within EU member countries after 2004 and 2007 enlargements throughout the CEE area, European Structural and Investment Fund supports have appeared to contribute to the process. Also, the findings of our analysis verify the innovation paradox for CEE regions. The failure of regions to accomplish efficiency gains show that the R&D input governance should follow a more targeted organization. This study is thought to constitute a comparison base for future studies on regional knowledge production in CEE countries. With a longer time dimension, the relationship between efficiency changes and fund types in R&D financing can provide a detailed analysis of inefficiency. Accordingly, partial effects of support policy can be outlined and policy advice can be drawn.

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Annexes

Annex 1 - Malmquist TFP index results for CEE regions (2001-2012)

No	**NUTS Code**	**NUTS Name**	**Eff. Change**	**Tech. Change**	**Pure Eff.**	**Scale Eff.**	**TFP Change**
1	BG31	Severozapaden	0.669	1.241	1.000	0.669	0.831
2	BG32	S. Tsentralen	0.861	1.241	1.000	0.861	**1.069**
3	BG33	Severoiztochen	0.625	1.241	0.635	0.985	0.776
4	BG34	Yugoiztochen	0.402	1.241	0.418	0.961	0.498
5	BG41	Yugozapaden	0.683	1.241	0.820	0.833	0.848
6	BG42	Y. Tsentralen	0.728	1.241	0.729	0.999	0.903
7	CZ01	Prague	0.620	1.585	1.010	0.613	0.982
8	CZ02	Strední Cechy	0.704	1.585	1.049	0.671	**1.115**
9	CZ03	Jihozápad	0.506	1.588	0.769	0.658	0.804
10	CZ04	Severozápad	0.832	1.583	0.824	1.010	**1.317**
11	CZ05	Severovýchod	0.626	1.601	1.000	0.626	**1.002**
12	CZ06	Jihovýchod	0.597	1.610	1.003	0.595	0.961
13	CZ07	Strední Morava	0.671	1.591	1.012	0.663	**1.067**
14	CZ08	Moravskoslezsko	0.492	1.583	0.735	0.669	0.779
15	EE00	Eesti	0.817	1.617	1.063	0.769	**1.321**
16	LV00	Latvija	0.778	1.327	0.922	0.844	**1.033**
17	LT00	Lietuva	0.804	1.241	0.965	0.833	0.997
18	HU10	K. Magyarország	0.691	1.478	1.000	0.691	**1.021**
19	HU21	Közép Dunántúl	0.735	1.586	0.958	0.767	**1.165**
20	HU22	Nyugat Dunántúl	0.762	1.588	0.923	0.826	**1.210**
21	HU23	Dél Dunántúl	0.655	1.605	0.784	0.835	**1.051**
22	HU31	É. Magyarország	0.752	1.623	0.856	0.879	**1.221**
23	HU32	Észak Alföld	0.546	1.611	0.705	0.774	0.879
24	HU33	Dél Alföld	0.716	1.614	0.965	0.742	**1.155**
25	PL11	Lódzkie	**1.305**	1.408	1.502	0.869	**1.838**
26	PL12	Mazowieckie	0.957	1.241	1.244	0.769	**1.187**
27	PL21	Malopolskie	**1.119**	1.281	1.345	0.832	**1.433**
28	PL22	Slaskie	0.911	1.241	1.033	0.883	**1.131**

29	PL31	Lubelskie	**1.031**	1.401	1.182	0.872	**1.445**
30	PL32	Podkarpackie	0.702	1.587	0.929	0.756	**1.115**
31	PL33	Swietokrzyskie	0.650	1.563	0.672	0.967	**1.016**
32	PL34	Podlaskie	0.753	1.470	0.830	0.907	**1.106**
33	PL41	Wielkopolskie	0.786	1.284	0.918	0.857	**1.010**
34	PL42	Z. Pomorskie	**1.230**	1.387	1.279	0.962	**1.707**
35	PL43	Lubuskie	1.000	1.462	1.000	1.000	**1.462**
36	PL51	Dolnoslaskie	0.978	1.249	1.120	0.873	**1.221**
37	PL52	Opolskie	0.969	1.523	0.947	1.024	**1.477**
38	PL61	K. Pomorskie	**1.575**	1.264	1.550	1.016	**1.991**
39	PL62	W. Mazurskie	0.646	1.594	0.700	0.923	**1.029**
40	PL63	Pomorskie	0.817	1.455	0.993	0.824	**1.190**
41	RO11	Nord-Vest	0.638	1.258	0.739	0.863	0.803
42	RO12	Centru	**1.369**	1.241	1.323	1.035	**1.699**
43	RO21	Nord-Est	0.937	1.241	0.918	1.021	**1.163**
44	RO22	Sud-Est	0.702	1.241	0.756	0.927	0.870
45	RO31	Sud - Muntenia	**1.354**	1.241	1.330	1.018	**1.679**
46	RO32	Bucuresti - Ilfov	0.806	1.354	1.037	0.777	**1.091**
47	RO41	Sud-Vest Oltenia	0.574	1.241	0.584	0.983	0.712
48	RO42	Vest	**1.170**	1.331	1.181	0.990	**1.556**
49	SK01	Bratislavský Kraj	0.579	1.603	0.896	0.646	0.928
50	SK02	Z.Slovensko	0.800	1.516	0.920	0.870	**1.213**
51	SK03	S. Slovensko	0.786	1.545	0.899	0.874	**1.214**
52	SK04	V. Slovensko	0.629	1.414	0.744	0.845	0.889