Central European Review of Economic Issues
EKONOMICKÁ REVUE

Malmquist index approach to efficiency analysis in selected old and new EU Member States

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Abstract

The paper deals with an application of data envelopment analysis (DEA) to the performance evaluation of NUTS 2 regions in the four Visegrad countries in comparison with selected advanced European Union (EU) Member States – Austria and Germany – in the reference period 2000–2014. The main aim of the paper is to measure the efficiency changes over the reference period and to analyse the level of productivity in individual NUTS 2 regions based on the Malmquist Productivity Index (MPI). DEA is applied to assess how efficiently NUTS 2 regions use their inputs for output production. The analysis produces a ranking of the performance development of individual NUTS 2 regions through the MPI to assess the relative importance of productivity's main components. The main purpose of this approach is to evaluate the numerical grades of efficiency of the economic processes within the evaluated NUTS 2 regions. Therefore, the efficiency of a region can be considered as a 'mirror' of regional competitiveness. The theoretical part of the paper is devoted to the fundamental basis of performance theory and the methodology of the MPI. The empirical part is aimed at measuring the degree of productivity and the level of efficiency changes of the evaluated NUTS 2 regions by measuring the change in technical efficiency and the movement of the production possibility frontier using the MPI. The final part of the paper offers a comprehensive comparison of the results obtained by calculating the MPI.

Keywords

Competitive potential, efficiency, input, OO MPI CCR CRS model, output.

JEL Classification: C67, O18, R11, R58

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This paper was created under the SGS project (SP2013/45) of the Faculty of Economics, VŠB-Technical University of Ostrava, and the Operational Programme Education for Competitiveness – Project CZ.1.07/2.3.00/20.0296.

ER-CEREI, Volume 19: 87–104 (2016).
ISSN 1212-3951 (Print), 1805-9481 (Online)
doi: 10.7327/cerei.2016.09.02

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1. Introduction

Over the past half century, the European Union (EU) has been successful in securing high and rising living standards for its citizens. However, it is currently facing critical economic and social challenges. Despite past success, the financial and economic crisis of the last five years has led several European economies and the EU itself to one experiencing one of its most difficult moments in the post-Second World War period. The EU is going through one of the most difficult periods since its establishment, with multiple challenges facing the region's policy makers. Recent years have seen a myriad of economic and social difficulties, specifically stagnating economic growth, rising unemployment leading to social tensions, continuing financial troubles and sovereign debt crises in several European countries, exacerbated by the fact that the future outlook remains uncertain. There is widespread agreement that the root causes of this prolonged crisis lie in the lack of competitiveness of many countries (WEF, 2013).

In the EU the process of achieving an increasing trend of performance and a higher level of competitiveness is made especially difficult by the *heterogeneity of the countries and regions in many areas*. Although the EU is one of the most developed parts of the world, with high living standards, significant *economic, social and territorial disparities exist, exerting a negative impact on the balanced development* across Member States and their regions and thus weakening the EU's performance in the global context. The history of the European integration process in the past five decades was and is thus guided by two different objectives: *to foster economic competitiveness* and *to reduce differences* (Molle, 2007). The support of cohesion and balanced development, together with an increasing level of EU competitiveness, thus belongs to the EU's temporary *key development objectives*. In relation to competitiveness, performance and efficiency are *complementary objectives*, which determine the long-term development of countries and regions. The measurement, analysis and evaluation of productivity changes, efficiency and level of competitiveness are controversial topics that attract great interest among researchers (see e.g. Camanho and Dyson, 2006; Khan and Soverall, 2007).

The motivation of this paper is based on the mutual relationship between the two significant themes of efficiency and competitiveness in the context of national economies. The *main aim of the paper* is to measure the regional efficiency changes over the reference period 2000–2014 and to analyse the level of efficiency within the group of the Visegrad Four (V4) in comparison with Austria and Germany based on the Malmquist Productivity Index (MPI). The performance analysis is used for evaluating NUTS 2 regions' development quality and potential (with respect to their factor endowment). The application of the data envelopment analysis (DEA) method is based on the assumption that the *efficiency* of regions calculated by the DEA method can be seen as the *source of regional competitiveness (competitive potential)* (see e.g. Staníčková and Melecký, 2012, 2013). Studies on cross-country and knowledge-based economy (KBE) performance assessment that employ the DEA method are listed in Table 1.

It is natural that nations in the Central European region should compete, but it is nonetheless crucial that they understand that together they have an appeal for foreign investors who are looking at the whole region when picking their new homes. The Visegrad region has had remarkable success in aligning and strengthening its economies to meet EU challenges and compete effectively with larger and more developed countries, both regionally and internationally; the intensification of regional cooperation, energy safety and competitiveness on internal markets are all among the V4 countries' priorities (Balogová, 2008), but the V4 at present trails other advanced economies in creating a smart, highly productive economy. However, considerable variation in performance exists across the V4 countries, with some countries performing very well in all areas and others still lagging behind. The competitiveness divide lies at the heart of the competitiveness challenge and reflects the inability of countries to adapt to a rapidly changing globalized economy.

2. Framework of efficiency analysis

In recent years the topics of measuring and evaluating *competitiveness* and *efficiency* have enjoyed economic interest. Although there is *no uniform definition* and understanding of these terms, these multidimensional concepts remain among the basic standards of performance evaluation and are seen as a reflection of the success of an area in a wider comparison. Efficiency and competitiveness are thus *complementary objectives*, which determine the long-term performance development of an area.

Differences in productivity performance across countries are seen by governments as important policy targets. For a number of years, government objectives have been set not only in terms of improving national productivity performance against other countries but also in terms of creating conditions to allow less productive countries to reduce the 'gap' between themselves and the most productive ones.

At a time when EU Member States have to deal with increased pressures on public balances, stemming from demographic trends and globalization, the improvement of the efficiency and effectiveness of public spending features high on the political agenda. The current economic situation, determined by the effects of the crisis, is causing the governments of countries worldwide to streamline their processes in terms of collecting revenue from the state budget and then redistributing it on the principle of performance and economic efficiency. The comparative analysis of efficiency in the public sector is thus the *starting point for studying the role of efficiency*, effectiveness and performance regarding the economic governance of resource utilization by public management for achieving the medium/long-term objectives of economic recovery and sustainable development of national economies (Mihaiu et al., 2010). Increasing productivity is generally considered to be the only sustainable way of improving living standards in the long term. Statistical evidence to help policy makers to understand the routes to productivity growth, especially those that can be influenced by the government, can help to lead to better policy.

2.1 Relationship between the concepts of efficiency and effectiveness in the context of performance

Nowadays, when countries have to deal with increased pressures on public balances, stemming from demographic trends (higher spending levels on lifelong learning, pensions and long-term care) and globalization (adjustment costs, mobile taxpayers), it is even more important that public resources are used in

Table 1 DEA method in countries' macroeconomic and KBE studies

Authors	*Data sets*	*Inputs and outputs used in the DEA model*	*Key results*
Tan, Hooy, Islam and Manzoni (2008)	WDI-2001 data set for 54 developing countries	Inputs: R&D expenditure, labour productivity, average schooling Outputs: mobile phone users, internet users, PC penetration, hi-tech exports	India, Indonesia, Thailand and China are inefficient countries due to the outflow of human resources.
Christopoulos (2007)	Selected OECD and non-OECD countries	Inputs: human capital, openness Output: real GDP	Movements towards openness increase the efficiency performance of non-OECD countries.
Mohamad (2007)	Selected Asia-Pacific countries. Data sets collected in 1996, 2000 and 2003	Inputs: gov. expenditure as % of GDP Outputs: real GDP growth, real employment rate, inflation rate	Only seven of twenty-five selected countries are efficient.
Ramanathan (2006)	Selected Middle Eastern and North African countries, WDI-1999	Inputs and outputs: ratio of labour to population, life expectancy, primary education teachers, GNP per capita, literacy rate, mortality rate, etc.	Bahrain, Jordan, Kuwait and the UAE are the most efficient while Yemen is the least efficient country.
Hsu, Luo and Chao (2005)	WCY-2004	WCY-2004 pillars used as input and output variables for OECD and non-OECD countries	Indonesia and Argentina outperform in all the efficiency scores and Turkey, Poland and Mexico appear to have stable efficiencies. Twenty-nine countries are shown to be efficient.
Golany and Thore (1997)	Statistical department of 72 developed and developing countries, 1970–1985	Inputs: real investment as % of GDP, real government consumption as % of GDP, education expenditure as % of GDP Outputs: real GDP growth, infant mortality, enrolment ratio for secondary schools, welfare payments	Japan, the USA, Canada and the Asian tigers show increasing returns to scale (IRS); Scandinavian and very poor developing countries show decreasing returns to scale (DRS).

Source: Afzal and Lawrey (2012)

the most *efficient and effective way*. But what do these words mean and what is background of these concepts? *The analysis of efficiency and effectiveness concerns the relationships between inputs (entries), outputs (results) and outcomes (effects)*. In 1957 Farrell investigated the question of how to measure efficiency and highlighted its relevance for economic policy makers. *It is important to know how far a given industry can be expected to increase its output by simply increasing its efficiency, without absorbing further resources* (Farrell, 1957). Since that time the techniques to measure efficiency have improved and investigations of efficiency have become more frequent. Nevertheless, the measurement of the efficiency and effectiveness of countries' and respectively governments' activities and the public sector remains a conceptual challenge. Problems arise because public spending has multiple objectives and because public sector outputs are often not sold on the market, which implies that price data are not available and that the output cannot be quantified (Mandl et al., 2008).

Efficiency is a central issue in analyses of economic growth, the effects of fiscal policies, the pricing of capital assets, the level of investments, technology changes and production technology and other economic topics and indicators. Efficiency can be achieved under the conditions of maximizing the results of an action in relation to the resources used, and it is calculated by comparing the effects obtained in their efforts. In a competitive economy, therefore, the *issue of efficiency* and respectively dynamic efficiency can be resolved by comparing these economic issues (Staníčková and Skokan, 2013). Efficiency is provided by the relationship between the effects or outputs, such as those found in the literature review, and the efforts or inputs. The relationship is apparently simple, but practice often proves the contrary, because identifying and measuring inputs and outputs in the public sector is generally a difficult operation, as shown by Mihaiu et al. (2010) in Figure 1.

Figure 2 illustrates the conceptual framework of efficiency and effectiveness. *Efficiency is given by the ratio of inputs to outputs*, but there is a difference between *technical efficiency* and *allocative efficiency*. Technical efficiency implies a relation between inputs and outputs on the frontier production curve, but not every form of technical efficiency makes sense in economic terms, and this deficiency is captured through allocative efficiency, which requires a cost/benefit ratio. *Effectiveness*, in terms of this meaning, implies the *relationship between outputs and outcomes*. In this sense the distinction between the output and the outcome must be made. The outcome is often linked to

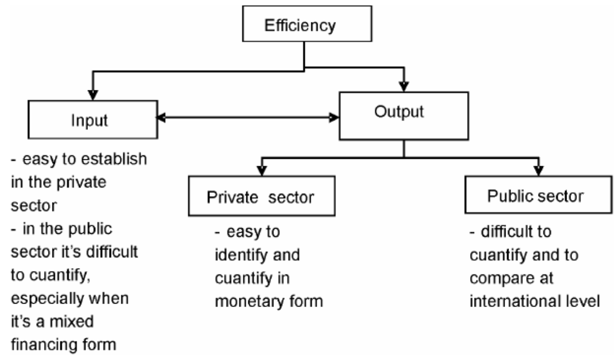

Figure 1 Determining the efficiency indicator
Source: Mihaiu et al. (2010)

welfare or growth objectives and therefore may be influenced by multiple factors (including outputs as well as exogenous 'environment' factors). Effectiveness is thus more difficult to assess than efficiency, since the outcome is influenced by political choice.

Peter Drucker (2001) believes that there is no efficiency without effectiveness, because it is more important to do well what you have proposed (the effectiveness) than to do well something else that was not necessarily a concern (Drucker, 2001). The relationship between efficiency and effectiveness is that of a part to the whole; effectiveness is a necessary condition for achieving efficiency. *This implies that efficiency and effectiveness are not always easy to isolate*.

2.2 Approaches to efficiency analysis

Productivity management is one of the major sources of sustainable organizational efficiency, and a systematic understanding of the factors that affect productivity is very important (Mohammadi and Ranaei, 2011). The measurement and analysis of productivity change is always a controversial topic and has enjoyed a great deal of interest among researchers and practitioners. Farrell had already investigated the question of how to measure efficiency and highlighted its relevance for economic policy makers in 1957. *It is important to know how far a given industry can be expected to increase its output by simply increasing its efficiency without absorbing further resources* (Farrell, 1957). Since that time the techniques to measure efficiency have improved and investigations of efficiency have become more frequent, particularly in industry. Nevertheless, the measurement of the efficiency of countries and regions and respectively their factors *remains a conceptual challenge*.

The primary problem in creating an effective evaluation system is establishing clear performance and efficiency standards and priorities at the beginning of

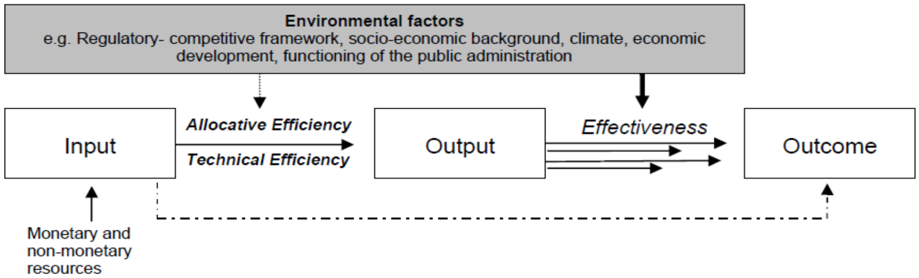

Figure 2 The relationship between efficiency and effectiveness
Source: Mandl et al. (2008)

the performance cycle. The early research work on this problem focused on separate measures of productivity, and there was a failure to combine the measurements of multiple inputs into any satisfactory measure of efficiency. These inadequate approaches included forming the average productivity for a single input (ignoring all the other inputs) and constructing an *efficiency index* in which a weighted average of the inputs is compared with the outputs. Responding to these inadequacies of separate indices of labour productivity, capital productivity and so on, Farrell (1957) proposed an activity analysis approach that could deal more adequately with the problem. His measures were intended to be applicable to any productive organization: in other words, *from a workshop to a whole economy* (Mohammadi and Ranaei, 2011). Farrell confined his numerical examples and discussion to single-output situations, although he was able to formulate a multiple-output case. Twenty years after *Farrell's model*, and building on those ideas, Charnes et al. (1978), responding to the need for satisfactory procedures to assess the relative efficiencies of multi-input/multi-output production units, introduced a powerful methodology that has been titled *data envelopment analysis* (DEA) (Zhu, 2012).

In the case of *international comparisons*, the quality of inputs and outputs and quality adjustment are among the most pressing challenges in measuring efficiency. Good-quality data are needed, because the available techniques to measure efficiency are sensitive to outliers and may be influenced by exogenous factors. Many studies assume that the quality of inputs and outputs is equivalent across countries. However, this does not match the reality. Therefore, quality adjustments should be made. Nevertheless, quality adjustment is still in its infancy and there are no ready-made solutions. If the quality of inputs and outputs is not properly taken into account when measuring efficiency, an underestimation of efficiency may result (Mandl et al., 2008).

Measuring performance implies taking into consideration the distinction between the means used (*inputs*), the process (*throughput*), the product (*output*) and the effect achieved (*outcome*). Performance assessment can be performed through some measurement categories (Mihaiu et al., 2010):

- *measuring the resource economy*, which can be determined by comparing the purchase price of the inputs with the designated value;
- *measuring the costs*, which involves measuring in monetary terms the resource consumption to provide a particular product or service;
- *measuring the efficiency*, which takes into account the obtained result in relation to the resources used, and a project is effective if the maximum results are achieved with a given level of resources or if it uses the minimum resources for a certain level of the result;
- *measuring the effectiveness*, which is quantified by the ratio of the actual result to its expected level. The process of measuring the effectiveness faces difficulties concerning the assessment and the quantification of the results, which often have a non-physical form and cannot be measured directly;
- *measuring the quality of services*, which is designed to follow the degree to which the public product/service satisfies the requirements of the citizens. In this sense the quality includes the effectiveness of a project. The concept of quality encompasses not only the quality of the product/service offered but also the quality of the production process and the quality of the system;
- *measuring the financial performance*;
- *measuring the overall performance*.

The measurement and evaluation of performance, efficiency and productivity are an important issue for at least *two reasons*. One is that, in a group of units in which only a limited number of candidates can be selected, the performance of each must be evaluated in a fair and consistent manner. The other is that, as time progresses, better performance is expected. Hence, the units with declining performance must be identified to make the necessary improvements (Greenaway et al., 2008). The performance of countries and regions can be evaluated in either a cross-sectional or a time-series manner, and DEA is a useful method for both types of efficiency evaluation (Mohammadi and Ranaei, 2011).

3. DEA method for efficiency measurement

The goal of the evaluation of the areas' operation is the correction, improvement and promotion of the performance. Nowadays, considering the increasing growth and importance of organizations in society and their presence in a competitive world, the evaluation of the performance of areas is subject to remarkable consideration, and various measures are proposed as a criterion for the evaluation of countries' performance. The evaluation and comparison of the performance of similar units is an important part of the management of a complex organization. Data envelopment analysis is one of the powerful management techniques that empowers researchers to estimate countries' performance in comparison with other competitors and make decisions for a better future (Hajiha and Ghilavi, 2012).

The measurement of the efficiency level of the evaluated countries is based on the procedure in Table 2. The EU makes an effort to restore the foundations of its competitiveness and economic performance through increasing its growth potential and its productivity. Based on the above facts, the performance analysis provided by the specialized DEA method – the Malmquist Productivity Index – can be used for evaluating national efficiency with respect to the national factor endowment.

Table 2 Scheme of efficiency measuring and evaluation

Pre-processing phase Collection of indicators » data analysis of indicators » groups of input/output indicators
DEA modelling Malmquist Productivity Index based on the OO CCR CRS model » efficiency evaluation

3.1 Background of the DEA method for measuring national efficiency and productivity

DEA was first proposed by *Charnes*, *Cooper* and *Rhodes* in 1978. Since then researchers in a number of fields have quickly recognized that it is an excellent and easy-to-use methodology for modelling operational processes for performance evaluations. This has been accompanied by other developments. Several researchers have employed the DEA method. DEA is based on the simple *Farrell model* (1957) for measuring the efficiency of units with one input and one output, which was initially expanded in 1978 by *Charnes*, *Cooper* and *Rhodes* (the CCR model) and later modified in 1984 by *Banker*, *Charnes* and *Cooper* (the BCC model). The DEA methods also include advanced additive models, such as the *Slack-Based Model* (SBM) introduced by *Tone* in 2002 and the *Free Disposal Hull* (FDH) and *Free Replicability Hull* (FRH) models, which were first formulated in 1984 by *Deprins*, *Simar* and *Tulkens*.

DEA is an approach for providing a relative efficiency assessment and evaluating the performance of a set of peer entities called decision-making units (DMUs), which convert multiple inputs into multiple outputs. DEA is thus a multi-criteria decision-making method for evaluating the efficiency and productivity of a homogeneous group (DMUs). The definition of a DMU is generic and flexible. DEA is convenient for determining the efficiency of DMUs that are mutually comparable – using the same inputs and producing the same outputs but with different performances. Determining whether a DMU is efficient from the observed data is equivalent to testing whether the DMU is on the *frontier of the production possibility set*. A DMU is efficient if the observed data correspond to testing whether the DMU is on the imaginary *production possibility frontier* (Cooper et al., 2011). All other DMUs are simply inefficient. The best-practice units are used as a reference for the evaluation of the other group units. The efficiency score of a DMU in the presence of multiple input and output factors is defined by the following equation (1) (Cook and Zhu, 2008):

$$Efficiency = \frac{weighted\_sum\_of\_outputs}{weighted\_sum\_of\_inputs}. \qquad (1)$$

In recent years the research effort has focused on the investigation of the causes and decomposition of productivity change. The *Malmquist Productivity Index* (MPI) has become the standard approach in productivity measurement over time within non-parametric research. The MI was introduced first by Caves et al. (1982). Färe et al. (1994) defined an input-oriented productivity index as the geometric mean of the two MIs developed by Caves et al. Although it was developed in a consumer context, the MI has recently enjoyed widespread use in the production context. It can be used to construct indexes of input, output or productivity as ratios of input or output distance functions. There are various methods for measuring distance functions, the most famous of which is the linear programming method. The MI allows the measurement of total productivity by means of distance–function calculation, which can be estimated by the solution of mathematical programming problems of the DEA kind.

There is a great variety of applications of DEA for evaluating the performances of many different kinds of entities engaged in many different activities. Because of the low assumption requirements, DEA has also opened up possibilities for use in cases that have been resistant to other approaches because of the complex (often unknown) nature of relations between multiple inputs and multiple outputs involved in DMUs. The *DEA method is a convenient method for comparing national efficiency as an assumption for the performance of territory*, because it evaluates not only one factor but a set of different factors that determine the degree of economic development. The DEA method used for our evaluation is based on a particular set of input and output indicators. The inputs and outputs form the key elements of the system evaluated for every country in the sense of their (in-)efficient economic position.

3.2 Basic characteristics of empirical analysis

The performance analysis, based on the application of the specialized DEA approach – *the Malmquist Productivity Index*, is used for evaluating the national development quality and potential (with respect to the national factor endowment). Based on the facts above, it is possible to determine the *initial hypothesis* of the analysis. The hypothesis is based on the assumption that the EU Member States and respectively their NUTS 2 regions that achieve the best results in efficiency (more advanced EU countries – Austria (AT) and Germany (DE)) are the regions that are best at converting inputs into outputs and therefore have greater performance and productive potential than the V4 NUTS 2 regions, that is, those in the Czech Republic (CZ), Hungary (HU), Poland (PL) and Slovakia (SK).

The analysis starts by building a database of indicators that are part of the *Regional Competitiveness Index* (RCI). The aim of the RCI approach is to develop a rigorous method to benchmark national competitiveness and to identify the key factors that drive the low competitiveness performance of some countries. The eleven pillars of the RCI may be grouped according to the different dimensions (*input versus output aspects*) of regional competitiveness that they describe. The terms *inputs* and *outputs* are meant to classify pillars into those that describe the driving forces of competitiveness, also in terms of long-term potentiality, and those that are direct or indirect outcomes of a competitive society and economy. From this point of view, the *Regional Competitiveness Index methodology is suitable and convenient for measuring national competitiveness using the DEA method* (Annoni and Kozovska, 2010). The indicators selected for the RCI framework are all of the quantitative type (hard data), and the preferred source was *the European Statistical Office* (Eurostat). Whenever information was unavailable or inappropriate at the required territorial level, other data sources were explored, such as the *World Bank*, *Eurobarometer*, *the Organisation for Economic Co-operation and Development* (OECD) and the *European Cluster Observatory*. In this paper the set of data files consists of *26 selected indicators* – 13 of which are inputs and 13 are outputs. The indicators are listed in Table 3.

The empirical analysis is based on a *frontier non-parametric approach* and aims to study productivity growth and performance. This is based on measuring the change in technical efficiency and the movement of the frontier in terms of individual countries (Färe et al., 1994) in the *reference period 2000–2014*. We analyse the total productivity changes that occurred across the reference years, that is, between 2000 and 2001, between 2001 and 2002 and so on to between 2013 and 2014.

For the calculation and evaluation of NUTS 2 regions' efficiency in the V4 countries in comparison with Austria and Germany, the advanced DEA approach of the *Malmquist Productivity Index* is used. Suppose that we have a production function in time period t as well as in period t + 1. The Malmquist Productivity Index calculation requires two single-period and two mixed-period measures. The two single-period measures can be obtained for example by using

Table 3 Indicators of inputs and outputs in the period 2000–2014 relevant to DEA modelling

Dimension: Indicators of inputs	*Dimension: Indicators of outputs*
1. Total Intramural R&D Expenditure, 2. Labour Productivity per Person Employed, 3. Gross Fixed Capital Formation, 4. Motorway Transport – Length of Motorways, 5. Railway Transport – Length of Tracks, 6. Hospital Beds, 7. Road Fatalities, 8. Total Public Expenditure on Education, 9. Participants in Education, 10. Collective Tourist Accommodation Establishments, 11. Tourism Intensity, 12. Crude Death Rate, 13. Victims of Road Accidents.	1. Gross Domestic Product, 2. Disposable Income, 3. Human Resources in Science and Technology, 4. Patent Applications to the European Patent Office, 5. Employment in Technology and Knowledge-Intensive Sectors, 6. Employment Rate (15 to 64 years), 7. Employment Rate (55 to 64 years), 8. Unemployment Rate (15 to 64 years), 9. Unemployment Rate of Young (15 to 24 years), 10. Long-Term Unemployment, 11. Compensation of Employees, 12. Venture Capital, 13. Gross Value Added in Sophisticated Sectors.

the *output-oriented CCR model with constant returns to scale* (CRS). For simplicity of the MPI calculation, we present basic DEA models based on the assumption of a single input and output.

Suppose that each DMU_j (j = 1, 2, … n) produces a vector of output $y_j^t = \left(y_{1j}^t, \ldots, y_{sj}^t\right)$ using a vector of inputs $x_j^t = \left(x_{1j}^t, \ldots, x_{mj}^t\right)$ in each time period t, t = 1, ... T. From time t to time t + 1, DMU_0's efficiency may change or (and) the frontier may shift. The MPI is calculated by (1) comparing x_0^t with the frontier at time t, that is, calculating $\theta_0^t\left(x_0^t, y_0^t\right)$ in the following input-oriented CCR CRS model equation (2) (Zhu, 2012):

$$\theta_0^t\left(x_0^t, y_0^t\right) = \min \theta_0, \tag{2}$$

subject to

$$\sum_{j=1}^{n} \lambda_j x_j^t \le \theta_0 x_0^t,$$

$$\sum_{j=1}^{n} \lambda_j y_j^t \ge y_0^t,$$

$$\lambda_j \ge 0,\ j = 1, \ldots, n.$$

$x_0^t = \left(x_{10}^t, \ldots, x_{m0}^t\right)$ and $y_0^t = \left(y_{10}^t, \ldots, y_{s0}^t\right)$ are input and output vectors of DMU_0 among others.

The MPI is further calculated via equation (3), comparing x_0^{t+1} with the frontier at time t + 1, that is, calculating $\theta_0^{t+1}\left(x_0^{t+1}, y_0^{t+1}\right)$ in the following input-oriented CCR CRS model equation (3) (Zhu, 2012) for $\lambda_j \ge 0,\ j = 1, \ldots, n$:

$$\theta_0^{t+1}\left(x_0^{t+1}, y_0^{t+1}\right) = \min \theta_0, \tag{3}$$

subject to

$$\sum_{j=1}^{n} \lambda_j x_j^{t+1} \le \theta_0 x_0^{t+1},$$

$$\sum_{j=1}^{n} \lambda_j y_j^{t+1} \ge y_0^{t+1}.$$

The MPI is further calculated by equation (4), comparing x_0^t with the frontier at time t + 1, that is, calculating $\theta_0^{t+1}\left(x_0^t, y_0^t\right)$ via the following linear programme equation (4) (Zhu, 2012) for $\lambda_j \ge 0,\ j = 1, \ldots, n$:

$$\theta_0^{t+1}\left(x_0^t, y_0^t\right) = \min \theta_0, \tag{4}$$

subject to

$$\sum_{j=1}^{n} \lambda_j x_j^{t+1} \le \theta_0 x_0^t,$$

$$\sum_{j=1}^{n} \lambda_j x_j^{t+1} \ge y_0^{t+1}.$$

The MPI is further calculated using equation (5), comparing x_0^{t+1} with the frontier at time t, that is, calculating $\theta_0^t\left(x_0^{t+1}, y_0^{t+1}\right)$ via the following linear programme equation (5) (Zhu, 2012) for $\lambda_j \ge 0$, $j = 1, \ldots, n$:

$$\theta_0^t\left(x_0^{t+1}, y_0^{t+1}\right) = \min \theta_0, \tag{5}$$

subject to

$$\sum_{j=1}^{n} \lambda_j x_j^t \le \theta_0 x_0^{t+1},$$

$$\sum_{j=1}^{n} \lambda_j x_j^t \ge y_0^{t+1}.$$

The MPI measuring the efficiency change in production units between successive periods t and t + 1 is formulated in the following equation (6):

$$M_0\ (x^{t+1}, y^{t+1}, x^t, y^t) = E_0 \cdot P_0 \tag{6}$$

where E_0 is the change in the relative efficiency of DMU_0 in relation to other units (i.e. due to the production possibility frontier) between time periods t and t + 1; P_0 describes the change in the production possibility frontier as a result of the technology development between time periods t and t + 1. The following modification of M_0 in equation (7) makes it possible to measure the change in technical efficiency and the movement of the frontier in terms of a specific DMU_0 (Zhu, 2012).

$$M_0 = \frac{\theta_0^t\left(x_0^t, y_0^t\right)}{\theta_0^{t+1}\left(x_0^{t+1}, y_0^{t+1}\right)}\left[\frac{\theta_0^{t+1}\left(x_0^{t+1}, y_0^{t+1}\right)}{\theta_0^t\left(x_0^{t+1}, y_0^{t+1}\right)} \cdot \frac{\theta_0^{t+1}\left(x_0^t, y_0^t\right)}{\theta_0^t\left(x_0^t, y_0^t\right)}\right]^{1/2}. \tag{7}$$

The first component E_0 on the right-hand side measures the magnitude of *technical efficiency change* (TEC) between time periods t and t + 1. Obviously, $E_0 = \frac{\theta_0^t\left(x_0^t, y_0^t\right)}{\theta_0^{t+1}\left(x_0^{t+1}, y_0^{t+1}\right)} < = > 1$, indicating that technical efficiency declines, remains or improves. The second term P_0 measures the shift in the possibility frontier, that is, the *technology frontier shift* (FS), between time periods t and $t+1$. The productivity improves if $P_0 > 1$, remains unchanged if $P_0 = 1$ and declines if $P_0 < 1$. In Table 4 the characteristics and trends of the MPI and efficiency change are shown.

Based on the facts, it is possible to determine the total productivity change in a successive period of time with the following equations (8) and (9):

Productivity change = Technical efficiency change · Technological changes, (8)

resp. MPI = TEC · FS. (9)

If a performance measure (input/output) is added to or deleted from consideration, it will influence the relative efficiencies. Empirically, when the number of performance measures is high in comparison with the number of DMUs, then most of the DMUs are evaluated as efficient. Hence, the obtained results are not reliable. There is a *rough rule of thumb* (Cooper et al., 2007) that expresses the relation between the number of DMUs and the number of performance measures as follows (10). Suppose that there are n DMUs, which consume m inputs to produce s outputs:

$$n \geq \max\{3(m+s), m \cdot s\}. \qquad (10)$$

Nevertheless, in some applications the numbers of performance measures and DMUs do not meet the mentioned formula (10). To tackle this issue, some performance measures should be selected in a manner that complies with (10) and imposes a progressive effect on the efficiency scores. These selected inputs and outputs are called selective measures. However, formula (10) needs more consideration. Toloo et al. checked more than 40 papers containing practical applications and found statistically that, in nearly all of the cases, the number of inputs and outputs does not exceed 6 (Toloo, 2012). A simple calculation shows that, when $m \leq 6$ and $s \leq 6$, then $3(m + s) \geq m \times s$. As a result, in this paper, instead of using (10), the following formula (11) is applied:

$$n \geq 3(m+s) \qquad (11)$$

In the case of this paper, the rule of thumb is met, because the number of DMUs is three times higher than the sum of input and outputs, that is, $83 \geq 3\ (13 + 13)$, $83 \geq 3\ (26)$, $83 \geq 78$.

For the solution of the *DEA method*, software tools for solving linear programming problems are used in the paper, for example Solver in MS Excel 2016, such as the *DEA Frontier*.

4. Application of the Malmquist Productivity Index to NUTS 2 regions' efficiency evaluation in the Visegrad Four countries in comparison with Austria and Germany

The initial hypothesis of efficiency being a mirror of competitive potential *is partly confirmed* through the analysis, as illustrated in the following Table 5 and Table 6. However, the results and hypotheses must be discussed with respect to the theory of economic growth. Why? Many European NUTS 2 regions have strong economies, are well integrated into international networks and are the locus of enterprises and labour forces that are globally competitive. However, not all regions make a strong contribution to competitive aims. How well are the EU's regions performing, and what makes a region competitive? Europe is a continent of special places – historic cities, coasts and cultural landscapes that are so familiar that it is easy to overlook their global significance (ESPON, 2006). Within the efficiency analysis of competitiveness, comparing the EU NUTS 2 regions of the Visegrad Four countries, Austria and Germany, recognition is made of the development in efficiency competitiveness, and the results provide evidence that territorial capital and potential for development are inherent in the regional diversity that is a major characteristic of Europe. In Table 5 (see the Annex), the results of the MPI are highlighted by the traffic light method. The range of colours of this method changes from light shadows of grey colour, through middle shadows of grey to dark grey. The regions with the highest and higher values of the MPI (based on catch-up and frontier shift) have a better level of efficiency and thus competitiveness is highlighted by the dark grey colour – the higher the value, the darker the shadow of grey. On the contrary, regions with the lowest and lower values of the MPI based on its two dimensions (catch-up and frontier shift) mean worse level of efficiency, whereby the levels of inefficiency are highlighted by light shadows of grey – the lower the value, the lighter the shadow of grey. Regions with values of the MPI and its dimension between groups of efficient (dark-grey shadows) and inefficient regions (light-grey shadows) are highlighted by middle shadows of grey. According to the use of the MPI in this paper, therefore, if it is equal to 1 it signifies no change in performance, if it is bigger than 1 it shows improving performance and in the case that it is less than 1 it signifies decreasing performance. In this context DEA provides further evidence of a dualistic (*centre vs. periphery*) pattern in the national economic activities, with the most efficient territories located in the most central or economically strategic areas of the continent. The application of the MPI shows that both the magnitude and the intrinsic features of the productivity dynamics are not so extremely differentiated across the evaluated countries. Again, we observe some differences between the core and the periphery of new and old EU countries, more specifically between the rich and industrialized regions that form the so-called *Old Europe/Old EU Member States* (Austria and Germany) and the relatively poorer

Table 4 Characteristics and trends of the Malmquist Productivity Index and efficiency change

Malmquist Productivity Index	*Productivity*	*TEC (Technical Change) FS (Frontier Shift)*	*Technical Efficiency Change Technology Efficiency Change*
> 1	Improving	< 1	Declining
= 1	Unchanging	= 1	Unchanging
< 1	Declining	> 1	Improving

ones that joined the EU in 2004, namely *New Europe/New EU Member States* (V4 countries).

Before discussing the efficiency analysis results, it is necessary to remember the important characteristics of the EU territory and its comparisons. It is possible to report increasing heterogeneity in the performance of regions across the whole EU. Consistent with the theory of economic growth and economic development, the overall results of regional competitiveness based on the EU Regional Competitiveness Index (RCI, see Annoni and Kozovska, 2010; Annoni and Dijsktra, 2013) confirm that the most competitive regions are those with the highest level of economic development (based on the stage of development). In the field of competitiveness, the best *EU top-ten* group includes Utrecht, the most competitive region in both editions of the RCI, the London area and the area including Oxford, the two Netherlands regions of Noord and Zuid Holland, which comprise Amsterdam, the Danish region Hovedstaden (including Copenhagen), Stockholm and Île de France (including Paris). The other entries in the top ten are the Frankfurt region (Darmstadt) and Surrey, East Sussex and West Sussex in the United Kingdom. It is striking that seven out of the top ten are either capital regions or regions including large cities. At the other end of the competitiveness scale, it is possible to find some regions that are unfortunately steadily the worst performers. These are the Bulgarian region Severozapaden, the Greek region Notio Aigaio and the two southern Romanian regions Sud-Est and Sud-Vest Oltenia. The RCIs show a more polycentric pattern with strong capital and metropolitan regions in many parts of the EU. Some capital regions are surrounded by similarly competitive regions, but in many countries the regions neighbouring the capital are less competitive. As this can also be observed in both the RCI editions, the RCIs show that, in the past three years (2010 to 2013 edition), no spillover effects helped to lift these lagging surrounding regions. The general economic and financial crisis certainly did not help. Thus, the substantial disparities within several countries also highlight the need for regional analysis and the limits of a purely national approach. The RCI 2010 and the RCI 2013 results underline that competitiveness has a strong regional dimension, which national-level analysis does not capture (Annoni and Dijsktra, 2013). For example, in some countries, like France, Spain, the United Kingdom, Slovakia, Romania, Sweden and Greece, the level of variability of the RCI scores is particularly high, with the capital region almost always being the best performer within the country. Italy is an exception, as Lombardy is the most competitive Italian region. These results demonstrate that territorial competitiveness in the EU has a strong regional dimension, which national-level analysis does not properly capture. The gap and variation in regional competitiveness should stimulate a debate regarding the extent to which these gaps are harmful to their national competitiveness and the extent to which the internal variation can be remediated.

Part of the explanation for the large inequalities within EU NUTS 2 regions may then relate to the differences in competitiveness. An economic entity in a region that has a low level of competitiveness may not have similar opportunities to an economic entity in a highly competitive region. This fact remains and is confirmed, but what does it mean for efficiency in competitiveness? In the case of the efficiency analysis of competitiveness and comparison analysis of change over time in 2000–2014, the results are just a little different. Why? The concept of competitiveness may then be important to evaluate not only why some regions grow faster than others but also why some regions have a better and more efficient distribution of competitiveness over time than others. Is a high level of competitiveness necessarily associated with a high level of efficiency and vice versa? It may not always be the case, because evaluated regions with a lower level of inputs were able to achieve competitiveness at the level of the RCI. The RCI value may not be high, and even in the less competitive regions it is not, but it is necessary to compare the values of inputs and outputs. Very important is also the fact that, with the given level of inputs, regions were able to achieve the level of outputs, although less at the end of the reference period than at the beginning; overall it is possible to state that the regions with the production of outputs based on inputs operate more efficiently at the end of the reference period than at the beginning and otherwise. These results are not surprising.

Finally, Table 6 shows the reordered regions, from best to worst, their MPI score and the corresponding rank (high ranks are associated with high MPI scores). This table also show the results of the average levels of the MPI's change across the reference years (arithmetic mean) and the continuous rank of regions based on the values of the average MPI change. According to the efficiency analysis and the results derived from the MPI solution, it emerges that the 2000–2014 efficiency ratio of 83 EU NUTS 2 regions for the comparison of the Visegrad Four countries, Austria and Germany ranges from 0.977 – eighty-third position (DE72 – Gießen) to 1.278 – first position (PL43 – Lubuskie). Of the 83 evaluated NUTS 2 regions, 39 recorded a positive trend in competitiveness efficiency and 44 achieved a negative trend in competitiveness efficiency in the comparison of 2000–2014. These results mean that one-half of all 83 regions made improvements in their competitiveness, that is, in the utilization of inputs for producing outputs. No NUTS 2 region recorded an unchanging trend in competitiveness efficiency. The differences in the MPI values are not so large in the case of efficient and inefficient regions. This is due to the fact that the evaluated groups can be considered as relatively balanced groups in the case of the Visegrad Four regions as well as in the case of Austria and Germany.

Based on the MPI results, it is clear that the best efficiency changes in competitiveness, comparing 2000–2014, were achieved by NUTS 2 regions belonging to the group of the Visegrad Four countries. This fact is not surprising, because it has the key political implications and there are several reasons/factors as follows:

- New EU Member States constantly fall into the category of less developed and competitive states based on the GDP per head in PPS – the reason for the inclusion of their NUTS 2 regions in the appropriate categorization stage of development;
- The belonging of each region to the relevant stage of development testifies to its competitive advantages and disadvantages and determines its weaknesses. The medium stage of development is associated with regional economies that are primarily driven by factors such as less skilled labour and basic infrastructures. Aspects related to good governance and the quality of public health are considered basic inputs in this framework. The intermediate stage of development is characterized by labour market efficiency, the quality of higher education and the market size, factors that contribute to more sophisticated regional economies and greater potential for competitiveness. In the high stage of development, factors related to innovation, business sophistication and technological readiness are necessary inputs for innovation-driven regional economies (Annoni and Dijkstra, 2013);
- The threshold defining the level of GDP as a percentage of the EU average was taken as a reference, as it is the criterion for identifying regions that are eligible for funding under the established criteria of the EU Regional Policy framework. European funds are an important tool for regional development and for reducing the economic, social and territorial disparities among European regions. Reducing disparities has a significant impact on competitiveness, and these two concepts are thus the EU's complementary objectives. Of the total budget allocated to regional policy, a substantial part is allocated just to NUTS 2 regions of EU12 countries, thus significantly supporting their development;
- New EU Member States are often significantly dependent on exports to old EU Member States and on the flow of money for this exchange shift.

Table 6 Average regional performance based on the MPI and the total rank and scores of the evaluated NUTS 2 regions

Rank	*DMU*	*MPI 2000–2014*	*Categories*	*NUTS 2 Region*
1	PL43	1.278	1.	Lubuskie
2	PL33	1.262		Świętokrzyskie
3	PL42	1.159	2.	Zachodniopomorskie
4	PL52	1.138		Opolskie
5	CZ04	1.114		Severozápad
6	PL62	1.111		Warmińsko-mazurskie
7	HU31	1.105		Észak-Magyarország
8	PL22	1.093	3.	Śląskie
9	HU22	1.092		Nyugat-Dunántúl
10	PL32	1.089		Podkarpackie
11	SK03	1.078		Stredné Slovensko
12	PL61	1.074		Kujawsko-pomorskie
13	CZ07	1.074		Střední Morava
14	HU21	1.073		Közép-Dunántúl
15	SK01	1.072		Bratislavský kraj
16	SK02	1.070		Západné Slovensko
17	HU33	1.069		Dél-Alföld
18	SK04	1.066		Východné Slovensko
19	PL41	1.066		Wielkopolskie
20	PL63	1.063		Pomorskie
21	CZ03	1.062		Jihozápad
22	PL51	1.059		Dolnośląskie
23	HU32	1.048		Észak-Alföld
24	AT34	1.046		Vorarlberg
25	HU23	1.046		Dél-Dunántúl
26	HU10	1.041		Közép-Magyarország
27	CZ08	1.040		Moravskoslezsko
28	DE50	1.040		Bremen
29	PL34	1.035		Podlaskie
30	CZ06	1.033		Jihovýchod
31	PL31	1.033		Lubelskie
32	CZ01	1.029		Praha
33	CZ05	1.028		Severovýchod
34	PL21	1.027		Małopolskie
35	PL11	1.016		Łódzkie
36	PL12	1.007		Mazowieckie
37	DEE0	1.006		Sachsen-Anhalt
38	DEB2	1.002		Trier
39	CZ02	1.001		Střední Čechy
40	DEA3	1.000	4.	Münster
41	DEC0	0.998		Saarland
42	AT12	0.998		Niederösterreich
43	DE25	0.997		Mittelfranken
44	DEA4	0.997		Detmold
45	DE30	0.996		Berlin

Rank	*DMU*	*MPI 2000–2014*	*Categories*	*NUTS 2 Region*
46	AT31	0.995		Oberösterreich
47	AT32	0.995		Salzburg
48	DE14	0.994		Tübingen
49	DE41	0.993		Brandenburg-Nordost
50	DE60	0.993		Hamburg
51	DE13	0.991		Freiburg
52	AT11	0.991		Burgenland
53	AT33	0.990		Tirol
54	DE26	0.989	5.	Unterfranken
55	DED2	0.989		Dresden
56	AT21	0.988		Kärnten
57	AT22	0.988		Steiermark
58	DED3	0.988		Leipzig
59	DE42	0.988		Brandenburg-Südwest
60	DEA5	0.987		Arnsberg
61	DE23	0.986		Oberpfalz
62	DEA2	0.985		Köln
63	DEF0	0.985		Schleswig-Holstein
64	DEG0	0.985		Thüringen
65	DE93	0.985		Lüneburg
66	DEB1	0.985		Koblenz
67	DE73	0.985		Kassel
68	DE80	0.985		Mecklenburg-Vorpommern
69	DE22	0.985		Niederbayern
70	DE94	0.985		Weser-Ems
71	DED1	0.985		Chemnitz
72	DEB3	0.983		Rheinhessen-Pfalz
73	DE21	0.983		Oberbayern
74	DE27	0.982		Schwaben
75	AT13	0.982		Wien
76	DE24	0.982		Oberfranken
77	DE71	0.981		Darmstadt
78	DE91	0.981		Braunschweig
79	DEA1	0.980		Düsseldorf
80	DE12	0.978	6.	Karlsruhe
81	DE11	0.977		Stuttgart
82	DE92	0.977		Hannover
83	DE72	0.977		Gießen

All these factors affect the convergence trend of new EU Member States and their regions to old EU Member States, and the growth in old EU Member States has an implicative impact on growth in new EU Member States. This growth may be of the same degree in the Visegrad Four countries as in Austria and Germany or rather greater and multiplied. Many of the differences in economic growth and quality of life within a region may be explained by the differences in competitiveness. Regions with more paved roads, better institutions, a better business environment and better human capital, for example, may experience faster economic growth and a clearer reduction in poverty levels (Charles and Zegarra, 2014). All these trends and facts are particularly significant for the competitiveness of all the EU Member States and their regions and the changes in their level and efficiency/inefficiency development. The gaps and variation in regional competitiveness should give rise to a debate on the extent to which these gaps are harmful to their national competitiveness and the extent to which the internal variation can be remediated (Dijsktra et al., 2011). The internal variation and heterogeneity also underline the inevitable steps needing to be taken at the national level. Policies oriented towards solving the main economic and social problems of their citizens may thus focus not only on the improvement of the aggregate or average indicators of competitiveness but also on the reduction of the regional differences in competitiveness. Just effective thematic policies and efficient use of public spending on the established aims will help the overall efficiency of the whole system and ensure the desired outcomes – effectiveness that has a significant impact on reducing the disparities and improving the competitiveness.

The MPI is decomposed into two components, one that measures changes in technical efficiency (i.e. whether regions are moving closer to the production frontier over time) and one that measures changes in technology (i.e. whether the production frontier is moving outwards over time). This decomposition is one of the main desirable features of frontier models, as it offers useful information to policy makers, who can thus analyse the results of past productivity-enhancing strategies and design better ones for the future (Foddi and Usai, 2013). Most importantly, this decomposition allows a focus on the differences between those countries that are rich and industrialized and form the so-called *Old Europe* (Austria and Germany) and those that are relatively poor and entered the EU quite recently (Visegrad Four countries). The illustration of Table 6 emphasizes that most of the NUTS 2 regions of the Visegrad Four countries are shown, based on the results, to have a low level of FS and a high level of EFCH. It means that efficiency change is the change in the relative efficiency of the evaluated region in relation to other regions, due to the production possibility frontier in the period 2000–2014, that is, technical efficiency change. This fact is not such positive information, because it means that regions extract their efficiency based on shifts in sources of competitiveness, that is, they make changes in the composition and quantity of sources based on exchanging business with other countries. The character of technical efficiency change thus contributes only to quantitative-based economic growth, which has its limits; this is disconcerting with reference to limited sources, utilization of sources and the possibility/impossibility of their recovery. The results for Austria and Germany, and respectively their

NUTS 2 regions, are more or less similar, but it is necessary to note that a significant number of their regions also result in parts of the MPI with a high level of FS and a high level of EFCH. This means that a significant part of efficiency change is caused especially by the change in the production possibility frontier as a result of the technology development in the period 2000–2014, that is, the technology frontier shift. This fact is positive information with respect to factors of competitiveness, as it signifies that regions are able to utilize their internal factor endowment effectively and are able to apply technological progress to boost their competitive advantages; specifically, they thus contribute to qualitative-based economic growth and provide the option to raise the steady state. Which factors (internal or external) have an impact on the steady state? Traditional factors, such as physical infrastructure and access to land, labour, materials, markets and capital, remain the basic determinants of competitiveness. However, the economy has changed, and so has regional policy. In the days when smoke-stack industries sat protected by national tariff barriers, regional policy was mainly about hard infrastructure – new factories and roads bestowed by governments and gifts from outside the region itself. Today the response involves upgrading the business environment through *soft infrastructure*. Less tangible assets need to be cultivated that enhance territorial capital and enable a region to realize its own potential (ESPON, 2006). The exact formula for efficiency development in competitiveness will depend on the particular region. For example, in less prosperous states and regions, gaps in health care can be a barrier to economic development. The promotion of social inclusion and sustainable communities may be particularly important in metropolitan regions. In addition, the urban environmental quality has become a more important factor. Some of these key *modern* drivers of competitive performance are now discussed.

5. Conclusion

Globalization makes international competitiveness a key concern in regional development. The European dimension is becoming essential for the effective development of smaller or larger NUTS 2 regions. The large geographic, demographic and cultural diversity of the EU is accompanied by differences in socio-economic position of the EU Member States and especially their regions. Different results in the economic performance and living standards of the population indicate the status of the competitiveness of every country and its regions. Each territory should know where its competitive advantages lie and try to strengthen its advantages and reduce its disadvantages, that is, the key factors of competitiveness. An understanding of the position of each region in comparison with others can thus highlight new potential for development. Key options have to be explored from a European perspective; understanding the larger territorial context makes it easier to spot new opportunities and under-used potentials (ESPON, 2006). Awareness raising, dialogue and involvement are vital parts of the process of empowering policy makers and practitioners at different levels, so they can exploit comparative advantages and add value through targeted territorial cooperation with other regions. By mobilizing the existing potential for growth in all regions, the cohesion policy can both improve the geographical balance of economic development and increase growth in Europe as a whole and thus support the level of competitiveness. All regions have their part to play, especially those where the potential for higher productivity and employment levels is greatest.

Based on the DEA method, the paper identifies a distinct gap between economic and social standards in the evaluated countries, so differences remain. The application of the MPI shows that both the magnitude and the intrinsic features of the productivity dynamics are differentiated across the evaluated regions. Again, we observe in NUTS 2 regions differences between the two selected rich and industrialized countries that form the so-called *Old Europe* (Austria and Germany) and the selected relatively poorer ones that have entered the EU quite recently, the so-called *New Europe* (V4 countries). The evaluated NUTS 2 regions are currently facing important economic and social challenges. The recent economic crisis has seriously threatened the achievement of sustainable development in the field of competitiveness. The crisis has underscored the importance of competitiveness – supporting the economic environment to enable national economies to absorb shocks better and ensure solid economic performance in the future. To maximize success, countries can find inspiration and learn from past practices that have shown that coherent and well-explained reform schemes building on multistakeholder partnerships, policy consistency and continuity, along with sustained political leadership, provide good results (WEF, 2013). The DEA method, as a matter of fact, allows the analysis and assessment of the level of efficiency of a set of economic units, EU NUTS 2 regions in our case, in the use of inputs/resources devoted to increasing efficiency and productivity. The implementation of the MPI, moreover, enables the study of the dynamics of productivity changes in time, providing useful indications to appraise those policies that are aimed at either incrementing or directing this process. The EU policies are clearly aimed at trying to lessen such concentration while favouring a convergence process. Convergence may be obtained through either technological transfer or an endogenous process, accompanied by the efficient use of scarce resources. The diverse phases and levels of competitiveness also show varying performances, opening the pathway to technological progress and economic growth specific to the local and contextual characteristics of each EU country and its regions.

Bringing together different development factors that illustrate single aspects of competitiveness gives the first impression of the overall international competitiveness of European regions and shows the diversity that exists within the EU territory (ESPON, 2006). Among the important driving forces influencing future territorial development are demographic development (including migration), economic integration, transport, energy, agriculture and rural development, climate change, further EU enlargements and territorial governance. A very important role is played by exogenous factors that have an impact on regional competitiveness, as mentioned (ESPON, 2006). Current theories of regional competitiveness emphasize the significance of *soft* factors, such as human, cultural (knowledge and creativity) and socio-institutional capital, environmental quality and so on. A wide range of soft location factors are thus of increasing importance. *Soft* factors, like governance, culture and the natural environment, are part of the territorial potential and offer synergies for the jobs and growth agenda. The potential for these *soft factors* differs widely between areas. Quality living environments and access to environmental and cultural amenities are among the factors that attract investment and people to a location, which is very important for competitiveness for each NUTS 2 region and its competitive advantage and factor endowment. Currently hazards do not undermine the competitiveness of a region. Only a few places have very low exposure to the main natural and technological hazards in Europe, and climate change is expected to increase the risk of hazards in the future. To gaze into the future, it is necessary to understand the driving forces that shape territorial development and various possible future developments and interrelations with the territory that each driving force might bring. Bringing them together into integrated prospective scenarios is then the final challenge.

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Annex

Table 5 Overall regional performance based on the Malmquist Productivity Index

No.	*DMU*	*Output-Oriented CCR CRS Malmquist Productivity Index*													
		2000–2001	*2001–2002*	*2002–2003*	*2003–2004*	*2004–2005*	*2005–2006*	*2006–2007*	*2007–2008*	*2008–2009*	*2009–2010*	*2010–2011*	*2011–2012*	*2012–2013*	*2013–2014*
1	CZ01	1.577	0.903	1.049	0.922	0.808	1.110	1.222	0.839	0.646	1.436	0.939	0.957	1.060	0.935
2	CZ02	0.953	0.838	0.989	1.052	0.974	1.140	0.852	1.040	0.701	1.550	0.889	0.997	1.095	0.943
3	CZ03	2.275	1.010	0.933	1.017	1.005	1.031	0.986	0.935	0.929	0.986	1.010	0.925	0.924	0.903
4	CZ04	2.613	1.068	0.919	1.120	1.002	1.072	0.789	0.951	1.068	1.158	0.929	1.002	0.979	0.920
5	CZ05	1.987	0.935	0.921	0.955	0.903	1.005	1.086	0.914	0.895	1.032	0.997	0.925	0.935	0.902
6	CZ06	1.697	0.999	0.954	1.024	1.025	1.029	1.035	0.964	0.865	1.142	0.947	0.935	0.958	0.896
7	CZ07	2.097	0.995	0.972	0.994	1.034	1.087	1.003	1.040	0.822	1.217	0.943	0.944	0.985	0.907
8	CZ08	1.886	1.023	0.916	0.973	0.993	0.956	0.937	1.037	1.013	1.054	0.965	0.961	0.943	0.906
9	HU10	1.719	1.124	0.928	1.114	0.912	1.080	1.010	0.961	0.628	1.314	0.949	0.914	1.009	0.907
10	HU21	2.372	0.934	0.834	1.001	0.916	1.009	1.002	0.964	1.034	1.159	0.924	0.989	0.974	0.912
11	HU22	2.473	1.029	1.063	0.917	1.046	1.036	0.957	0.918	0.935	1.152	0.937	0.958	0.965	0.903
12	HU23	2.015	0.904	0.941	0.929	1.003	1.054	1.209	0.799	0.906	1.097	0.975	0.943	0.955	0.907
13	HU31	2.856	0.921	0.969	1.014	0.869	0.923	1.156	0.903	0.920	1.175	0.929	0.958	0.970	0.902
14	HU32	1.887	0.928	0.994	1.027	0.990	1.021	0.936	1.002	0.980	1.097	0.967	0.965	0.960	0.914
15	HU33	1.802	0.975	0.926	1.041	1.006	1.111	1.029	1.007	0.850	1.346	0.919	0.988	1.034	0.930
16	PL11	1.881	1.005	1.002	0.990	1.027	0.889	0.767	0.820	1.057	1.026	0.959	0.964	0.933	0.902
17	PL12	1.570	0.987	0.974	0.987	0.951	0.999	0.928	0.876	1.046	0.947	1.028	0.957	0.927	0.921
18	PL21	1.663	1.000	1.000	1.000	1.000	0.982	0.946	0.972	0.984	1.025	1.000	0.953	0.943	0.915
19	PL22	2.749	1.043	0.967	1.008	1.000	0.920	0.923	0.912	0.972	1.033	0.983	0.946	0.937	0.906
20	PL31	2.095	0.999	0.949	0.979	0.963	0.924	0.882	0.917	0.870	1.083	0.998	0.933	0.955	0.912
21	PL32	2.674	1.006	0.961	0.942	1.053	0.829	0.814	0.986	1.169	1.043	0.930	0.997	0.940	0.906
22	PL33	4.875	1.172	1.470	0.834	0.982	0.923	0.734	0.604	1.049	1.174	0.933	1.002	0.986	0.924
23	PL34	2.147	0.946	0.988	0.935	0.986	0.937	0.909	0.816	0.988	1.062	0.966	0.955	0.945	0.905
24	PL41	2.344	1.000	1.000	1.004	1.299	0.709	0.869	0.887	1.006	1.002	1.000	0.953	0.935	0.913
25	PL42	3.800	0.976	1.044	0.935	0.968	0.883	0.892	0.935	1.021	1.006	0.982	0.953	0.930	0.905
26	PL43	5.074	0.778	0.975	1.490	0.604	0.965	0.890	0.779	1.578	0.962	0.870	1.087	0.923	0.910
27	PL51	2.247	1.000	1.000	1.000	0.983	0.917	0.918	0.970	1.000	1.013	0.989	0.951	0.934	0.908
28	PL52	3.204	1.156	1.018	0.984	0.849	0.923	0.846	0.931	0.998	1.198	0.927	0.991	0.989	0.919
29	PL61	2.712	1.013	0.967	0.987	0.954	0.922	0.874	0.828	0.996	1.000	1.000	0.949	0.933	0.910
30	PL62	3.258	1.114	0.988	0.865	0.907	0.858	0.841	0.940	1.036	0.980	0.988	0.951	0.923	0.904

No.	*DMU*	*Output-Oriented CCR CRS Malmquist Productivity Index*													
		2000–2001	*2001–2002*	*2002–2003*	*2003–2004*	*2004–2005*	*2005–2006*	*2006–2007*	*2007–2008*	*2008–2009*	*2009–2010*	*2010–2011*	*2011–2012*	*2012–2013*	*2013–2014*
31	PL63	2.346	1.019	0.957	0.954	1.072	0.816	0.950	0.988	0.977	1.043	0.974	0.948	0.938	0.904
32	SK01	1.844	0.966	1.122	0.827	1.212	0.998	0.835	0.990	0.645	1.638	0.865	0.999	1.117	0.944
33	SK02	2.153	0.973	0.946	1.047	1.029	1.026	1.019	0.910	1.060	1.128	0.885	0.974	0.946	0.885
34	SK03	2.088	1.010	0.937	1.048	0.994	0.992	0.934	0.879	0.985	1.442	0.803	1.027	1.041	0.907
35	SK04	2.473	1.071	0.907	1.113	0.958	0.924	0.783	0.884	1.073	1.078	0.892	0.964	0.928	0.878
36	AT11	0.947	1.159	0.994	1.105	0.989	1.095	0.826	1.012	0.971	1.106	0.911	0.946	0.938	0.881
37	AT12	0.996	1.017	1.016	1.034	1.031	1.025	1.025	1.011	1.014	1.021	0.981	0.955	0.936	0.907
38	AT13	0.920	1.018	0.969	0.989	1.075	1.013	0.919	0.966	0.910	1.165	0.955	0.960	0.976	0.914
39	AT21	1.000	1.008	1.000	1.058	0.993	0.978	1.029	0.971	1.003	1.000	1.000	0.951	0.934	0.912
40	AT22	1.000	1.000	1.000	1.015	1.002	1.005	1.000	1.000	0.997	1.012	1.000	0.953	0.938	0.914
41	AT31	1.000	1.000	1.008	1.027	1.028	1.038	1.026	0.999	0.968	1.056	0.978	0.951	0.945	0.908
42	AT32	0.980	1.031	1.010	1.054	0.993	1.033	1.041	0.996	0.992	1.016	0.991	0.950	0.936	0.909
43	AT33	1.000	1.000	1.011	1.011	1.015	1.009	1.017	1.000	1.003	1.036	0.968	0.952	0.936	0.902
44	AT34	1.019	0.969	1.473	0.956	1.121	0.932	1.336	0.758	0.749	1.491	0.868	0.986	1.065	0.923
45	DE11	1.013	0.976	1.008	1.008	1.012	0.944	1.052	0.848	0.757	1.264	0.947	0.939	1.000	0.912
46	DE12	1.031	0.976	1.037	1.050	1.026	0.973	0.983	0.912	0.815	1.214	0.904	0.927	0.965	0.882
47	DE13	1.000	1.000	1.019	1.008	1.042	0.993	1.028	0.928	0.800	1.217	0.977	0.948	0.997	0.924
48	DE14	1.021	1.033	0.994	1.037	1.035	1.011	0.989	0.952	0.765	1.283	0.935	0.944	1.004	0.911
49	DE21	0.987	0.980	0.985	1.027	1.029	1.034	0.989	0.927	0.768	1.188	0.998	0.935	0.990	0.924
50	DE22	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.950	0.933	0.911
51	DE23	0.948	0.975	0.993	1.099	0.997	1.023	0.974	0.908	0.762	1.247	0.985	0.948	1.010	0.931
52	DE24	1.000	1.000	1.000	1.000	1.023	0.970	0.979	0.935	0.784	1.262	0.937	0.944	0.998	0.910
53	DE25	1.093	0.930	0.963	1.066	1.094	1.104	0.915	0.968	0.751	1.295	0.927	0.941	1.004	0.908
54	DE26	1.054	0.979	0.955	1.163	0.955	0.976	1.023	0.902	0.730	1.318	0.927	0.942	1.012	0.911
55	DE27	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.949	1.018	1.000	0.939	0.936	0.908
56	DE30	1.136	0.943	1.056	1.106	1.042	0.989	1.013	0.914	0.807	1.136	0.991	0.928	0.968	0.912

No.	DMU	Output-Oriented CCR CRS Malmquist Productivity Index													
		2000–2001	*2001–2002*	*2002–2003*	*2003–2004*	*2004–2005*	*2005–2006*	*2006–2007*	*2007–2008*	*2008–2009*	*2009–2010*	*2010–2011*	*2011–2012*	*2012–2013*	*2013–2014*
57	DE41	1.122	0.896	0.999	1.088	0.983	1.000	1.000	1.000	0.988	1.043	0.980	0.954	0.942	0.908
58	DE42	1.015	1.000	1.000	1.020	1.000	1.000	1.000	1.000	0.992	1.016	0.993	0.951	0.937	0.910
59	DE50	1.067	1.121	1.181	1.855	0.698	0.969	0.710	1.104	0.707	1.260	0.999	0.939	1.016	0.935
60	DE60	1.003	1.022	1.006	0.985	1.064	1.065	0.900	0.987	0.731	1.275	0.976	0.944	1.015	0.928
61	DE71	1.000	1.000	1.000	1.007	1.008	0.992	1.024	0.944	0.943	1.047	0.983	0.941	0.940	0.905
62	DE72	0.974	0.932	1.031	1.022	1.031	0.981	0.968	1.010	0.830	1.139	0.965	0.928	0.961	0.901
63	DE73	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.950	0.933	0.911
64	DE80	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.950	0.933	0.911
65	DE91	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.962	1.000	1.000	0.937	0.929	0.906
66	DE92	1.000	1.000	1.007	0.999	1.000	1.000	1.000	0.990	0.908	1.042	0.978	0.926	0.932	0.895
67	DE93	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.950	0.933	0.911
68	DE94	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.950	0.933	0.911
69	DEA1	1.017	1.016	1.014	0.982	1.025	1.003	0.996	0.909	0.949	1.026	1.000	0.942	0.939	0.910
70	DEA2	1.000	1.000	1.007	0.995	1.005	1.000	1.012	0.967	1.009	1.000	1.000	0.953	0.934	0.912
71	DEA3	1.017	1.006	1.018	1.034	1.018	0.996	1.050	0.964	1.078	1.044	0.951	0.974	0.940	0.905
72	DEA4	1.011	0.998	1.013	0.989	1.000	1.105	0.920	1.005	0.836	1.290	0.911	0.962	1.005	0.909
73	DEA5	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.017	1.005	0.997	0.956	0.936	0.913
74	DEB1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.950	0.933	0.911
75	DEB2	1.027	1.000	1.000	1.000	1.097	1.023	1.016	1.031	1.038	0.991	0.998	0.959	0.933	0.913
76	DEB3	0.990	1.000	1.037	1.031	1.054	0.969	1.100	0.859	0.787	1.180	0.958	0.925	0.971	0.901
77	DEC0	0.910	1.132	0.913	0.907	1.000	1.042	1.113	1.049	0.953	1.090	1.004	0.966	0.970	0.930
78	DED1	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.007	0.994	0.950	0.934	0.909
79	DED2	1.000	1.000	1.000	1.000	1.000	1.090	0.962	1.000	0.993	1.022	0.984	0.950	0.935	0.906
80	DED3	1.064	1.071	0.967	1.127	1.024	0.972	0.984	0.917	0.886	1.054	0.994	0.928	0.942	0.905
81	DEE0	1.000	1.000	1.000	1.000	1.645	0.600	0.870	1.000	1.000	1.444	0.693	0.996	0.994	0.844
82	DEF0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.950	0.933	0.911
83	DEG0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.950	0.933	0.911