Multidimensional Approach to Assessment of Performance in Selected EU Member States

M. Staníčková, K. Skokan

***Abstract*—**The paper deals with an application of Data Envelopment Analysis (DEA) method to multi-criteria performance evaluation of the Visegrad Four countries (V4) in comparison with selected advanced European Union's (EU) countries – Austria and Germany. The aim of the paper is to analyze a degree of efficiency achieved in individual countries which is perceived as a reflection of the level of competitive potential in the reference years 2000, 2005 and 2010. The theoretical part of the paper is devoted to the fundamental bases of competitiveness in the context of performance/productivity theory and the methodology of factor analysis (FA) and DEA method. The multivariate method (FA) has been used to DEA modeling. The empirical part is aimed at measuring the degree of productivity and level of efficiency changes of evaluated countries by basic (CCR, BCC) and advanced (SBM, FDH, FRH) DEA models and especially by the specialized DEA approach – the Malmquist (Productivity) Index (MI/MPI) measuring the change of technical efficiency and the movement of the frontier in terms of evaluated countries. The final part of the paper offers a comprehensive comparison of results obtained by used methods.

***Keywords*—**BCC/CCR/FDH/FRH/SBM model, Competitiveness, Evaluation, Efficiency/Inefficiency, DEA method, Factor analysis, Malmquist productivity index, Performance

I. Introduction

EUROPEAN Union (EU) is a heterogeneous unit with significant disparities between its Member States and their regions. The support of cohesion and balanced development together with increasing level of EU competitiveness belong to the temporary *EU's key development objectives*. The process of European integration is thus guided by striving for two different objectives: *to foster economic competitiveness* and *to reduce territorial differences*. Although the EU is one of the most developed parts of the world with high living standards, there exist huge economic, social and territorial disparities having a negative impact on the balanced development across Member States and their regions, and thus weaken EU's performance in a global context. In relation to *competitiveness, performance* and *efficiency* are *complementary objectives*, which determine the long-term development of countries and regions. *Measurement, analysis and evaluation of productivity changes, efficiency and level of competitiveness are controversial topics* acquire great interest among researchers. In the EU, the process of achieving an increasing trend of performance and a higher level of competitiveness is significantly difficult by the heterogeneity of countries and regions in many areas. The concept of competitiveness in the EU is specific regarding the inclusion of elements of European integration that goes beyond the purely economic parameters.

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II. Theoretical Background of Competitiveness in the Context of Performance and Efficiency Analysis

In recent years, the topics about measuring and evaluating of *competitiveness* have enjoyed economic interest. Although there is no uniform definition and understanding of competitiveness, this concept remains one of the basic standards of performance evaluation and it is also seen as a reflection of success of area (company/country/region) in a wider (international/inter-regional) comparison.

A. Concept of Competitiveness in the Framework of Performance and Efficiency

The exact definition of competitiveness is difficult because of the *lack of mainstream view* for understanding this term. Competitiveness remains a concept that can be understood in different ways and levels despite widespread acceptance of its importance. The concept of competitiveness is distinguished at different levels – *microeconomic, macroeconomic and regional*. Anyway, there are some differences between these three approaches; see e.g. [16].

Competitiveness is monitored characteristic of national economies which is increasingly appearing in evaluating their performance and prosperity, welfare and living standards. The need for a theoretical *definition of competitiveness* at macroeconomic level emerged with the development of globalization process in the world economy as a result of increased competition between countries. Despite that, growth competitiveness of the territory belongs to the main priorities of countries' economic policies. There is not a standardized definition and understanding of national competitiveness (compared with the competitiveness at microeconomic level).

In last few years the topic about *regional competitiveness* stands in the front of economic interest. The concept of competitiveness has quickly spread into regional level, but the notion of regional competitiveness is also contentious. In the global economy regions are increasingly becoming the drivers of the economy and generally one of the most striking features of regional economies is the presence of clusters, or geographic concentrations of linked industries (Porter, 2003). Current economic fundamentals are threatened by shifting of production activities to places with better conditions. Regional competitiveness is also affected by the regionalization of public policy because of shifting of decision-making and coordination of activities at regional level. Within governmental circles, interest has grown in the *regional foundations of national competitiveness*, and with developing new forms of regionally based policy interventions to help improve competitiveness of every region and major city, and hence the national economy as a whole. *Regions play an increasingly important role in the economic development of states.*

Nowadays competitiveness is one of the *fundamental criteria for evaluating economic performance* and reflects the success in the broader comparison. Organizations (e.g. companies, states, regions) need *highly performing units* in order to meet their goals, to deliver the products and services they specialized in, and finally *to achieve competitive advantage*. Low performance and not achieving the goals might be experienced as dissatisfying or even as a failure. Moreover, performance – if it is recognized by others organizations – is often rewarded by benefits, e.g. better market position, higher competitive advantages, financial condition etc. Performance is a major – although not the only – prerequisite for future economic and social development and success in the broader comparison.

Performance is also highly important for an area (company/country/region) as a whole and for the individuals involving in it. Performance comprises both a behavioral and an outcome aspect, and it is thus a multidimensional and dynamic concept as competitiveness. Despite the great relevance of performance and widespread use of this term as an outcome measure in empirical research, relatively little effort has been spent on clarifying the performance concept. Performance management is one of the major sources of sustainable national effectiveness and a systematic understanding of the factors that affect productivity, and subsequently competitiveness, is very important. In relation to competitiveness and performance, *efficiency* is a term that recently has come to the forefront of the scientific world.

As mentioned above, in relation to competitiveness and performance, *efficiency* is a term that recently has come to the forefront of the scientific world. As the world struggles to accommodate the enormous growth in population and to manage the distribution of resources, to reach higher competitive potential, the effort to make things more efficient has become increasingly more relevant. The economy may be competitive but if the society and the environment suffer too much the country will face major difficulties. The same problem would happen vice versa when the economy is too weak. Therefore governments in the long run period cannot focus alone on the economic competitiveness of their country; instead they need an integrated approach to govern the country and focus on the broadest aspects affecting efficiency. As the world struggles to accommodate the enormous growth in population and to manage the distribution of resources, to reach higher competitive potential, the effort to make things more efficient has become increasingly more relevant. Efficiency is a central issue in analyses of economic growth, effects of fiscal policies, pricing of capital assets, level of investments, technology changes and production technology, and other economic topics and indicators. In a competitive economy, therefore, the issue of efficiency, resp. dynamic efficiency, can be resolved by comparing these economic issues.

B. Approaches to Evaluation of Competitiveness in the Context of Performance and Efficiency

Evaluating competitiveness belongs to main issues of economic research, which also lacks a mainstream approach. Evaluation of competitiveness in terms of differences between countries and regions should be measured through complex of economic, social, environmental criteria identifying imbalance areas that cause main disparities. Currently not only quantitative but also qualitative development at national level, and especially at regional level, increase socio-economic attraction and create new opportunities that are fundamentals for subsequent overcoming disparities and increasing the competitiveness of territory.

Competitiveness is most commonly evaluated by *decomposition of aggregate macroeconomic indicators.* Competitiveness of countries is monitored by many institutions, however, two well-known international institutes publish most reputable competitiveness reports. To compare a level of competitiveness of countries we can use the databases performed by *Institute for Management Development* (IMD) – the *World Competitiveness Yearbook* (WCY), and *World Economic Forum* (WEF) – the *Global Competitiveness Report* (GCR). *Decomposition of aggregate macroeconomic indicators* of international organizations WEF and IMD is most commonly used approach at the regional level, as well as *comprehensive* (mostly descriptive) *analysis* aimed at identifying the key factors of regional development, productivity and economic growth; see e.g. [2], [17].

EU competitiveness can be measured also by indicators of *EU' growth strategies* (Lisbon strategy – Structural (Lisbon) indicators, Strategy Europe 2020 – Indicators of Europe 2020). The multidimensionality of indicators of these growth strategies reflects the multiple forces driving economic growth and development. These growth strategies present trails other advanced economies in creating a smart, highly productive economy. Highly productive economy is competitive and is able to provide high and rising livings standards, allowing all members of a society to contribute to and benefit from high levels of efficiency. Another approach is the evaluation by *macro-econometric modelling* with creation of an econometric panel data model; see e.g. [13], [14], [20], or by *DEA method*, which measures national efficiency and subsequent national competitive potential; see e.g. [23].

The primary problem in creating an effective competitiveness evaluation system is establishing clear performance and efficiency standards and priorities at the beginning of the performance cycle. The early work on this problem focused on separate measures for productivity and there was a failure to combine the measurements of multiple inputs into any satisfactory measure of efficiency. These inadequate approaches included forming an average productivity for a single input (ignoring all other inputs), and constructing an index of efficiency in which a weighted average of inputs is compared with output. Responding to these inadequacies of separate indices of labour productivity, capital productivity, etc., Farrell (1957) [11] proposed an activity analysis approach that could more adequately deal with the problem. His measures were intended to be applicable to any productive organization; in other words, „from a workshop to a whole economy" [19]. 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, Cooper and Rhodes (1978) [4], responding to the need for satisfactory procedures to assess the relative efficiencies of multi-input/multi-output production units, introduced a powerful methodology which has subsequently been titled *DEA* [25].

Measurement and evaluation of performance, efficiency and productivity is an important issue for at least *two reasons*. One is that in a group of units where only 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 in order to make the necessary improvements. The performance of a countries and regions can be evaluated in either a cross-sectional or a time- series manner, and the DEA is a useful method for both types of efficiency evaluation [11].

III. Multivariate Methods and Efficiency Analysis of Competitive Potential Measurement

The most common quantitative methods convenient for a high number of multivariate measured variables can be identified as *multivariate statistical methods*. Multivariate analysis is an ever-expanding set of techniques for data analysis that encompasses a wide range of possible research situation [12]. Between collections of multivariate statistical methods we can include e.g. *Method of main components, Factor analysis* or *DEA method*, which are used in the paper. Measuring the efficiency level of evaluated countries is based on procedure in following Table I.

Table I Basic scheme of efficiency measuring and evaluation

Input Pre-processing phase » Collection of indicators » Groups of indicators for input and output
Factor analysis Correlation » Input factors/Output factors » Set of new composite indicators » Factor description
DEA modelling BCC/CCR/SBM/FDH/FRH models » Malmquist productivity index » Efficiency evaluation

Source: Own elaboration, 2012

A. Fundamental Basis of Factor Analysis

Factor analysis is a collection of methods used to examine how underlying constructs influence the responses on a number of measured variables. Factor analysis is a method for investigating whether a number of variables of interest $Y_1, Y_2,\dots Y_n$, are *linearly related* to a smaller number of unobservable factors $F_1, F_2,\dots F_k$. If we suggest that one measured variable Y_1, is function of two underlying factors, F_1 and F_2, then it is assumed that Y variable is linearly related to the two factors F, as follows in equation (1) [12]:

$$Y_1 = \beta_{10} + \beta_{11}F_1 + \beta_{12}F_2 + e_1. \tag{1}$$

The error terms e_1, serves to indicate that the hypothesized relationships are not exact. In the special vocabulary of factor analysis, the parameters $\beta_{i,j}$ are referred to as *loadings*. For example, β_{12} is called the loading of variable Y_1 on factor F_2. There is generally a wide range of literature based on factor analysis. For example, a hands-on how-to approach can be found in Stevens [24]; more detailed technical descriptions are provided in Cooley and Lohnes (1971) [7] or in Harman [15]. De Coster [9] posted, that there are basically *two types of factor analysis*: exploratory and confirmatory. *Exploratory factor analysis* (EFA), which is applied in this paper, attempts to discover the nature of the constructs influencing a set of responses. *Confirmatory factor analysis* (CFA) tests whether a specified set of constructs is influencing responses in a predicted way.

The main *applications* of factor analytic techniques are (1) to *reduce* the number of variables and (2) to *detect structure* in the relationships between variables that is to *classify variables*. Therefore, factor analysis is applied as a *data reduction* or *structure detection method*. Factor analyses are performed by examining the pattern of *correlations* between the observed measures. Measures that are highly correlated (either positively or negatively) are likely influenced by the same factors, while those that are relatively uncorrelated are likely influenced by different factors. The primary objectives of an *EFA* are to determine (1) The number of common factors influencing a set of measures and (2) The strength of the relationship between each factor and each observed measure. There are *seven usual basic steps* to performing *EFA*, used in the empirical analysis of the paper: (1) Collection of measurement variables; (2) Obtain the correlation matrix between each of variables; (3) Selection of the number of factors for inclusion; (4) Extraction of initial set of factors; (5) Rotation of factors to a final solution; (6) Interpretation of factor structure; (7) Construction of factor scores for further analysis.

B. Theoretical Background of DEA method

Since DEA was first introduced in 1978, researchers in a number of fields have quickly recognized that it is an excellent and easily used methodology for modelling operational processes for performance evaluations. This has been accompanied by other developments. DEA is based on *Farrel model* for measuring the effectiveness of units with one input and one output, which expanded *Charnes*, *Cooper* and *Rhodes* (CCR) and *Banker*, *Charnes* and *Cooper* (BCC), advanced *Slack-Based Model* (SBM), *Free Disposal Hull* (FDH) and *Free Replicability Hull* (FRH) models and others [6].

DEA is a relatively new 'data oriented' approach for providing a relative efficiency assessment (*DEA efficient*) 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 *multicriteria decision making method* for evaluating effectiveness, efficiency and productivity of homogenous group (DMUs). The definition of a DMU is generic and flexible. DEA is convenient to determine efficiency of DMU which are mutually comparable – using same inputs, producing same outputs, but their performances are different. The efficiency score of DMU in the presence of multiple input and output factors is defined by the following equation (2) [6]:

$$efficiency = \frac{weighted\_sum\_of\_outputs}{weighted\_sum\_of\_inputs}. \quad (2)$$

The aim of DEA method is to examine DMU if they are *effective* or *not effective* by the size and quantity of consumed resources by the produced outputs (Andresen, Petersen, 1993). The best-practice units are used as a reference for evaluation of other group units. DMU is *efficient* if the observed data correspond to testing whether the DMU is on the imaginary '*production possibility frontier*'. All other DMU are simply *inefficient*. For every inefficient DMU, DEA identifies a set of corresponding efficient units that can be utilized as benchmarks for improvement. However DEA is primarily a diagnostic tool and does not prescribe any reengineering strategies to improve performance of DMUs [5].

In recent years, we have seen a great variety of applications of DEA for evaluating the performances of many different kinds of entities engaged in many different activities. Because of low assumption requirements DEA has also opened up possibilities for use in cases which have been resistant to other approaches because of the complex (often unknown) nature of relations between multiple inputs and multiple outputs involved in DMUs. *DEA method is a convenient method for comparing national or regional efficiency as an assumption for performance of territory* because DEA does not evaluate only one factor, but a set of different factors that determine degree of economic development. DEA method used in analysis of V4 is based on a particular set of input and output indicators. Inputs and outputs form key elements of system evaluated for every country and regions within V4 in the sense of their effective (ineffective) economic position. For this purpose, DEA method can identify a competitive/uncompetitive position of each country [18], [22].

IV. APPLICATION OF MULTIVARIATE METHODS TO EFFICIENCY EVALUATION OF V4 COUNTRIES IN COMPARISON WITH AUSTRIA AND GERMANY

A. Fundamental Basis of Empirical Analysis

The aim of this paper is to measure and evaluate the efficiency level of countries the group of Visegrad Four (V4), i.e. Czech Republic (CZ), Hungary (HU), Poland (PL) and Slovakia (SK), in comparison with selected advanced EU Member States – Austria (AT) and Germany (DE). At first glance, it could seem that V4 is incomparable group, because there is different geographic size, number of population, regional administrative structure and segmentation, different economic performance as well as different levels of economic, social and territorial disparities. On the other hand, these countries have (to certain extent) identical features, as especially common historical background, similar cultural backgrounds, traditions and interdependent economic relations. As well as trends in production and elimination of regional disparities in these countries are very similar. However, despite similar historical, political, and economic characteristics of V4 countries, each country disposes of different economic and social conditions at the beginning of the new millennium. This fact is also reflected in the success of convergence process in achieving EU competitiveness level.

The performance analysis, based on application of *Factor Analysis* (FA) and selected *Data Envelopment Analysis* (DEA) models and *Malmquist (Productivity) Index* (MI/MPI), is used for evaluating national development quality and potential (with respect to the national factors endowment). DEA method becomes a suitable tool for ranking competitive (uncompetitive) position of countries based on efficiency within V4. Application of DEA method is based on assumption that *efficiency* of V4 countries calculated by DEA method can be seen as the *source of national competitiveness (competitive potential).* Based on the above facts, it is possible to determine the initial *hypothesis of the analysis.* The hypothesis is based on the assumption that V4 countries achieving best results in efficiency are countries best at converting inputs into outputs and therefore having the greatest performance and productive potential. This hypothesis has been used also in authors` previous papers, e.g. [23]. Similar assumption was also used by other authors; see e.g. [3].

The efficiency analysis starts from building database of indicators that are part of a common approach of WEF and EU in the form of *Country Competitiveness Index* (CCI). The aim of this approach is to develop a rigorous method to benchmark national competitiveness and to identify the key factors which drive the low competitiveness performance of some countries.

The reference to CCI is the well-established *Global Competitiveness Index* (GCI) by WEF. Eleven pillars of CCI may be grouped according to the different dimensions (*input versus output aspects*) of national competitiveness they describe. The terms '*inputs*' and '*outputs*' are meant to classify pillars into those which describe driving forces of competitiveness, also in terms of long-term potentiality, and those which are direct or indirect outcomes of a competitive society and economy. From this point of view, *methodology of Country Competitiveness Index is suitable and very convenient for measuring of national competitiveness by DEA method* [1].

The indicators selected for the CCI framework are all of quantitative type (hard data) and the preferred source has been *the European Statistical Office* (Eurostat). Whenever information has been unavailable or inappropriate at the required territorial level, other data sources have been explored such as the *World Bank*, *Euro barometer*, *the Organisation for Economic Co-operation and Development* (OECD) and *the European Cluster Observatory*. In this paper, database analysis consists of *66 selected indicators* – 38 of them are inputs and 28 outputs. We do not use all indicators included in CCI because all indicators were not available for the whole period for each country, but for some indicators we found comparable indicators. The pillars and used indicators are listed in Tables I and II in Appendix. The reference period is set across the board for years 2000-2005-2010. We evaluate the change, individual countries achieved in its overall performance in the years 2000, 2005 and 2010 in comparison with basis year, i.e. 2000: 2000-2005 and 2000-2010. Furthermore, we analyse productivity changes that occurred between evaluated periods, i.e. the between 2000-2005 and 2005-2010 compared to previous period, not to basis period.

For calculations of economic efficiency of V4 countries in comparison with Austria and Germany, basic and advanced DEA models with multiple inputs and outputs are used, such as *CCR input oriented model, assuming constant returns to scale (CRS)*, *CCR output oriented model assuming CRS*, *BCC input oriented model assuming variable returns to scale (VRS)*, *BCC output oriented model assuming VRS*, *SBM additive model not-focusing on input and output assuming CRS, SBM additive model not-focusing on input and output assuming variable returns to scale VRS, FDH input oriented model, FDH output oriented model, FRH input oriented model, FRH output oriented model*.

Basic DEA models, *primary CCR input/output oriented models* (with multiple inputs and outputs), assume constant returns to scale (CRS). In 1984, Banker, Charnes and Cooper suggested a modification of CCR model, which considers variable returns to scale (VRS) (decreasing, increasing or constant) – *BCC input/output oriented models* (with multiple inputs and outputs). VRS enable better identify more efficient units, because VRS provides a more realistic expression of economic reality and factual relations, events and activities existing in countries.

CCR and BCC models evaluate the efficiency of units (in our case countries) for any number of inputs and outputs. The *coefficient of efficiency* is the ratio between the weighted sum of outputs and the weighted sum of inputs. Each country selects input and output weights that maximize their *efficiency score*. The coefficient of efficiency (CE) takes values in the interval <0,1>. In *DEA models aimed at inputs* the efficiency coefficient of efficient countries (located on the efficient frontier package) always equals 1, while the efficiency coefficient of inefficient countries is less than 1. In *DEA models aimed at outputs* the efficiency coefficient of efficient countries (located on the efficient frontier package) always equals 1, but the efficiency coefficient of inefficient countries is greater than 1. DEA also allows for computing the necessary improvements required in the inefficient country's inputs and outputs to make it more efficient.

CCR and BCC models are radial, which means that they contain radial variables θ_q (for models aimed at inputs) and φ_q (for models aimed at outputs). These variables indicate the required level of reduction in all inputs (θ_q) and the rate of increase of all outputs (φ_q) to achieve efficiency. However, *CCR and BCC models must focus on the distinction between inputs and outputs*. SBM additive models measure directly the effectiveness of using additional variables (s^+ and s^-). *In formulation of SBM additive models is not necessary to distinguish between a focus on inputs and outputs*. As mentioned above, in CCR and BCC models, the efficiency coefficient of efficient units always equals 1, while the efficiency coefficient of inefficient units is less/greater than 1. *In SBM models, the efficiency coefficient of efficient units always equals 0, because it is the sum of additional variables for inputs and outputs (s^+ and s^-), which express the distance from the efficient frontier*. The sum of additional variables for inputs and outputs is lower, evaluated unit (in our case countries) is closer to the efficient frontier package and thus has a higher degree of efficiency, and otherwise [8].

Basic DEA models compare inputs and outputs of evaluated units (country, region) with a linear (convex) combination of inputs and outputs of other units. This unit is not in most cases assessed to really existing unit, but to a kind of virtual unit, which is a combination of inputs and outputs of existing units. The basic idea of FDH model, which was first formulated by *Deprins, Simar* and *Tulkens* (1984), is unconvexity of set of production possibilities. This means that evaluated unit can be only relatively compared towards really existing units. For comparison with CCR and BCC models, it should be added that limits of efficiency rate is similar to these models, and it depends on model orientation on inputs or outputs. Rate of efficiency, obtained by FDH models, is generally higher than in CCR and BCC models. This is due to the possibility that a production unit is dominated not only by specific production units of set of units (in the case of CCR and BCC models), as well as convex combinations of these units. A simple extension of FDH model is FRH model, which unlike FDH model, allows evaluated unit compares with multiplied combinations of other units [21].

For calculations of economic efficiency of V4 countries in comparison with Austria and Germany, it is also used advanced DEA approach to performance evaluation known as the *Malmquist (Productivity) Index* (MI/MPI). Since the publication of Färe et al. (1994) [10], several studies have analysed the reasons for differing performance in different countries from a frontier approach estimated through non-parametric methods. Research effort has focused on the investigation of the causes of productivity change and on its decomposition. In recent years, the *MI/MPI* has become the standard approach in the productivity measurement over time within the non-parametric literature. The Malmquist index was introduced by Caves, Christensen and Diewert in 1982, whose use became generalized after Färe et al. in 1994, was published. Färe et al. defined an input-oriented productivity index as the geometric mean of the two Malmquist indices developed by Caves et al. [10].

Although it was developed in a consumer context, MI/MPI recently has enjoyed widespread use in a production context, in which multiple but cardinally measurable output replaces scalar-valued but ordinal measurable utility. In producer analysis Malmquist indexes 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, and the most famous one is the linear programming method. The Malmquist index allows measuring of total productivity by means of distance-functions calculation, which can be estimated through the solution of mathematical programming problems of the DEA kind.

Suppose we have a production function in time period t as well as period $t+1$. The Malmquist index calculation requires two single period and two mixed period measures. The two single period measures can be obtained by using the *CCR model with Constant Returns to Scale* (CRS). For simplicity of the Malmquist index calculation, we present basic DEA models based on assumption of a single input and output.

Suppose each DMU_j $(j=1, 2\dots n)$ produces a vector of output $y_j^t = \left(y_{1j}^t,\dots,y_{sj}^t\right)$ by using a vector of inputs $x_j^t = \left(x_{1j}^t,\dots,x_{mj}^t\right)$ at each time period t, $t=1\dots T$. From t to $t+1$, DMU_0's efficiency may change or (and) the frontier may shift. The Malmquist productivity index is calculated via (1) comparing x_0^t to the frontier at time t, i.e., calculating $\theta_0^t\left(x_0^t, y_0^t\right)$ in the following input-oriented CCR CRS DEA model (3) [25]:

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

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

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

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

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

The Malmquist productivity index is further calculated via (4) comparing x_0^{t+1} to the frontier at time $t+1$, i.e., calculating $\theta_0^{t+1}\left(x_0^{t+1}, y_0^{t+1}\right)$ in the following input-oriented CCR CRS envelopment DEA model (4) [25] for $\lambda_j \ge 0,\ j = 1,\dots,n$:

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

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 Malmquist productivity index is further calculated via (5) comparing x_0^t to the frontier at time $t+1$, i.e., calculating $\theta_0^{t+1}\left(x_0^t, y_0^t\right)$ via the following linear program equation (5) [25] for $\lambda_j \ge 0,\ j = 1,\dots,n$:

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

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 Malmquist productivity index is further calculated via (6) comparing x_0^{t+1} to the frontier at time t, i.e., calculating $\theta_0^t\left(x_0^{t+1}, y_0^{t+1}\right)$ via the following linear program equation (6) [25] for $\lambda_j \ge 0,\ j = 1,\dots,n$:

$$\theta_0^t\left(x_0^{t+1}, y_0^{t+1}\right) = \min \theta_0, \tag{6}$$

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 Malmquist index M_0 measuring the efficiency change of production units between successive periods t and $t+1$, is formulated in the following form (7) [25]:

$$M_0\ (x^{t+1}, y^{t+1}, x^t, y^t) = E_0 \cdot P_0, \tag{7}$$

where E_0 is 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 (equation (8)) makes it possible to measure the change of technical efficiency and the movement of the frontier in terms of a specific DMU_0 [25]:

$$M_0 = \frac{\theta_0^t\left(x_0^t, y_0^t\right)}{\theta_0^{t+1}\left(x_0^{t+1}, y_0^{t+1}\right)}\left[\frac{\theta_0^{t+1}\left(x_0^{t+1}, y_0^{t+1}\right)}{\theta_0^t\left(x_0^{t+1}, y_0^{t+1}\right)} \cdot \frac{\theta_0^{t+1}\left(x_0^t, y_0^t\right)}{\theta_0^t\left(x_0^t, y_0^t\right)}\right]^{1/2}. \quad (8)$$

The first component P_0 on the right hand side measures the magnitude of *technical efficiency change* (TEC) between time periods *t* and *t+1*. Obviously the second component E_0 on the left hand indicating that technical efficiency improves, remains or declines. The second terms measures the shift in the possibility frontier, i.e. *technology frontier shift* (FS), between time period's *t* and *t+1*. *Productivity declines if $P_0>1$, remains unchanged if $P_0=1$ and improves if $P_0<1$.* In Table II characteristics of Malmquist index and efficiency change are shown.

Table II Characteristics and trends of the Malmquist index and efficiency change.

Malmquist Index	Productivity
> 1	Declining
= 1	Unchanging
< 1	Improving
Efficiency Change	**Technical Efficiency**
< 1	Improving
= 1	Unchanging
> 1	Declining

Source: Own elaboration, 2012

Based on the above facts, we can determine the total productivity change in a successive period of time with the following equations (9) and (10):

Productivity change = Technical efficiency change · Technological changes, (9)

resp. MI/MPI = TEC · FS. (10)

If the Malmquist index on the basis of minimization of production factors was less than one, it indicates productivity improvement, on the other hand, if on the basis of maximization of production factors, the index or any of its elements were less than one, it signifies productivity getting better, while if the index is bigger than one, it indicates productivity decrease [25].

For solution of *factor analysis and cluster analysis* statistical package *SPSS – IBM SPSS Statistics – Version 20* is used in the paper. For solution of *DEA models* software tools based on solving linear programming problems are used, e.g. Solver in MS Excel, such as the *DEA Frontier* [6], [8], this is used in the paper.

B. Measurement of Competitiveness' factors by Factor Analysis

For utilization of above mentioned sources, set of 66 variables was compiled. In order to ensure comparability between different countries, all variables have to be relativized, and these variables thus entered into analysis. Firstly, it was necessary to obtain the correlation matrix between each of our variables and exclude variables do not meet specific requirements placed on input data in using of factor analysis. In process of data pre-processing is necessary to make their standardization (normalization), thus to unify their standards. The most commonly used method of standardization is to transform data into *Z-scores*. Unlike the original data matrix, *Z-score matrix* is a matrix of zero averages and unit standard deviations of all variables, which is ideal for processing by factor analysis method. Based on used data standardization method, Pearson's correlation coefficient was chosen as a measure of correlation. The ideal would be case in which correlation degree of variables do not fall below 0.3. Like would not fall below 0.3, correlation coefficients should appropriate variables or vice versa exceed 0.9. On basis of defined conditions, database consists of *38 indicators – 23 input* and *15 output indicators*, thus *15 variables for inputs* and *13 variables for outputs were excluded*. Database and excluded variables (illustrated by crossed font) are shown in Table I and Table II in Appendix.

After a relatively lengthy and complex process of variables selection, the core of factor analysis follows. Statistical package SPSS (in our case IBM SPSS Statistics – Version 20) provides a wide range of methods for factors extraction. In this paper was chosen specifically modified method of principal components because of higher number of variables. By its application to input set of variables, an estimate of the factor/component matrix (often called also as a matrix of factor loads) was provided. Content of matrix of factor loads are values of correlation coefficients between individual variables and now firmly specified number of factors. This number has been predefined in input parameters by determining the value of own number to a value greater than 1.0. Own number (eigenvalue) of a particular factor indicates the amount of total variability explained by just this factor. Very frequently criterion for finding the optimal number of factors, the percentage of total variance explained collectively by selected factors, is used. For an imaginary boundary of quality solution is widely accepted 70 % of explained variability. In our case, five dominating factors for inputs explained 100 % of total variability in years 2000, 2005 and 2010, which can be considered as very satisfactory result. In the case of outputs, four dominating factors explained *95,168 % of total variability in year 2000, 98,558 % of total variability in year 2005* and *94,188 % of total variability in year 2010*, which can be considered also as very satisfactory results. These results are illustrated in Appendix – in Tables III, IV, V, VI, VII and VIII.

The optimal number of factors is already known, their interpretation still proceed not. One of yet unnamed conditions is that each factor has influence the most of variables, while each of variables, if it is possible, and should depend on the fewest number of factors. Further step is to rotate of factors or factorial axes, which task is just to maximize the load of each variable in one of the extracted factors, while her loads under other factors are substantially minimized. In the paper we used *Varimax method of rotation*, which rotates the coordinate axes in the direction of maximum variance. The matrix of factor loads, rotated just by this method, Tables III, IV, V, VI, VII and VIII in Appendix offer. These tables also clearly show that target of rotation (to find concise and more favourable interpretation of solution) was almost completely fulfilled. Only a few variables are now characterized by high loads in more than one factor and the total structure of factor matrix is considerably simplified. For interpretation, those variables were identified as relevant, factor loadings exceeded the 0.4. This frontier was marked as convenient by Stevens [24]. Jurisdiction of inputs and outputs to relevant factors is illustrated by grey colour in Tables III, IV, V, VI, VII and VIII in Appendix. Based on results of correlation and factor analysis, we could proceed to cluster analysis and DEA method. Indicators for inputs and outputs, depending on their level of significance for competitiveness of evaluated countries, these indicators were divided by results of factor analysis in 2000, 2005 and 2010.

C. Evaluation of national efficiency by DEA method

The initial hypothesis of efficiency being a mirror of competitive potential was confirmed through analysis as illustrated in following Table III and Table IV. In the case of national efficiency evaluation was found out that in used DEA models were comparable results in all V4 countries, but also in Austria and Germany. Table III presents a comparison of efficiency evaluation of V4 countries in comparison with Austria and Germany by CCR, BCC, SBM, FDH and FRH models. *At national level, it is evident that levels of efficiency of individual V4 countries are on average lower in CCR models than in BCC, FDH and FRH models* (except Austria and Germany, which were evaluated to be efficient in all models during the referred period). *This fact confirms theory that in BCC models with VRS, the coefficients of efficiency reach higher values and higher number of evaluated DMUs is classified as efficient. This has been also confirmed in SBM models with VRS by higher number of evaluated units identified as efficient compared to SBM models with CRS. This fact is also confirmed in FDH and FRH models*, because these models relatively compare inputs and outputs of evaluated countries towards really existing countries, and not to virtual country.

The overall evaluation of efficiency of V4 countries, Austria and Germany shows that the best results achieved 2, respectively 3 of 6 countries during the period 2000-2010. The best results are predictably achieved by economically powerful countries which were *efficient* during the whole referred period; see Table III and Table IV. It means that the outputs achieved were greater than incurred inputs. Ratio of inputs and outputs is in an optimum and there is no requirement to change them. These countries were *efficient* in both *CCR* and *BCC inputs/outputs oriented models*, as well as in *SBM*, *FDH* and *FRH models*, and therefore, according to hypothesis, should have the *greatest competitive potential*. Efficient countries are highlighted by dark grey colour in Table III. These countries are *Austria* and *Germany*. The Czech Republic was evaluated also as effective, but only in *BCC models*, *SBM model with VRS* and *FDH models*.

The efficient countries are followed by a group of countries which are also *highly efficient*. These countries do not achieved efficiency equal to 1 in *CCR, BCC, FDH* and *FRH models* or low sum of values of additional variables in *SBM* models, but their efficiency indices reached consistently highly effective values close during the referred period (coloured by light grey colour in Table III). These countries are Slovakia and Poland in all used models, thus *CCR, BCC, SBM, FDH and FRH models*. In the case of *CCR models*, *SBM model with CRS* and *FRH models*, the Czech Republic was evaluated also as *highly efficient.*

Only Hungary *was classified as inefficient in all used DEA models,* so it shows low competitive potential and development perspective (coloured by ultra-light grey colour and italics in Table III).

Table IV shows position of individual V4 countries and Austria and Germany within selected models in terms of the order of achieved average values of efficiency coefficients in CCR, BCC, FDH and FRH models or sum of values of additional variables in SBM models over the period 2000-2010. The overall evaluation of individual countries shows that the best results, in terms of efficiency in all used DEA models, *Austria* and *Germany* have reached and are ranked in *first place* during the whole period. These countries thus effectively utilize their competitive advantages and have the highest development potential. In *second place*, there is *the Czech Republic*, which was evaluated as highly efficient, as it has reached full level of efficiency in BCC and FDH models, also in SBM model with VRS, and high level of efficiency in CCR and FRH models, in SBM model with CRS too. *Slovakia* and *Poland* are ranked in *third* and *fourth place* because they have reached the lower values of efficiency coefficients in CCR, BCC, FDH and FRH models, and higher sum of values of additional variables in SBM models. *Hungary* was ranked in *last – fifth place*, because it was classified as *inefficient* and reached the lowest values of efficiency coefficients in CCR, BCC FDH and FRH models, and the highest sum of values of additional variables in SBM models.

It is necessary to note that 'old' EU Member States, thus Austria and Germany, reached comparable and balanced values for the referred period. Development in 'new' EU Member States, thus in V4 countries, has a convergence trend towards 'old' ones. There was a growth in their performance, increasing trend in effective use of their advantages and improve in competitive position. Most countries experienced also a decline in their performance (outputs decline as a result of declines in inputs) as a result of economic crisis. This is proved by a decrease in the efficiency index.

Table III Comparison of Efficiency in DEA Models for V4, Austria, Germany

Country	DEA MODELS									
	CCR IO	**CCR OO**	**BCC IO**	**BCC OO**	**SBM CRS**	**SBM VRS**	**FDH IO**	**FDH OO**	**FRH IO**	**FRH OO**
	CE*	CE*	CE*	CE*	CE*	CE*	CE*	CE*	CE*	CE*
AT	1,000	1,000	1,000	1,000	0	0	1,000	1,000	1,000	1,000
DE	1,000	1,000	1,000	1,000	0	0	1,000	1,000	1,000	1,000
CZ	0,995	1,009	1,000	1,000	3 867	0	1,000	1,000	0,997	0,999
HU	*0,910*	*1,075*	*0,940*	*1,057*	*1 422 912*	*246 397*	0,950	0,950	*0,940*	*0,950*
PL	0,950	1,052	0,969	1,030	45 882	27 901	0,975	0,980	0,970	0,975
SK	0,975	1,028	0,980	1,015	16 493	9 617	0,989	0,990	0,980	0,985

Note: * Coefficient of efficiency = average efficiency rate of country in period 2000-2005-2010
IO = input oriented model, OO = output oriented model
Source: Own calculation and elaboration, 2012

Table IV Ranking of V4, Austria, Germany in DEA Models by Values of CEs

Country	DEA MODELS											
	CCR IO	**CCR OO**	**BCC IO**	**BCC OO**	**SBM CRS**	**SBM VRS**	**FDH IO**	**FDH OO**	**FRH IO**	**FRH OO**	**Average Rank of Country***	**Absolute Rank of Country***
	Rank	Rank	Rank	Rank	Rank	Rank	Rank	Rank	Rank	Rank		
AT	1	1	1	1	1	1	1	1	1	1	1,0	**1.**
DE	1	1	1	1	1	1	1	1	1	1	1,0	**1.**
CZ	2	2	1	1	2	1	1	1	2	2	1,5	**2.**
HU	5	5	4	4	5	4	4	4	5	5	4,5	**5.**
PL	4	4	3	3	4	3	3	3	4	4	3,5	**4.**
SK	3	3	2	2	3	2	2	2	3	3	2,5	**3.**

Note: * Average and absolute ranking of countries is based on their rank in DEA models in period 2000-2005-2010
IO = input oriented model, OO = output oriented model
Source: Own calculation and elaboration, 2012

According to the use of the minimization-based Malmquist productivity index in this paper, therefore, if it was equal to 1, signifies no change in performance, if bigger than 1 it shows performance getting worse, and in the case it is less than 1 it signifies performance advancement. The amount of total productivity elements of all evaluated countries in years 2005 and 2010 in comparison with basic year 2000 is shown in Table V. In Table V is also illustrated the productivity change occurred between evaluated periods, i.e. the between 2000-2005 and 2005-2010 compared to previous period, not to basis period. Considering the information of Table V, all evaluated countries have the total productivity decrease through the whole time period because the level of MI/MPI is higher than 1 (except Austria's increase in time period 2000-2005). By analysing the elements of evaluated countries' MI/MPI, we can see that technical efficiency change (TEC) equals 1 and meaning no change. The shift in the possibility frontier (FS) is higher than 1 (and so have increasing trend), thus countries delaying the possibility frontier (except in Austria in time period 2000-2005 – there is opposite trend).

The worst performance was produced by Hungary because its total productivity was the lowest through the whole time period, *Hungary* has placed at last – *sixth position*. But Hungary's MI/MPI was decreasing across time periods, thus illustrating positive trend. Hungary's TEC change equals 1 and meaning no change. Hungary's FS is higher than one (but has a decreasing trend), so Hungary gradually slow approximates the possibility frontier.

The worst productivity growth was recognized also in Slovakia which illustrated the worst performance change and productivity trend and *Slovakia* thus has placed at *fifth position*. Through analysing the elements of Slovakia's MI/MPI it is clear that its TEC equals 1 so no change. The shift in the possibility frontier is higher than 1 (and has an increasing trend), Slovakia delaying the possibility frontier. In the case of Slovakia is clear the highest deterioration in performance in year 2010 compared to year 2000.

Czech Republic and Poland have recognized similar values of MI/MPI. *Poland* has illustrated slight deterioration in performance during reference period and it has placed at *fourth position*. Poland's TEC equals 1 so no change. The shift in the possibility frontier is higher than 1 (and has a increasing trend), Poland thus delaying the possibility frontier. *Czech Republic* has recognized slight improvement in performance during reference period, and thus has placed at *third position*. Czech Republic has illustrated the best results of all V4 countries. TEC of Czech Republic equals 1 so no change. The shift in the possibility frontier is higher than 1 (and has a decreasing trend), Czech Republic thus very slowly approximates the possibility frontier.

Germany and Austria have also illustrated very similar values of MI/MPI. *Germany* has recognized very balanced trend in performance development across reference period and it has placed at *second place*. Germany's TEC equals 1 so no change. The shift in the possibility frontier is higher than 1 (and has a decreasing trend), Germany thus approximates the possibility frontier very slowly, resp. moving more or less the same level. Austria has illustrated the best performance of all evaluated countries and thus *Austria* is placed at *first position*. Austria's TEC change equals 1 and meaning no change. Austria's FS is higher than 1 (and has a increasing trend), Austria thus delaying the possibility frontier. Compared Austria and Germany in period 2000 and 2010, it is necessary to note, that Germany has recognized lower level of MI/MPI than Austria's. Austria thus has illustrated significant decrease of productivity in this period, because it is only one country which has MI/MPI below 1 (in period 2000 and 2005) in the whole reference period.

Table V Overall Productivity of Countries Based on Malmquist Index in 2000-2005-2010.

Country/Time		**1. Period 2000-2005**			**2. Period 2005-2010**			**3. Period 2000-2010**		
No.	**Country**	**IO CCR CRS MI***	**TEC**	**FS**	**IO CCR CRS MI***	**TEC**	**FS**	**IO CCR CRS MI***	**TEC**	**FS**
1	AT	**0,93944**	1,00000	0,93944	**1,44783**	1,00000	1,44783	**1,56376**	1,00000	1,56376
2	CZ	**2,40284**	1,00000	2,40284	**2,14987**	1,00000	2,14987	**2,17382**	1,00000	2,17382
3	DE	**1,41060**	1,00000	1,41060	**1,29947**	1,00000	1,29947	**1,44304**	1,00000	1,44304
4	HU	**6,84979**	1,00000	6,84979	**2,28662**	1,00000	2,28662	**5,05474**	1,00000	5,05474
5	PL	**2,46138**	1,00000	2,46138	**1,72731**	1,00000	1,72731	**2,89633**	1,00000	2,89633
6	SK	**1,09512**	1,00000	1,09512	**3,74183**	1,00000	3,74183	**3,16362**	1,00000	3,16362

Note: * IO CCR CRS MI = Malmquist Index of Input Oriented CCR Model with CRS
Source: Own calculation and elaboration, 2012

These facts indicate that all V4 countries, Austria and Germany have faced a noticeable performance decline during reference period 2000-2005-2010. Slight improvement in overall efficiency was illustrated in most evaluated countries between period 2005 and 2010 (except Austria and Slovakia). Prevailing deteriorating results in performance is especially apparent in comparing years 2000 and 2010, which corresponds to the real facts, because all countries to cope with consequences of the economic crisis. Based on analysis' results it is possible to state, there is significant differences in efficiency trend between Germany and Austria on the one side and Visegrad Four countries on the other side.

I. Conclusion

Competitiveness, performance and efficiency are complementary objectives, which determine the long-term development of countries and regions. These are also concepts that cannot be avoided in economic theory and practice. Evaluation of competitiveness, performance and efficiency can be performed only if we use existing concept of these terms or selected mainstream. Because of the fact that there is no mainstream in competitiveness, performance and efficiency evaluation, especially at regional level, there is space for alternative approach in this area. It is necessary to note that using different approaches to evaluation generate different results. This is logical and predictable. It cannot be expected that different approaches lead to identical conclusions about the level of competitiveness, performance and efficiency. Many methods and approaches to competitiveness, performance and efficiency evaluation are (to a certain extent) incomparable, and therefore their results must be taken into account individually. A certain degree of individual assessment should therefore apply in terms of concrete results (and order) of individual V4 countries. But it is necessary to note, that national efficiency, as a mirror of performance, is based on competitive potential of individual regions.

Based on factor analysis and DEA method has been found out that in evaluated countries is a *distinct gap* between economic and social standards, so *differences still remain*. Measuring the Malmquist productivity index on the basis of the DEA method is an important method which has many applications. This index has been used in this paper to analyse and evaluate performance of individual V4 countries, Austria and Germany in period 2000-2005-2010. Regarding the findings and the analysis each country can decide whether it had a productivity increase during the time period, or not. By having this information and dividing productivity into its elements, the basic trend in productivity whether it be increase or decrease is observed. According to the Malmquist index results, it is necessary to note that in all evaluated countries was mostly achieved noticeable productivity decreases and thus performance deteriorating during reference period. Development in V4 countries has a trend towards advanced Austria and Germany. Most countries experienced decline in their performance (outputs decline as a result of declines in inputs) as a result of economic crisis. The recent economic crisis has seriously threatened the achievement of sustainable development in the field of competitiveness. The crisis has underscored importance of competitiveness – supporting economic environment to enable national economies to better absorb shocks and ensure solid economic performance going into the future.

APPENDIX

Table I Indicators of Inputs in Period 2000-2005-2010 Relevant to Factor Analysis

Dimension	Pillar	Indicator*
Inputs	1. Institution	In: **Political Stability** Out: ~~Voice and Accountability~~, ~~Government Effectiveness, Regulatory Quality, Rule of Law, Control of Corruption~~
	2. Macroeconomic Stability	In: **Harmonized Index of Consumer Prices, Gross Fixed Capital Formation** Out: ~~Income, Saving and Net Lending/Net Borrowing~~, ~~General Government Gross Debt, Total Intramural Research & Development Expenditure, Labour Productivity per Person Employed~~
	3. Infrastructure	In: **Railway transport - Length of Tracks, Air Transport of Passengers, Volume of Passenger Transport, Volume of Freight Transport** Out: ~~Motorway Transport -Length of Motorways, Air Transport of Freight~~
	4. Health	In: **Healthy Life Expectancy, Infant Mortality Rate, Cancer Disease Death Rate, Heart Disease Death Rate, Suicide Death Rate** Out: ~~Hospital Beds, Road Fatalities~~
	5. + 6. Primary, Secondary and Tertiary Education, Training and Lifelong Learning	In: **Mathematics-Science-Technology Enrolments and Graduates, Pupils to Teachers Ratio, Financial Aid to Students, Total Public Expenditure at Primary Level of Education, Total Public Expenditure at Secondary Level of Education, Total Public Expenditure at Tertiary Level of Education, Participants in Early Education, Participation in Higher Education, Early Leavers from Education and Training, Accessibility to Universities** Out: ~~Lifelong Learning~~
	9. Indicators for Technological Readiness	In: **Level of Internet Access** Out: ~~E-government Availability~~

Note: * Number of indicators was decreased after correlation from 38 to 23
Source: [1]; own calculation and elaboration, 2012

Table II Indicators of Outputs in Period 2000-2005-2010 Relevant to Factor Analysis

Dimension	Pillar	Indicator*
Outputs	7. Labour Market Efficiency	In: **Labour productivity, Male employment, Female employment, Male unemployment, Female unemployment, Public expenditure on Labour Market Policies** Out: ~~Employment rate, Long-term unemployment, Unemployment rate~~
	8. Market Size	In: **Gross Domestic Product** Out: ~~Compensation of employees, Disposable income~~
	10. Business Sophistication	In: **Gross Value Added in sophisticated sectors, Venture capital (expansion- replacement)** Out: ~~Employment in sophisticated sectors, Venture capital (investments early stage)~~
	11. Innovation	In: **Human resources in Science and Technology, Total patent applications, Employment in technology and knowledge-intensive sectors, Employment in technology and knowledge-intensive sectors-by gender, Employment in technology and knowledge-intensive sectors-by type of occupation, Employment in technology and knowledge-intensive sectors-by level of education** Out: ~~Human resources in Science and Technology – Core, Patent applications to the EPO, Total intramural R&D expenditure, High-tech patent applications to the EPO, ICT patent applications to the EPO, Biotechnology patent applications to the EPO~~

Note: * Number of indicators was decreased after correlation from 28 to 15
Source: [1]; own calculation and elaboration, 2012

Table III Explanation of Total Variance and Rotated Component Matrix for Inputs in Year 2000

Year	2000		
Component	Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %
1	7,014	30,497	30,497
2	5,008	21,772	52,269
3	4,638	20,164	72,433
4	4,375	19,022	91,455
5	1,965	8,545	**100,000**

	Component				
	1	2	3	4	5
Zscore(HICP)	-,969				
Zscore(CDDR)	-,947				
Zscore(SDR)	-,889				
Zscore(MSTEG)	,815				
Zscore(GFCF)	,807				
Zscore(LIA)	,800	,476			
Zscore(VFT)	-,679				
Zscore(AU)	-,586			,533	
Zscore(FAS)		,968			
Zscore(ATP)	,494	,823			
Zscore(PS)	,543	-,818			
Zscore(PTR)	,496	,670			
Zscore(TPESLE)			,977		
Zscore(HDDR)			-,940		
Zscore(TPETLE)			,822		
Zscore(ELET)		,687	,708		
Zscore(PEE)		,523	,590		
Zscore(VPT)				,924	
Zscore(RTLT)				,862	
Zscore(TPEPLE)		-,503		,761	
Zscore(PHE)				,753	
Zscore(HLE)				,750	,544
Zscore(IM)					-,873

Source: Own calculation and elaboration, 2012

Table IV Explanation of Total Variance and Rotated Component Matrix for Inputs in Year 2005

Year	2005		
Component	Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %
1	6,131	27,868	27,868
2	4,880	22,180	50,047
3	4,279	19,450	69,497
4	3,976	18,072	87,569
5	2,735	12,431	**100,000**

	Component				
	1	2	3	4	5
Zscore(PHE)	,949				
Zscore(PS)	-,903				
Zscore(AU)	,853	-,425			
Zscore(HDDR)	,820		,542		
Zscore(GFCF)	-,690		,408		,546
Zscore(TPEPLE)	,674	-,545	,409		
Zscore(HLE)	,664		,466	-,584	
Zscore(PEE)	-,655		-,403		,595
Zscore(SDR)		-,959			
Zscore(MSTEG)		,944			
Zscore(PTR)		,943			
Zscore(TPETLE)			,913		
Zscore(FAS)			-,866		
Zscore(CDDR)		-,535	-,731		
Zscore(VPT)	,533		,677		
Zscore(ELET)				,939	
Zscore(ATP)		,586		,772	
Zscore(LIA)		,432	,572	,679	
Zscore(VFT)	,568			,660	
Zscore(RTLT)	,590	,481		,632	
Zscore(IM)					-,915
Zscore(TPESLE)				,472	,654
Zscore(PHE)	,949				

Source: Own calculation and elaboration, 2012

Table V Explanation of Total Variance and Rotated Component Matrix for Inputs in Year 2010

Year	2010				
Component	Rotation Sums of Squared Loadings				
	Total	% of Variance	Cumulative %		
1	7,014	30,497	30,497		
2	5,008	21,772	52,269		
3	4,638	20,164	72,433		
4	4,375	19,022	91,455		
5	1,965	8,545	**100,000**		
	Component				
	1	2	3	4	5
Zscore(HICP)	,949				
Zscore(CDDR)	-,903				
Zscore(SDR)	,853				
Zscore(MSTEG)	,820				
Zscore(GFCF)	-,690				
Zscore(LIA)	,674	,476			
Zscore(VFT)	,664				
Zscore(AU)	-,655			,533	
Zscore(FAS)		-,959			
Zscore(ATP)	,494	,944			
Zscore(PS)	,543	,943			
Zscore(PTR)	,496	,670			
Zscore(TPESLE)			,913		
Zscore(HDDR)			-,866		
Zscore(TPETLE)			-,731		
Zscore(ELET)		,687	,697		
Zscore(PEE)		,523	,590	,939	
Zscore(VPT)				,772	
Zscore(RTLT)				,679	
Zscore(TPEPLE)		-,503		,660	
Zscore(PHE)				,632	
Zscore(HLE)				,939	-,915
Zscore(IM)					,654

Source: Own calculation and elaboration, 2012

Table VI Explanation of Total Variance and Rotated Component Matrix for Outputs in Year 2000

Year	2000			
Component	Rotation Sums of Squared Loadings			
	Total	% of Variance	Cumulative %	
1	5,091	33,938	33,938	
2	4,367	29,111	63,049	
3	2,860	19,067	82,116	
4	1,958	13,052	**95,168**	
	Component			
	1	2	3	4
Zscore(FU)	-,944			
Zscore(MU)	-,907			
Zscore(EiTaKIS)	,755			,408
Zscore(ETKIgen)	,731			,460
Zscore(ME)	,719		-,441	
Zscore(LP)	,714	,482	-,506	
Zscore(GDP)	,659	,611	-,432	
Zscore(FE)	,622		-,531	,437
Zscore(GVA)		,988		
Zscore(TPAp)		,954		
Zscore(PEoLMP)		,919		
Zscore(HRST)		,817		,455
Zscore(VCexp)			,949	
Zscore(ETKIocc)			,850	
Zscore(ETKIedu)				,932

Source: Own calculation and elaboration, 2012

Table VII Explanation of Total Variance and Rotated Component Matrix for Outputs in Year 2005

Year	2005			
Component	Rotation Sums of Squared Loadings			
	Total	% of Variance	Cumulative %	
1	4,991	33,274	33,274	
2	4,232	28,211	61,485	
3	4,221	28,138	89,622	
4	1,340	8,935	**98,558**	
	Component			
	1	2	3	4
Zscore(ME)	,922			
Zscore(FE)	,882	,449		
Zscore(MU)	-,826		-,422	
Zscore(FU)	-,817		-,472	
Zscore(LP)	,797	,555		
Zscore(GDP)	,769	,592		
Zscore(GVA)		,982		
Zscore(TPAp)		,936		
Zscore(PEoLMP)		,856		
Zscore(HRST)	,618	,742		
Zscore(ETKIedu)			,977	
Zscore(ETKIocc)			,959	
Zscore(EiTaKIS)			,932	
Zscore(ETKIgen)			,932	
Zscore(VCexp)				,937

Source: Own calculation and elaboration, 2012

Table VIII Explanation of Total Variance and Rotated Component Matrix for Outputs in Year 2010

Year	2010			
Component	Rotation Sums of Squared Loadings			
	Total	% of Variance	Cumulative %	
1	6,456	43,039	43,039	
2	2,699	17,993	61,032	
3	2,615	17,433	78,464	
4	2,359	15,724	**94,188**	
	Component			
	1	2	3	4
Zscore(FE)	,959			
Zscore(GDP)	,949			
Zscore(ME)	,936			
Zscore(FU)	-,899			
Zscore(LP)	,892			
Zscore(MU)	-,857			
Zscore(PEoLMP)	,837			
Zscore(HRST)	,714	,623		
Zscore(TPAp)		,955		
Zscore(GVA)	,410	,878		
Zscore(ETKIgen)			,989	
Zscore(EiTaKIS)			,973	
Zscore(ETKIocc)				,917
Zscore(VCexp)			,470	-,850
Zscore(ETKIedu)			,580	,683

Source: Own calculation and elaboration, 2012

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