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GROWTH IN EUROPE: DECOMPOSITION AND HUMAN CAPITAL CONTRIBUTION

Abstract

Keywords: economic growth, human capital, data envelopment analysis, SBM model, decomposition

The role of human capital for economic growth has been given a massive body of evidence up to the present, mostly employing parametric regression analysis. In this study, a non-parametric data envelopment analysis method is used to identify the type of technological progress in Europe with respect to involvement of human capital over the period of 2000 – 2010. The decomposition procedure is based on the ratios of benchmarks resulting from linear optimization problems, specifically, output-oriented slacked-based DEA models with labour, physical and human capital as inputs producing GDP. The results imply that economic growth is taking place mainly due to technology combining capital, knowledge and labour rather than pure human capital or extensive factors of production accumulation. The implementation for European integration policies should thus involve putting more stress on factors facilitating synergy effects rather than pursuing particular goals.

INTRODUCTION

There is a massive body of research proving the role of variously defined human capital in creating the economic value. Microeconomic studies concentrate on human capital impact on productivity of the firm while on the macrolevel, the focus is placed on the quantification of the contribution of human capital (HK) to economic growth. Endogenous theory of growth considers HK being the main driver of economic development. Productivity studies have been incorporating HK into exogenously determined growth since Mankiw, Romer & Weil (1992). All these approaches exploit parametric functional relationship between inputs and the output. All economic subjects are considered efficiently producing the maximal output prescribed by the production function whereas deviations can be caused by other factors than included in the model. Taking alternative approach viewing input and output data as deterministic and barely a result of the production process, one can speak of efficiency of transformation of the inputs into the output or even multiple outputs. The core of non-parametric approach is thus to determine whether a unit under consideration transforms its inputs efficiently or not with respect to a given set of assessed subjects. The method of Data Envelopment Analysis (DEA) was pioneered by Charnes, Cooper & Rhodes (1978) giving rise to a number of modifications of the basic model.

In non-parametric studies, Henderson & Russell (2005), HR hereafter, decomposition method is noticeable determining contribution of HK to productivity change worldwide. Borrowing their idea and focusing on coefficient of growth rather than on productivity on the national level, the aim of this study is to identify factors contributing to growth and pointing out the human capital contribution in particular. In contrast to HR, we explore European countries in the span of 2000 – 2010. Another difference is type of DEA model employed. We use slack-based model which does not suffer from the problem of *weak efficiency* present in radial models used by HR.

We proceed by giving general picture of DEA and introducing efficiency assessment via slack-based (SBM) model in Sections 1.1 and 1.2. Decomposition based on HR is theoretically elaborated in 1.3 followed by the description of approach to averaging across units. Data, variables and models are described in Section 2. Section 3 presents condensed results. Section 4 briefly discusses and concludes.

1. ASSESSMENT METHOD: DEA MODEL

1.1. Basic concepts and notation

In standard DEA subjects being evaluated are called Decision Making Units (DMUs). These are viewed as transforming *m* inputs into *s* outputs. Inputs and outputs are organized in matrices *X* and *Y*, element x_{ij} meaning amount of input *i* used by DMU *j*, the similar way for outputs in *Y*.

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ . & . & \cdots & . \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix}, \quad Y = \begin{bmatrix} y_{11} & y_{12} & \cdots & y_{1n} \\ y_{21} & y_{22} & \cdots & y_{2n} \\ . & . & \cdots & . \\ y_{s1} & y_{s2} & \cdots & y_{sn} \end{bmatrix}$$

in DEA, no specific form of production (transformation) function is assumed. Instead of that, the empirical production possibility set boundary is constructed as the set of linear combinations of the data of DMU under consideration. Thus, some unit can appear inefficient as one observes that actual activity of one DMU is outperformed by a composite unit formed as a linear combination of some other DMUs. Once DMU cannot increase one of the outputs without increasing at least one input or decreasing other output, it is efficient in Pareto-Koopmans interpretation.

Given matrices *X* and *Y*, for every DMU$_0$ the following expressions hold:

$$\begin{aligned} \mathbf{x_0} &\geq X\boldsymbol{\lambda} \\ \mathbf{y_0} &\leq Y\boldsymbol{\lambda}, \ \boldsymbol{\lambda} \geq 0 \end{aligned} \tag{1.1}$$

Thus production possibility set is described by inequations (1.1), its frontier constitute linear combination of the efficient DMUs “enveloping” the observed data.

There is a variety of approaches as regards quantifying inefficiency with respect to the efficiency boundary, the problem amounts to measuring distance to the frontier.

1.2. SBM measure of efficiency

The most comprehensive measure of efficiency requires introducing input and output *slack* variables. In DEA, slacks act as exact measure of deviation from the frontier which stands to describe best practice available given the technology. The meaning of slacks in DEA differs from that in managerial science where it could be less exact and have more qualitative substance. Inequalities (1.1) can be then rewritten as

$$\begin{aligned} \mathbf{x_0} &= X\boldsymbol{\lambda} + \mathbf{s}^- \\ \mathbf{y_0} &= Y\boldsymbol{\lambda} - \mathbf{s}^+ \end{aligned} \tag{1.2}$$

Output and input slack variables can be seen as a potential for underperforming units which can be reached by increasing output by $\mathbf{s}^+$ and/or reducing inputs by $\mathbf{s}^-$.

The slack-based model (SBM) introduced by Tone (2001) is one of the powerful developments to capture all sources of inefficiency. The objective function ρ which measures a “distance” of the DMU to the frontier has two important properties of unit invariance and monotonicity.

Efficiency assessment is obtained by solving a fractional program

$$\begin{aligned} \min_{\boldsymbol{\lambda},\mathbf{s}^+,\mathbf{s}^-} \quad & \rho = \frac{1-\frac{1}{m}\sum_{i=1}^{m} s_i^- / x_{i0}}{1+\frac{1}{s}\sum_{r=1}^{s} s_r^+ / y_{r0}} \\ \text{s.t.} \quad & \mathbf{x_0} = X\boldsymbol{\lambda} + \mathbf{s}^- \\ & \mathbf{y_0} = Y\boldsymbol{\lambda} - \mathbf{s}^+ \\ & \boldsymbol{\lambda} \geq 0,\ \mathbf{s}^- \geq 0,\ \mathbf{s}^+ \geq 0 \end{aligned} \tag{1.3}$$

which can be linearized and solved for slacks and **λ**. As described in the section 1.1, optimal non-zero solutions for λ define set of indexes of efficient DMUs with all slacks equal zero. Thus the measure of efficiency for efficient DMUs is equal one. Every inefficiency represented by slacks is penalized forcing $\rho < 1$.

To give the model input orientation in order to reflect preferences and feasibility of the policy, output slacks are omitted in the objective function of 1.3. SBM output oriented model assuming constant returns to scale takes the form of

$$\begin{aligned} \max \quad & \rho = 1+\frac{1}{m}\sum_{i=1}^{m} s_i^+ / x_{i0} \\ \text{s.t.} \quad & \mathbf{x_0} = X\boldsymbol{\lambda} + \mathbf{s}^- \\ & \mathbf{y_0} = Y\boldsymbol{\lambda} - \mathbf{s}^+ \\ & \boldsymbol{\lambda} \geq 0,\ \mathbf{s}^- \geq 0,\ \mathbf{s}^+ \geq 0 \end{aligned} \tag{1.4}$$

After determining relevant input and output variables, this measure can be used to assess efficiency of DMUs. For inefficient DMUs, a benchmark suggesting the potential improvement is determined by the projection onto the efficiency frontier given the observed values of output $\mathbf{y}_0$ of the DMU_0 under consideration.

$$\hat{\mathbf{y}}_0 \Leftarrow \mathbf{y}_0 + \mathbf{s}^{+0} \tag{1.5}$$

Thus, solving DEA model results provide efficiency scores for each unit of assessment as well as maximum potential for improvement. One speaks of projection of the actual values onto the efficiency frontier. Obviously, zero slacks imply efficiency (score = 1) and the actual inputs or outputs of the efficient DMU project onto themselves.

1.3. Decomposition of growth coefficient

The key purpose of the decomposition method is to separately describe three "movements" of the DMU with respect to efficiency frontier over time:

(1) technology change – *frontier-shift* movement
(2) *catch-up* – movement towards or away from the frontier
(3) factors accumulation – movement along the frontier.

Relative magnitude of these effects can help interpret the nature of the technology change – whteher there is an input-saving technological improvement exploiting better use of technical inputs to increase eco-efficiency or environment- saving technology which enables to produce more output while reducing pollution.

Referring to the work of Henderson and Russell (2005, HR hereafter), we set out defining indicator subject to decomposition. Contrasted to HR focusing on productivity, we analyze the economic growth expressed as ratio of outputs in two different periods of time. Intertemporal change between starting period 1 and the period 2 and indexing variables with respective numbers, the ratio of the interest is Y_2/Y_1. Output $Y(K,L,H)$ is viewed as the outcome of transformation of macroeconomic inputs – capital stock K, labour L, and human capital H. Employing DEA, one can compute efficiency scores as optimal values of (1.3) or (1.4). Observed values of Y can be expressed by means of the benchmarks indicated by bar and obtained from (1.5) :

$$\frac{Y_2}{Y_1} = \frac{e_2}{e_1} \cdot \frac{\overline{Y}_2(K_2,L_2,H_2)}{\overline{Y}_1\ (K_1,L_1,H_1)}$$

For inefficient DMUs is the actual value obviously below the potential since efficiency is lower than unit. The following step consists in multiplying numerator and denominator by the terms $\overline{Y}_1(K_2,L_2,H_1)$ and $\overline{Y}_1(K_1,L_1,H_2)$ which would represent counterfactual situations of achieving the first-period benchmark by means of K and L at the levels of period 2, and achieving the first-period benchmark by raising H to the level of the period 2.

$$\frac{Y_2}{Y_1} = \frac{e_2}{e_1} \cdot \frac{\overline{Y}_2(K_2,L_2,H_2)}{\overline{Y}_1\ (K_1,L_1,H_1)} \cdot \frac{\overline{Y}_1(K_2,L_2,H_1)}{\overline{Y}_1\ (K_2,L_2,H_1)} \cdot \frac{\overline{Y}_1(K_1,L_1,H_2)}{\overline{Y}_1\ (K_1,L_1,H_2)}$$

After rearranging one obtains

$$\frac{Y_2}{Y_1} = \frac{e_2}{e_1} \cdot \frac{\overline{Y}_2(K_2,L_2,H_2)}{\overline{Y}_1(K_2,L_2,H_2)} \cdot \frac{\overline{Y}_1(K_2,L_2,H_1)}{\overline{Y}_1\ (K_1,L_1,H_1)} \cdot \frac{\overline{Y}_1(K_2,L_2,H_2)}{\overline{Y}_1\ (K_2,L_2,H_1)} \tag{1.6}$$

The first factor in decomposition represents efficiency change over time, it is the ratio of efficiency scores. In the second term, factors of production are held fixed at the period 2 level, yet
Third, the effect of changing levels of K and L producing fixed level of output Y is reflected. The last term captures effect of change in H, i.e. human capital accumulation (from H_1 to H_2) while keeping K and L fixed. We denote respective factors EFF, TECH, KLACC and HACC. Thus, output ratio can be written as

$$\frac{Y_2}{Y_1} = EFF \times TECH \times KLACC \times HACC$$

The latter formula enables to calculate four decomposition terms for each DMU (country) which can provide insight for decision-making in particular countries. To assess overall Europe-wide effects of the production factors, some kind of averaging would be required.

1.4. Averaging

The simplest possibility to average factors determined in the previous section is to take simple arithmetic mean. One could though argue that if size of the economy matters, weighted average should be taken, weights being labour employed or output produced. To get over arbitrariness of determining weights we take the following approach.

To obtain average value of efficiency and other decomposition factors for EU, we construct an artificial DMU with inputs and output equal the sum of those of individual countries. Thus, the joint output, capital stock or labour enter the DEA model for assessing Europe´s efficiency among all the constituent economies.

2. DATA AND MODELLING

In our modelling, we consider European countries in two time periods – 2000 and 2010 – transforming two inputs (human-capital-augmented labour and capital) into a single output – GDP. Number of countries involved is 28. Among the EU-28, members we exclude Luxembourg due to outlying data and Croatia due to data on HK availability for the period 1. On the other hand, we include Norway and Switzerland to make a Europe-wide picture more comprehensive. Thus in our setting *n*=28, *m*=2, *s*=1.

2.1. Modelling human capital

Modelling human capital follows Hall & Jones (1999) as labour-augmenting coefficient *H*:

$$\hat{L}_{jt} = H_{jt}L_{jt} = h(\varepsilon_{jt})L_{jt} = e^{\phi(\varepsilon_{jt})}L_{jt}$$

where function □(ε) reflects the relative efficiency of a unit of labour with ε schooling years relative to one with no schooling. Thus if □(0)=0 then *h*(0)=1 and no augmentation of labour takes place.

The derivative $\frac{d \ln h(\varepsilon_{jt})}{d\varepsilon_{jt}} = \phi'(\varepsilon_{jt})$ is the return to schooling. The concrete values are borrowed from estimations in Mincerian regressions provided by Psacharopoulos (2004) where values of returns to educations for primary, secondary, and tertiary schooling are reported. □ is thus a piecewise linear function with segments corresponding to the three educational levels. To complete calculations of H for individual countries, Barro – Lee database values of average years of schooling was used. Difference made by taking HK into account in evaluating technical efficiency of the countries was showed in Nežinský and Fifeková (2014). Obtaining labour-augmenting coefficient *H* from the calculations described above, we employ product *HL* as an input of factor labour in the models.

2.2. Data sources and overview of the models employed

Modelling strategy consists of obtaining results from four models – each providing benchmarks which are subsequently plugged in the expression (1.6). In Pareto-Koopmans interpretation, eco-efficient unit thus cannot produce more output without worsening at least one input, i.e. increasing technical input or pollute more. Data on GDP (PPS) and labour come from Eurostat database. Average years of education are reported in Barro – Lee world database. The data have been used in the models listed in Table 1.

Table 1: Overview of the models and variables

model	type	variables		
		inputs		output
1	SBM-O-C	K_1	H1L1	Y_1
2	SBM-O-C	K_2	H2L2	Y2
3	SBM-O-C	K_2	H2L2	Y1

4	SBM-O-C	K_2	H1L2	Y1

Source: The author´s elaboration

Data on capital come from the database of the European Commission's Directorate General for Economic and Financial Affairs (DG ECFIN) – AMECO. Capital stock is converted into PPS as well. SBM output oriented models assume constant returns to scale. Statistical properties of the data used in model 2 are given in the Table 2, there is a similar variation of *HL* in the other three models.

Table 2: Data properties

	Y2	K2	H2L2
Mean	429900,2	1271212,1	10433,8
Standard Error	113050,5	354151,0	2481,7
Median	193291,0	536000,1	5148,5
Standard Deviation	598207,2	1873990,8	13131,8
Minimum	8168,5	13578,3	232,4
Maximum	2290365,9	6722919,4	54920,5

Source: The author´s elaboration

3. RESULTS

Computation of SBM efficiency measures by a specific model involves computing 29 optimization programs formulated by 1.4 (one program for each DMU – 28 countries plus composite European unit). In Table 3, compacted results of the computations are presented. In the first column, DMUs (countries) are listed, the last row “Average” corresponds to the composite unit described in Section 1.4.The second column contains output ratio as economic growth indicator. Clearly, each economy experienced growth over the period of 2000 – 2010 which translates into the ratio above unit. There is though some variation across countries, the highest growth can be observed in the CEE countries (Slovakia, Romania, Lithuania above 1,5) while developed European countries had been growing moderately at below 1,2.

The coefficient of growth expands to decomposition terms exhibited in columns labelled in line with the description in Section 1.3. Again, individual results for European countries can be read off. In particular, one can notice that individual change in performance is at variance – some economies got closer to the efficiency frontier showing *EFF* > 1 (Czech Republic, Romania and Slovakia at most) while efficiency score of others (Estonia, Latvia, Spain, Germany) deteriorated. The average value is below one implying worsening of the average efficiency over time. *TECH* term measures the shift of the frontier (technology) in the output direction. The values are above unit without exception for each DMU, the same holds for the average. The magnitude is at some variance while the pattern corresponds exactly to the one showing up in the output ratio. Taking a look at the KLACC values one infers on the effect of the extensive factors of production accumulation. For most countries, the terms is below or very close to unit, the exception constitute Cyprus, Spain, Ireland, and Estonia. On average, there is virtually no effect of change in *K* and *L* across Europe. Human capital accumulation effect is expressed in *HACC* values. Being on average very close to one, the most negative effects show Czech Republic, Belgium, Slovenia while Finland, Greece or Germany experienced the positive ones (*HACC* > 1).

CONCLUSION

The study focused on determination and quantification of impacts of particular factors affecting growth. In contrast to parametric approach, the non-parametric one enabled to get efficiency involved in the production process. Decomposition revealed a negligible effect of both extensive factors of production (capital and labour) and human capital. Since the effects of frontier-shift outweigh those of production factor or human capital accumulation extensively, the overall growth is mostly determined just by technology change. Though some critics can be aimed at the human capital measurement or assumption of constant returns to scale, the presented method appears to be useful in approaching this type of questions. In the context of implementation of European policies, it can be concluded that the stress should be put on facilitating synergic effects rather than pursuing particular goals, e.g. in education.

Table 3: Coefficient of growth and decomposition factors

	Y2/Y1	EFF	TECH	KLACC	HACC
Belgium	1,148	1,033	1,148	0,984	0,985
Bulgaria	1,492	0,994	1,513	0,992	1
Czech Republic	1,395	1,309	1,183	0,936	0,963
Denmark	1,061	1,006	1,134	0,930	1
Germany	1,100	0,942	1,151	0,940	1,080
Estonia	1,412	0,854	1,294	1,278	1
Ireland	1,274	0,992	1,142	1,121	1,003
Greece	1,223	0,986	1,141	1,011	1,076
Spain	1,224	0,941	1,128	1,126	1,024
France	1,117	0,959	1,130	1,011	1,020
Italy	1,037	0,980	1,058	1	1
Cyprus	1,321	0,973	1,162	1,201	0,972
Latvia	1,430	0,934	1,516	1,009	1
Lithuania	1,533	1,053	1,516	0,960	1
Hungary	1,212	0,951	1,344	0,948	1
Malta	1,197	1	1,197	1	1
Netherlands	1,142	1,032	1,139	0,977	0,995
Austria	1,160	1,046	1,104	1,009	0,996
Poland	1,465	1,086	1,314	1,026	1
Portugal	1,071	0,955	1,139	0,958	1,028
Romania	1,501	1,296	1,516	0,764	1
Slovenia	1,303	1,049	1,180	1,086	0,970
Slovakia	1,597	1,226	1,428	0,912	1
Finland	1,187	0,997	1,149	0,954	1,086
Sweden	1,238	1,102	1,146	0,979	1,001
United Kingdom	1,177	1	1,151	1	1,022
Norway	1,158	0,984	1,148	1,013	1,013
Switzerland	1,186	1,105	1,128	0,968	0,982
Average	**1,161**	**0,985**	**1,176**	**0,997**	**1,004**

Source: Eurostat, AMECO, Barro-Lee, the author´s calculations

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