NEW MEMBER STATES: EFFICIENCY MEASUREMENT WITHIN THE EU AND HUMAN CAPITAL

Eduard Nežinský,
University of Economics in Bratislava, Slovakia
eduard.nezinsky@euba.sk (corresponding author)

Elena Fifeková
University of Economics in Bratislava, Slovakia
fifekova@gmail.com

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Abstract:
Non-parametrical approach to productivity analysis helps avoid assumption as to specific type of production function. Moreover, slack-based models as part of Data Envelopment Analysis are capable of identifying all sources of inefficiency. In the paper, we show that taking human capital into account in evaluating technical efficiency of economies matters. Employing human capital as labour-augmenting coefficient reveals inefficiency of use of such type of input in many European countries. On the other hand, catching up countries appear to use their human capital effectively, all with respect to selected inputs – physical and human capital, and output proxied by GDP to describe transformation process, the method being decomposition of the overall efficiency measure to components attributable to country and the group.

Keywords: data envelopment analysis, human capital, new EU member states

1. INTRODUCTION

Human capital has been a subject of analysis for quite a long time. First macroeconomic empirical studies starting from Mankiw, Romer & Weil (1992) developed parametric approach to productivity analysis based on Solow model and specifically the assumption of Cobb-Douglas production function. The other strand comprising Henderson & Russell (2005) as an example, employ non-parametric DEA (Data Envelopment Analysis) approach to construct world efficiency frontier and obtain terms attributable to human capital accumulation by decomposition of productivity. In this study, we utilize DEA models to obtain measure of efficiency capturing all sources of inefficiency. For this purpose, we introduce slack variables expressing deviations from the potential to employ them in slack-based measuring of the distance from efficiency frontier (SBM model). In exploring human capital as input to transformation process, we first find out whether including human capital makes difference in efficiency evaluating. In the following, we use SBM models to determine how new European Union member states are performing as compared to developed European countries.

2. NON-PARAMETRIC APPROACH: DEA

2.1. Basic concepts and notation

In classical DEA, we call subjects being evaluated DMUs (Decision Making Units). These are considered transforming *m* inputs into *s* outputs. Inputs are organized in the matrix *X*, element x_{ij} meaning amount of input *i* used by DMU *j*, and the similar way in the output matrix *Y*.

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

By way of contrast to parametric production function approach, in DEA no specific form of transformation function is assumed. Instead of that, the empirical frontier of production possibility set is constructed by linear combinations of the data of DMU under consideration. Thus, some DMU can appear inefficient as one observe that actual performance (activity) of one DMU is outperformed by a composite unit formed as a linear combination of some other DMUs. One can talk about efficiency in Pareto-Koopmans interpretation if DMU cannot improve its performance (increase one of the outputs) without increasing at least one input or decreasing other output.

Given matrices **X** and **Y**, for every DMU_0 the following expressions hold:

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

Production possibility set is thus described by inequations 1.1, its frontier being points are linear combination of the efficient DMUs and present an “envelope” of the data. Indexes of variables $\lambda_j > 0$ constitute the reference set R_0 (efficiency frontier), every frontier point being positive linear combination of the other elements of the reference set:

$$\hat{\mathbf{x}}_\mathbf{0} = \sum_{j \in R_0} \mathbf{x}_j \boldsymbol{\lambda}_j, \quad \hat{\mathbf{y}}_\mathbf{0} = \sum_{j \in R_0} \mathbf{y}_j \boldsymbol{\lambda}_j$$

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

2.2. 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

$$\mathbf{x_0} = X\boldsymbol{\lambda} + \mathbf{s}^- \qquad \mathbf{y_0} = Y\boldsymbol{\lambda} - \mathbf{s}^+ \tag{1.2}$$

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) 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:

- unit invariance
- monotonicity.

Evaluation of efficiency itself takes the form of a fractional program:

$$\min_{\boldsymbol{\lambda},\mathbf{s}^+,\mathbf{s}^-} \quad \rho = \frac{1-\frac{1}{m}\sum_{i=1}^{m} s_i^- / x_{i0}}{1+\frac{1}{s}\sum_{r=1}^{s} s_r^+ / y_{r0}} \tag{1.3}$$

$$\text{s.t.} \quad \mathbf{x_0} = X\boldsymbol{\lambda} + \mathbf{s}^-, \quad \mathbf{y_0} = Y\boldsymbol{\lambda} - \mathbf{s}^+, \quad \boldsymbol{\lambda} \geq 0,\ \mathbf{s}^- \geq 0,\ \mathbf{s}^+ \geq 0$$

The fractional program 1.3 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 units is unit. Every inefficiency given by slacks is penalized so that $\rho < 1$.

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. Return to scale can be incorporated in the model the way proposed by Banker et al. (1984) which consists in the additional constraint $\mathbf{e}^T\boldsymbol{\lambda} = 1$ (**e** being the unit vector) allowing for variable returns to scale (VRS). SBM input oriented model with VRS takes the form of

$$\min \quad \rho = 1-\frac{1}{m}\sum_{i=1}^{m} s_i^- / x_{i0} \tag{1.4}$$

$$\text{s.t.} \quad \mathbf{x_0} = X\boldsymbol{\lambda} + \mathbf{s}^-, \quad \mathbf{y_0} = Y\boldsymbol{\lambda} - \mathbf{s}^+, \quad \mathbf{e}^{\mathrm{T}}\boldsymbol{\lambda} = 1, \quad \boldsymbol{\lambda} \geq 0,\ \mathbf{s}^- \geq 0,\ \mathbf{s}^+ \geq 0$$

After determining relevant input and output variables, this measure can be used to assess efficiency of DMUs.

3. DATA AND MODELLING

In our modelling, we consider European countries as DMUs (n=28) transforming inputs (labour or human capital augmented labour and capital) into a single output – GDP.

3.1. Modelling human capital

We model human capital following Hall & Jones (1999) as labour-augmenting coefficient H:

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

The function □(ε) reflects the relative efficiency of a unit of labour with ε years of schooling relative to one with no schooling, i.e. □(0)=0. Thus 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. We adopted these measures from estimations in Mincerian regressions (Psacharopoulos, 2004) where three values of returns to educations are reported for primary, secondary, and tertiary schooling. □ is thus a piecewise linear function with three segments corresponding to primary, secondary, and tertiary level. To complete calculations of H for individual countries, we used Barro – Lee database values of average years of schooling. To give a picture of difference made by taking human capital (HK) into account in evaluating technical efficiency of the countries, we compute and compare ρ_{HL} and ρ_L as SBM measures with and without HK taken into account. The respective models are named *HK* and *no_HK*.

3.2. Comparison of two systems

Once the importance of incorporating HK have been proved, we use this measure as variable in DEA efficiency models. We compare two groups of countries – new EU member states (EU12, Croatia is not included due to data availability) labelled G1 and the group the “old” developed EU countries EU15 (less Luxembourg and Iceland) plus Norway and Switzerland labelled G2.

Borrowing the idea of Thanassoulis (1999), we construct three efficiency frontiers – one frontier for each group (models *HK_g1* and *HK_g2*) and the “pooled” frontier. The latter have been in fact computed in the course of determining ρ_{HL} by *HK* model. Models *HK_g1* and *HK_g2* provide *within-group* efficiency for a DMU while the *inter-group* efficiency measure is provided by HK. Now we can decompose overall efficiency measure to the component attributable to DMU (country) and the second attributable to the group.

Within-group DEA efficiency is computed by considering DMUs belonging to one of the two groups. When put together, the overall DEA efficiency is determined which clearly cannot exceed the *within-group* score attributable to individual country. Efficient units of individual groups may prove inefficient relative to the other group´s units. Dividing overall *HK* score by *HK_g1* or *HK_g2* efficiency yields component attributable to group, thus

HK (overall) **score = *HK_gx* score** (attributable to country) **x *group_comp*** (attributable to group)

Clearly the closer a country is to a referent boundary the larger its DEA-efficiency relative to that boundary. A country will always be at least as far from the *inter-group* as it is from the *within-group* efficient boundary as the *inter-group* boundary encloses all the countries. Thus the within-school DEA efficiency of a pupil can never be lower than its *inter-group* one.

3.3. Technical inputs and output

The analysis is carried out on the data of 2010 due to availability of the data on human capital. We use the same standard inputs and output as in most productivity studies. Labour is measured in thousands of workers and the data come from Eurostat database as well as output proxied by GDP in PPS in millions. We use data on capital stock at 2005 prices from AMECO database denoted by K with upper and lower indices “2005” in the upper left corner of the scheme.

$$
\begin{array}{ccc}
K_{2005}^{2005} & \overset{k_{2010/2005}}{\longrightarrow} & K_{2010}^{2005} \\
\vdots & & \\
PLI_{2005}^{GFCF} & & \\
\vdots & & \\
K_{2005}^{PPS_K} & \overset{k_{2010/2005}}{\longrightarrow} & K_{2010}^{PPS_K}
\end{array}
$$

To obtain capital stock measures in comparable units (PPS for capital), we transform capital stock measures by means of price level index for gross fixed capital formation in 2005 (PLI). We further assume that capital expressed in PPS_K grows at the same rate as that expressed in euros (k being coefficient of growth between 2005 and 2010 computed for real growth of K at 2005 prices). Growth coefficient k is then applied to calculate capital stock in 2010 expressed in PPS_K.

3.4. Data sources and overview of models employed

Data on price level indexes, GDP, and labour are 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 employed

model	type	variables		
		inputs		output
no_HK	SBM-I-V	K	L	Y
HK	SBM-I-V	K	HL	Y
HK_g1	SBM-I-V	K	HL	Y
HK_g2	SBM-I-V	K	HL	Y

Source: The authors´ elaboration

Data on capital are available from annual macro-economic database of the European Commission's Directorate General for Economic and Financial Affairs (DG ECFIN) – AMECO database.
All models are SBM input oriented type with the assumption of variable returns to scale incorporated.

4. RESULTS

Determining SBM efficiency measures by a specific model involves computing 28 optimization programs in the form of 1.4 (one program for each DMU). A total of four models listed in Table 1 have been computed.

4.1. Human capital vs labour

Table 2 shows scores (ρ values) obtained by Models *no_HK* and *HK*. It is obvious that incorporating HK makes difference to the scores. Some efficient countries (Lithuania, Germany, Malta, Romania, Slovakia, United Kingdom) remain inaffected by the change of variable. In case of Ireland or France, *no_HK* gave better result, Austria, on the other hand, improved in *HK*.

Columns with headings “inefficiency” provide penalties for slacks in respective inputs, so one can read off relative importance of inputs with respect to the total efficiency score – the higher the value the more potential improvement in the input.

Nine DMUs form efficiency frontier - Belgium, Germany, Lithuania, Malta, Austria, Poland, Romania, Slovakia, and United Kingdom, five of them being new EU member states. As for HK inefficiency, Netherlands, Latvia, and Denmark show exclusive source of inefficiency in the use of HK. In countries efficient under both measures of capital one can infer that physical capital as well as labour force was used efficiently. Augmenting labour by factor H relatively hurt countries with higher human capital measures such as Finland or Sweden. Intact scores of some countries could mean relatively poor HK endowment which though does not prevent high technical output.

Table 2: Technical efficiency with and without human capital

	Model *no_HK*				Model *HK*			
	score	inefficiency			score	inefficiency		
		K	L	Y		K	HL	Y
Belgium	0,993	0,007	0	0	1	0	0	0
Bulgaria	0,646	0,095	0,259	0	0,654	0,095	0,251	0
Czech Republic	0,836	0,054	0,109	0	0,783	0,063	0,154	0
Denmark	0,914	0,015	0,070	0	0,952	0	0,048	0
Germany	1	0	0	0	1	0	0	0
Estonia	0,683	0,196	0,120	0	0,628	0,196	0,176	0
Ireland	1	0	0	0	0,964	0,035	0,001	0
Greece	0,713	0,134	0,153	0	0,725	0,156	0,119	0
Spain	0,833	0,133	0,033	0	0,816	0,126	0,059	0
France	1	0	0	0	0,900	0,084	0,017	0
Italy	0,823	0,146	0,031	0	0,845	0,146	0,009	0
Cyprus	0,769	0,227	0,004	0	0,769	0,227	0,004	0
Latvia	0,848	0	0,152	0	0,848	0	0,152	0
Lithuania	1	0	0	0	1	0	0	0
Hungary	0,880	0,069	0,051	0	0,841	0,069	0,090	0
Malta	1	0	0	0	1	0	0	0
Netherlands	1	0	0	0	0,974	0	0,026	0
Austria	0,866	0,082	0,052	0	1	0	0	0
Poland	1	0	0	0	1	0	0	0
Portugal	0,735	0,144	0,121	0	0,847	0,062	0,092	0
Romania	1	0	0	0	1	0	0	0
Slovenia	0,803	0,197	0	0	0,731	0,223	0,046	0
Slovakia	1	0	0	0	1	0	0	0
Finland	0,886	0,002	0,112	0	0,936	0,045	0,019	0
Sweden	0,927	0,020	0,053	0	0,899	0,037	0,064	0
United Kingdom	1	0	0	0	1	0	0	0
Norway	1	0	0	0	0,964	0,036	0	0
Switzerland	0,843	0,071	0,086	0	0,888	0,089	0,023	0

Source: Eurostat, AMECO, Barro-Lee, the authors´ calculations

4.2. Efficiency measures

As described in the section 2.2, three additional indicators have been computed. Table 3 contains scores obtained by Models *HK_g1* for new member states and *HK_g2* for old" developed countries. The "pooled" model is *HK* has been presented above. Clearly, *HK* score cannot be higher than *HK_g1* or *HK_g2* since efficient DMU of a group can only worsen its score after adding other (perhaps better performing) DMUs to dataset. It is also clear that *HK* efficient countries remain efficient in their groups.

In Table 3 we also list variable *group_comp* obtained by dividing "pooled" *HK* score by respective group score. Unit score *group_comp* implies that the *HK* score of DMU is only determined by its *within-group* score and the *within-group* and "pooled"frontiers coincide. In the group 1, all DMUs achieve *group_comp* of unit, in the group 2 only United Kingdom, Austria, Germany, ang Belgium do. This allows to infer on comparably good technical utilization of physical and human capital in the New member states. This only means that given the model setup, these countries are able to produce technical output with presumably less HK which results in high efficiency scores.

Table 3: Decomposition of efficiency

	HK_g1	*HK_g2*	*HK*	*group_comp*
Belgium		1	1	1
Bulgaria	0,654		0,654	1
Czech Republic	0,787		0,783	1
Denmark		1	0,952	0,952
Germany		1	1	1
Estonia	0,628		0,628	1
Ireland		1	0,964	0,964
Greece		0,734	0,725	0,990
Spain		0,816	0,816	1
France		0,900	0,900	1
Italy		0,845	0,845	1
Cyprus	0,769		0,769	1
Latvia	0,848		0,848	1
Lithuania	1		1	1
Hungary	0,841		0,841	1
Malta	1		1	1
Netherlands		1	0,974	0,974
Austria		1	1	1
Poland	1		1	1
Portugal		0,869	0,847	0,983
Romania	1		1	1
Slovenia	0,731		0,731	1
Slovakia	1		1	1
Finland		0,981	0,936	0,955
Sweden		0,909	0,899	0,996
United Kingdom		1	1	1
Norway		0,985	0,964	0,980
Switzerland		0,893	0,888	0,995

Source: Eurostat, AMECO, Barro-Lee, the authors´ calculations

5. CONCLUSION

We showed that taking human capital into account in evaluating technical efficiency of economies matters. Employing human capital as labour-augmenting coefficient reveals inefficiency of use of such type of input in many European countries. On the other hand, catching up countries appear to use their human capital effectively, all with respect to selected inputs and output to describe transformation process which was shown by decomposition of the overall efficiency measure to components attributable to country and the group. The result of this analysis should be statistically verified in case of not so clear-cut outcomes.

The study could serve as an example of employing non-parametric way of approaching efficiency as a theoretical foundation for decision-making though there is much space for further refinement in the possible direction of taking into account other outputs where higher level of human capital could show its potential rather than act as excessively used input.

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