Scientific Papers (www.scientificpapers.org)
Journal of Knowledge Management, Economics and Information Technology

Vol. III, Issue 3
June 2013

Relative Efficiency of Education Expenditures in Eastern Europe: A Non-parametric Approach

Author: **Aleksander Aristovnik**, University of Ljubljana, Faculty of Administration, Slovenia, aleksander.aristovnik@fu.uni-lj.si

The article attempts to measure relative efficiency in utilizing public education expenditures in the new EU member states in comparison to the selected EU (plus Croatia) and OECD countries. As resources allocated to education are significantly limited, a special emphasis should be given to their efficient use regarding the institutional and legal constraints. By applying non-parametric methodology, i.e. Data Envelopment Analysis (DEA), a relative efficiency is defined as the deviation from the efficiency frontier which represents the maximum output/outcome attainable from each input level. An analysis of (output-oriented) efficiency measures shows that among the new EU member states Hungary, Estonia and Slovenia seem to be good benchmark countries in the field of primary, secondary and tertiary education, respectively. The empirical results also suggest that, in general, new EU member states show relatively high efficiency in tertiary education efficiency measures.

Keywords: *public expenditure; education; technical efficiency; DEA; Eastern Europe; EU; OECD*

Introduction

An essential feature of knowledge is that it requires human capital (educated persons) for both its production and its application. Indeed, long-term economic growth of the economy rests with its capacity to increase productivity through rapid technological progress. Therefore, the national system of education is the quintessential tool for the creation and application of knowledge. However, as most of the countries are faced with increasing demands on their limited (public) resources, there is an increasing pressure to improve resource allocation and utilisation. Accordingly, policy makers in a number of countries became increasingly concerned with measuring efficiency. With education expenditures comprising a relatively important amount of national income, the interest in examining whether such expenditures are cost-effective has increased, recently.

The article joins the efforts of other scholars in investigating education efficiency by applying a non-parametric methodology. Hence, the purpose of the article is to review some previous researches on the efficiency measurement of public education sector as well as some conceptual and methodological issues of non-parametric approach. Most importantly, Data Envelopment Analysis (DEA) technique is presented and then applied to the wide range of the EU and OECD countries, including Eastern European (EE) countries[1], to evaluate technical efficiency of the selected sector. The importance of examining public sector expenditure efficiency is particularly pronounced for emerging market economies where public resources are normally insufficient. When services are publicly provided, performance measurement becomes an inevitable management tool because when inefficiency continues, the constituents of that inefficient unit suffer. The government needs benchmarking tools to provide incentives to good performing sectors and to induce inefficient sectors to perform better. However, the focus of the article is not on how to cut (public) expenditures, but rather more on investigating potential reserves to increase the value for money of public spending, i.e. how to make the most of limited public (and private) resources[2].

1 In this paper, the group of Eastern Europe (EE) consists of Bulgaria, Cyprus, Czech R., Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia.
2 Note, however, that it is not only public expenditure but also tax regulatory policies that affect the efficiency of the public sector. While expenditure is a relatively good proxy of the tax burden, we ignore the composition of tax revenue and other characteristics of tax system.

Vol. III, Issue 3
June 2013

The article is organized as follows. In the next section we present a brief literature review of measuring public education expenditure efficiency. Section 3 shows a theoretical background of non-parametric methodologies with special focus on Data Envelopment Analysis (DEA) and the specifications of the models. Section 4 outlines the results of the non-parametric efficiency analysis of education sector. The final section provides concluding remarks.

A brief literature review

Previous studies on the performance and efficiency of the public sector (at national level) that applied non-parametric methods find significant divergence of efficiency across countries. Studies include notably Fakin and Crombrugghe [1] for the public sector, Gupta and Verhoeven [2] for education and health in Africa, Clements [3] for education in Europe, St. Aubyn [4] for education spending in the OECD, Afonso et al. [5], [6] for public sector performance expenditure in the OECD and in emerging markets, Afonso and St. Aubyn [7], [8], [9] for efficiency in providing health and education in OECD countries. De Borger and Kerstens [10], and Afonso and Fernandes [11] find evidence of spending inefficiencies for the local government sector. Additionally, Afonso et al. [12] assess the efficiency of public spending in redistributing income. Most studies apply the Data Envelopment Analysis (DEA) method while Afonso and St. Aubyn [8] undertook a two-step DEA/Tobit analysis, in the context of a cross-country analysis of secondary education efficiency.

Other authors (e.g. Mandl et al. [13]; Jafarov and Gunnarsson [14]) have tried to improve on the work by Afonso et al. [5]. The country-clusters resulted are very similar. Southern European countries present low general and educational performance, the EE countries show low general performance but high educational one, and the Northern European and Anglo-Saxon countries with high scores in both items (although the differences among countries in the educational performance are high; e.g. Luxembourg with a high macroeconomic score but fairly poor results for the effectiveness of its education system). Additionally, a number of studies examine technical efficiency in education (see also Castano and Cabanda

[15]; Grosskopf and Mourtray [16]; Johnes [17], [18]; Johnes and Johnes [19]; Ng and Li [20]; Cherchye et al. [21]).

Non-parametric methodology for assessing efficiency in public sector

A common approach to measure efficiency is based on the concept of efficiency frontier (productivity possibility frontier). There are multiple techniques to calculate or estimate the shape of the efficiency frontier. Most investigations aimed at measuring efficiency are based either on parametric or non-parametric methods. The main difference between the parametric and the non-parametric approach is that parametric frontier functions require the ex-ante definition of the functional form of the efficiency frontier. While a parametric approach assumes a specific functional form for the relationship between input and output, a non-parametric approach constructs an efficiency frontier using input/output data for the whole sample following a mathematical programming method[3]. A calculated frontier provides a benchmark by which the efficiency performance can be judged. This technique is therefore primary data-driven. Among the different non-parametric methods the Free Disposal Hull (FDH) technique imposes the fewest restrictions[4]. It follows a stepwise approach to construct the efficiency frontier. Along this production possibility frontier one can observe the highest possible level of output/outcome for a given level of input. Conversely, it is possible to determine the lowest level of input necessary to attain a given level of output/outcome. This allows identifying inefficient producers both in terms of input efficiency and in terms of output/outcome efficiency (Afonso et al. [5]).

An alternative non-parametric technique that has recently started to be commonly applied to (public) expenditure analysis is Data Envelopment Analysis (DEA)[5]. DEA is a non-parametric frontier estimation methodology originally introduced by Charnes, Cooper, and Rhodes in 1978 that compares

3 For an overview of non-parametric techniques see Simar and Wilson [22]
4 FDH analysis was first proposed by Deprins et al. [23]
5 DEA analysis, originating from Farrell's [24] seminal work was originally developed and applied to firms that convert inputs into outputs (see Coelli et al. [25] for a number of applications).

Vol. III, Issue 3
June 2013

functionally similar entities described by a common set of multiple numerical attributes. DEA classifies the entities into "efficient" or "performers" versus "inefficient" or "non-performers." According to DEA framework, the inefficiencies are the degrees of deviance from the frontier. Input inefficiencies show the degree to which inputs must be reduced for the inefficient country to lie on the efficient practice frontier. Output inefficiencies are the needed increase in outputs for the country to become efficient. If a particular country either reduces its inputs by the inefficiency values or increases its outputs by the amount of inefficiency, it could become efficient; that is, it could obtain an efficiency score of one. The criterion for classification is determined by the location of the entities' data point with respect to the efficient frontier of the production possibility set. The classification of any particular entity can be achieved by solving a linear program (LP).

As an example, consider a situation that has F DMUs, with each of them having M inputs and N outputs. Let be the level of input l at DMU f and let be the level of out k at DMU f. Without loss of generality, it will be assumed that the inputs and the outputs are defined in a manner such that lower inputs and higher outputs are considered better. The relative efficiency of DMU f, denoted by wf, is computed by solving the following linear program (Verma and Gavirneni [26]):

$$Maximize\ w_f = \sum_{k=1}^{N} \beta_k Y_k^f$$

Subject to:

$$\sum_{l=1}^{M} \alpha_l X_l^f$$

$$\sum_{k=1}^{N} \beta_k Y_k^f - \sum_{l=1}^{M} \alpha_l X_l^f \leq 0 \ \forall f = 1, 2, \dots, F$$

$$\alpha_l, \beta_k \geq 0$$

The basic idea in this approach is that, through the use of weights α and β, the sets of inputs and outputs are converted to a single "virtual input" and a single "virtual output". The ratio of the virtual output to the virtual input determines the efficiency associated with the DMU. In addition, when the efficiency of a DMU is being computed the weights are determined in such a way that its virtual input is set equal to 1. The resulting virtual output for that DMU determines its relative efficiency. Due to the presence of multiple measures of performance, each DMU would like to choose weights that put it in the best light and this linear programming formulation does just that. That is, when solving for DMU f, the weights chosen are those that result in that DMU achieving the highest efficiency possible. Any other set of weights would only result in the DMU having a lower efficiency rating. In order to complete the analysis, k linear programs (one each for a DMU) need to be solved and the relative efficiencies of the DMUs can be tabulated. The technique is therefore an attempt to find the "best" virtual unit for every real unit. If the virtual unit is better than the real one by either making more output with the same input or making a similar output with less input then we say that the real unit is inefficient. Thus, analyzing the efficiency of N real units becomes an analysis of N linear programming problems.

In the majority of studies using DEA, the data are analyzed cross-sectionally, with each decision making unit (DMU) – in this case the country – being observed only once. Nevertheless, data on DMUs are often available over multiple time periods. In such cases, it is possible to perform DEA over time, where each DMU in each time period is treated as if it were a distinct DMU. However, in our case the data set for all the tests in the study includes an average data for the 1999-2007 period (including PISA 2006 average scores) in order to evaluate long-term efficiency measures as education process is characterized by time lags in up to 37 EU (plus Croatia) and OECD countries. The program used for calculating the technical efficiencies is the DEA Frontier software. The data are provided by Eurostat, OECD, UNESCO and the World Bank's World Development Indicators database.

Table 1: Input and output/outcome set for the DEA – Education Sector (at different levels)

Model	Inputs	Outputs/Outcomes
1 (Primary)	Expenditure per student, primary (% of GDP per capita) [2]	• School enrolment, primary (% gross) • Pupil-teacher ratio in primary education [2] • Primary completion rate, total (% of relevant age group) [2]
2 (Secondary)	Public expenditure per pupil as a % of GDP per capita. Secondary. [1]	• PISA 2006 Average [3] • School enrolment, secondary (% gross) [2] • Pupil-teacher ratio. Secondary. [1]
3 (Tertiary)	Expenditure per student, tertiary (% of GDP per capita) [2]	• Unemployment with tertiary education (% of total unemployment) [2] • Labor force with tertiary education (% of total) [2] • School enrolment, tertiary (% gross) [2]
4 (Total)	Total expenditure on education, (in % of GDP) [2]	• PISA 2006 Average

Sources: [1][28]; [2][29]; [3][30]

The specification of the outputs and inputs is a crucial first step in DEA, since the larger the number of outputs and inputs included in any DEA, the higher will be the expected proportion of efficient DMUs, and the greater will be the expected overall average efficiency (Chalos, 1997). Common measures of teaching output in education used in previous studies are based on graduation and/or completion rates (see Johnes [17]; Jafarov and Gunnarsson [14]), PISA scores (see Afonso and Aubyn [7]; Jafarov and Gunnarsson [14]) pupil-teacher ratio and enrolment rate (see Jafarov and Gunnarsson [14]).

Hence, similar to the former empirical literature, in this analysis the data set to evaluate education sector efficency (at different levels) includes input data, i.e. (public) expenditure per student, tertiary (% of GDP per capita) or total expenditure on education (in % of GDP) and output/outcome data, i.e. school enrolment, tertiary (% gross), teacher/pupil ratio, primary completion rate, total (% of relevant age group), unemployment with tertiary education (% of total unemployment), labor force with tertiary education (% of total) and PISA 2006 average score. There are up to thirty-seven countries included in the analysis (selected EU (plus Croatia) and OECD countries). Different inputs and outputs/outcomes have been tested in four models (see Table 1).

Empirical results

This subsection shows the empirical application of the Data Envelopment Analysis (DEA)[6]. When looking at the education results[7], by using model 1 (see Table 1) and applying the DEA efficiency frontier technique within a selected group of EU/OECD countries and Croatia to measure efficiency of primary education, Denmark, Hungary and Portugal are seen as most efficient. The efficient countries are also Greece, Iceland and Romania, however, their primary expenditures per student (in % of GDP) is very low and has averaged less than 12% (the EU/OECD average is 18.7% in the considered period). One can also see that some countries come very close to the frontier (e.g. Czech R. and Italy), while the other countries are further away and therefore less efficient (e.g. Turkey and Croatia) (see Table 2). Some less efficient countries should significantly decrease their input (primary expenditure per student) (e.g. Slovenia from 27.0% to 22.0%) and/or increase their outputs, i.e. school enrolment (e.g. Ireland and Poland), primary completion rate (Belgium) and teacher-pupil ratio (Turkey and Ireland) in order to become efficient[8]. Interestingly, the EE countries are, in general, relatively more efficient than non-EU countries in the sample, however, they show relatively low efficiency against the old EU-member states.

In terms of the efficiency scores of secondary education, even ten analyzed countries are labeled as efficient (see Table 2), however, only

6 All the calculated results are available from the author on request.

7 All of the results relate to DEA with an output orientation, allowing for variable returns to scale (VRS). An output orientation focuses on the amount by which output quantities can be proportionally increased without changing the input quantities used. Using an input orientation approach leads to similar efficiency results as those presented in the text.

8 The average output efficiency score for primary education is 1.050, which means that the average country could increase the outputs/outcomes for about 5.0% if it were efficient. The results also confirm our expectations, that larger public sector increases the inefficiency in a primary education.

Vol. III, Issue 3
June 2013

Romania and Slovakia represents new EU member states in this group of efficient countries. The average output efficiency score is 1.06715, which means that the average country could increase the outputs/outcomes for almost 7.0% if it were efficient. The worse performers are Mexico and Bulgaria with a well below average PISA scores (considerably less than 490), school enrolment (significantly less than 103.6%) and teacher-pupil ratio (less than 0.086). Indeed, both countries should increase their outputs by more than 10% in order to become an efficient (similar to the EE countries average efficiency, which is the least efficient sub-group in the analysis).

When testing tertiary education efficiency, eleven among the 37 countries analyzed within the formulation for tertiary education presented in Table 1 were estimated as efficient. These countries are Canada, Czech R., Finland, Korea, Latvia, Lithuania, Poland, Russia, Slovakia, Slovenia and the United States. The results of the DEA analysis (Model 3) also suggest a relatively high level of inefficiency in tertiary education in a wide range of countries and, correspondingly, significant room to rationalize public spending without sacrificing, while also potentially improving tertiary outputs and outcomes. Indeed, the countries under consideration could improve their efficiency scores by decreasing their input (expenditure per student (in % of BDP)), in particular in Denmark and Switzerland. However, even more importantly, a significant increase of outputs/outcomes is need in the form of school enrolment (in particular in Cyprus and Mexico), and in the form of labour force with tertiary education (in Portugal, Turkey and Romania). In general, output/outcome scores could be higher for about 6% on average. Interestingly, non-EU member states show significantly worse DEA scores as they should increase their tertiary outputs/outcomes by more than 13% (in comparison to the old EU member states for about 7% and the EE countries only for 1.4%).

Table 2: The Relative Efficiency of the EU Member States (plus Croatia) and OECD Countries in Education (Distribution by quartiles of the ranking of efficiency scores)

Level	**I. Quartile**	**II. Quartile**	**III. Quartile**	**IV. Quartile**
Primary Edu.	Denmark Greece *Hungary* Iceland Portugal *Romania* *Czech Republic* Italy	Spain *Slovakia* Germany Norway Austria Finland	*Lithuania* Netherlands Ireland France *Bulgaria* *Cyprus* *Estonia* United States	*Slovenia* *Poland* *Latvia* Turkey Croatia Sweden Belgium
Secundary edu.	Belgium Finland Greece Ireland Korea Netherlands Norway Portugal *Romania* *Slovakia*	New Zealand Denmark *Estonia* *Czech Republic* Japan Sweden	*Hungary* Austria *Lithuania* *Poland* Germany Iceland *Latvia* *Slovenia* Croatia	Spain France Italy United Kingdom *Bulgaria* Mexico United States
Tertiary edu.	Canada *Czech R.* Finland Korea *Latvia* *Lithuania* *Poland* Russia *Slovakia* *Slovenia* United States	*Hungary* *Romania* *Bulgaria* Australia Austria Ireland Italy Greece	Portugal *Estonia* United Kingdom Sweden Japan New Zealand Croatia Norway Belgium	Turkey Iceland Switzerland Spain Netherlands France Denmark Mexico *Cyprus*

Notes: Relative efficiency scores are based on models presented in Table 1. Thirty-seven (or less) countries are included in the analysis (EU-27, OECD and Croatia). The EE countries are presented in italic.
Sources: [1][28]; [2][29]; [3][30]; own calculations.

Conclusions

The empirical results show that technical efficiency in education sector differs significantly across the great majority of the EU (including the EE countries) and OECD countries. The analysis of different (output-oriented) efficiency (under VRS framework) shows that Japan, Korea and Finland seem to be the most efficient countries in the field of education sector. When focusing only on the EE countries, Hungary, Estonia and Slovenia seem to be good efficiency performers in the field of primary, secondary and tertiary education, respectively. The empirical results also suggest that, in general, the EE countries show relatively high efficiency in tertiary education. In addition, the analysis finds evidence that most of the EE countries have a great potential for increased efficiency in (public) spending of limited education resources. Nevertheless, the improvement of data quality and testing the influences of the environmental factors (such as climate, socio-economic background etc.) remain important issues for further research.

References

[1] Fakin. B. and de Crombrugghe, A. (1997). *Fiscal adjustment in transition economies: social transfers and the efficiency of public spending: a comparison with OECD countries*. Policy Research Working Paper 1803. Washington, DC: World Bank.

[2] Gupta, S. and Verhoeven, M. (2001). *The efficiency of government expenditure Experiences from Africa*. Journal of Policy Modelling, 23, 433-467.

[3] Clements, B. (2002). *How Efficient is Education Spending in Europe?* European Review of Economics and Finance, 1, 3-26.

[4] St. Aubyn, M. (2003). *Evaluating Efficiency in the Portuguese Education Sector*. Economia, 26, 25-51.

[5] Afonso, A., Schuknecht L. and Tanzi, V. (2005). *Public Sector Efficiency: An International Comparison*. Public Choice, 123 (3-4), 321-347.

[6] Afonso, A., Schuknecht L. and V. Tanzi (2006). *Public Sector Efficiency: Evidence for New EU Member States and Emerging Markets*, European Central Bank, Working Paper Series 581, European Central Bank: Frankfurt.

[7] Afonso, A. and St. Aubyn (2005). *Non-parametric Approaches to Education and Health Efficiency in OECD Countries*. Journal of Applied Economics, 8 (2), 227-246.
[8] Afonso, A. and St. Aubyn (2006a). *Cross-country Efficiency of Secondary Education Provision: a Semi-parametric Analysis with Non-discretionary Inputs*. Economic Modelling, 23 (3), 476-491.
[9] Afonso, A. and St. Aubyn (2006b). *Relative Efficiency of Health Provision: a DEA Approach with Non-discretionary Inputs*. ISEG-UTL, Department of Economics Working Paper nº 33/2006/DE/UECE.
[10] De Borger, B. and Kerstens, K. (1996). *Cost efficiency of Belgian local governments: A comparative analysis of FDH, DEA, and econometric approaches*. Regional Science and Urban Economics, 26, 145-170.
[11] Afonso, A. and Fernandes, S. (2008). *Assessing and Explaining the Relative Efficiency of Local Government (October 01, 2008).* Journal of Socio-Economics, Vol. 37, No. 5, pp. 1946-1979.
[12] Afonso, A., Schuknecht L. and V. Tanzi (2008). *Income distribution determinants and public spending efficiency.* Working Paper Series 861, European Central Bank: Frankfurt.
[13] Mandl, U., Dierx A. and F. Ilzkovitz (2008). *The effectiveness and efficiency of public spending.* European Commission, Economic Papers 31, Februar.
[14] Jafarov, E. and Gunnarsson, V. (2008). *Government Spending on Health Care and Education in Croatia: Efficiency and Reform Options;* International Monetary Fund; IMF Working Paper; WP/08/136.
[15] Castano MC, Cabanda E (2007). *Performance evaluation of the efficiency of Philippine Private Higher Educational Institutions: application of frontier approaches.* Int Trans Oper Res, 14, 431-444.
[16] Grosskopf, S. and Mourtray, C. (2001). *Evaluating performance in Chicago public high schools in the wake of decentralization.* Econ. Educ. Rev., 20:1–14.
[17] Johnes, J. (1996). *Performance assessment in higher education in Britain.* Eur. J. Oper. Res., 89:18-33.
[18] Johnes, J. (2006). *Data envelopment analysis and its application to the measurement of efficiency in higher education.* Economics of Education Review, 25 (3), 273-288.
[19] Johnes, J. and Johnes, G. (1995). *Research funding and performance in U.K. university departments of economics: a frontier analysis.* Econ Educ Rev, 14:301-314.

[20] Ng YC, Li, SK (2000). *Measuring the research performance of Chinese higher education institutions: an application of data envelopment analysis.* Educ Econ, 8:2-139.
[21] Cherchye, L., De Witte, K., Ooghe E. and I. Nicaise (2010). *Efficiency and equity in private and public education: nonparametric comparison.* European Journal of Operational Research, 202 (2), 563-573.
[22] Simar, L. and P. Wilson (2003). *Efficiency analysis: the statistical approach, lecture notes.*
[23] Deprins, D., Simar L. and Tulkens, H. (1984). *Measuring labor-efficiency in post offices;* in: Marchand, M.; Pestieau, P. and Tulkens, H. (Eds.), The performance of public enterprises: concepts and measurement. Amsterdam: North-Holland.
[24] Farrell, M. (1957). *The Measurement of Productive Efficiency.* Journal of the Royal Statistical Society Series A (General), 120 (3), 253-281.
[25] Coelli T., Rao, D. and Battese, G. (2002). *An Introduction to Efficiency and Productivity Analysis.* 6th edition, Massachusetts, Kluwer Academic Publishers.
[26] Verma, A. and Gavirneni, S. (2006). *Measuring police efficiency in India: an application of data envelopment analysis.* Policing: An International Journal of Police Strategies & Management, 29(1), pp. 125-145
[27] Chalos, P. (1997). *An Examination of Budgetary Inefficiency in Education Using Data Envelopment Analysis*. Financial Accountability & Management, 13 (1), 55–69.
[28] UNESCO: Data Centre, Montreal: *UNESCO Institute for Statistics*, On-line. 2011.
[29] World Bank: *World Development Indicators*, On-line, 2011.
[30] OECD: *Statistics Data Base*, Paris, On-line, 2011.