ICT expenditures and education outputs/outcomes in selected developed countries

An assessment of relative efficiency

Aleksander Aristovnik
Chair of Economics and Public Sector Management, Faculty of Administration, University of Ljubljana, Ljubljana, Slovenia

Abstract

Purpose – The aim of the paper is to review some previous researches examining ICT efficiency and the impact of ICT on educational output/outcome as well as different conceptual and methodological issues related to performance measurement.

Design/methodology/approach – This paper adopts a non-parametric methodology, i.e. data envelopment analysis (DEA) technique, and applies it to selected EU-27 and OECD countries.

Findings – The empirical results of the varying levels of (output-oriented) efficiency (under the VRSTE framework) show that Finland, Norway, Belgium and Korea are the most efficient countries in terms of their ICT sectors. In addition, the analysis also finds evidence that most of the countries under consideration hold great potential for increased efficiency in ICT and for improving their educational outputs and outcomes.

Originality/value – This is the first paper that investigates such a wide range of countries with DEA technique when analyzing efficiency of ICT sector from an educational perspective.

Keywords ICT, Education, Performance, Efficiency, Non-parametric model, DEA, EU, OECD, Communication technologies

Paper type Research paper

Introduction

Many theoretical and empirical efforts have been made to assess the impact of ICT on in educational performance in various settings. Currently, there is a significant number of initiatives to assess and monitor the efficiency of ICT use and its impact on education. The second information technology in educational study (SITES), sponsored by the International Association for the Evaluation of Educational Achievement (IEA), is an exemplary study which identifies and describes the educational use of ICT across 26 countries in the world. The study explores the use of computers in teaching through sampling teachers, principals and ICT responsibility in schools. While it does not look into student achievement, it does look at the perceived impact of ICT on students from the teacher's perspective (Pelgrum and Anderson, 1999; Kozma, 2003). Moreover, Balanskat *et al.* (2006) reviewed several studies on the impact of ICT on schools in Europe. They conclude that the evidence is scarce and comparability is limited. Each study employs a different methodology and approach, and comparisons between countries must be made cautiously. In addition, in several other studies (see Yusuf and Afolabi, 2010; Shaikh, 2009; Jayson, 2008; Shaheeda *et al.*, 2007) it is argued that ICT helps to improve the quality of learning and educational outcomes. Some other surveys (e.g. Iqbal and Ahmad, 2010; Hameed, 2006; Amjad, 2006; Khan and Shah, 2004) argue that, in order to be successful, a country should improve its education system by implementing effective and robust ICT policies.

Campus-Wide Information Systems
Vol. 30 No. 3, 2013
pp. 222-230

1065-0741
DOI 10.1108/10650741311330401

A few previous studies on the performance and efficiency of the education sector (at the national level) applied non-parametric methods. For instance, Gupta and Verhoeven (2001) measure the efficiency of education in Africa, Clements (2002) does so for Europe, St Aubyn (2003) for education spending in the OECD, and Afonso and St Aubyn (2005, 2006a, b) in OECD countries. Most studies apply the data envelopment analysis (DEA) method, while Afonso and St Aubyn (2006a) undertake a two-step DEA/Tobit analysis in the context of a cross-country analysis of secondary education efficiency. However, very few recent studies have examined the efficiency of countries in utilising their ICT resources for educational outputs and outcomes and the impact of ICT on education in a particular country, for instance in Turkey (Tondeur *et al.*, 2007) and Belgium (Gulbahar, 2008). Since very insightful, cross-country analyses have rarely been used for ICT policy analysis, the present research addresses this gap in the literature.

Accordingly, the paper's purpose is to discuss and review some previous researches on ICT efficiency and ICT's impact on educational outcomes as well as different conceptual and methodological issues related to measuring performance in education. Moreover, a definition, measurements and an empirical application of a model measuring the efficiency of ICT at national levels will be considered, with a special focus on educational variables as outputs/outcomes. In this context, the DEA technique will be presented and then applied to selected EU-27 and OECD countries.

The paper is structured as follows: first, a brief survey of the literature relating to ICTs and their impact on education performance is presented, then the methodology is established and the specifications of the models are defined. The next section outlines the results of the non-parametric efficiency analysis and presents partial correlation coefficients in order to assess the impact of ICT on educational performance. The final section provides concluding remarks.

Methodology and data

A common non-parametric technique that has recently started to be commonly applied to expenditure efficiency analysis is DEA. DEA is a non-parametric frontier estimation methodology originally introduced by Charnes *et al.* (1978) that compares functionally similar entities described by a common set of multiple numerical attributes. DEA classifies entities into "efficient" or "performers" vs "inefficient" or "non-performers". Various types of DEA models can be used, depending upon the problem at hand. The DEA model we use can be distinguished by the scale and orientation of the model. If one cannot assume that economies of scale do not change, then a variable returns-to-scale (VRSTE) type of DEA model, the one selected here, is an appropriate choice (as opposed to a constant-returns-to-scale (CRS) model). Furthermore, if in order to achieve better efficiency, economies' priorities are to adjust their outputs (before inputs), then an output-oriented DEA model rather than an input-oriented model is appropriate. The way in which the DEA program computes efficiency scores can be explained briefly using mathematical notation (adapted from Ozcan, 2007). As an example, consider a situation that has f decision-making units (DMUs), with each having M inputs and N outputs. Let X_1^f be the level of input 1 at DMU f and let X_k^f be the level of output k at DMU f. Without loss of generality, it will be assumed that the inputs and outputs are defined in such a manner that lower inputs and higher outputs are considered better. The relative efficiency of DMU f, denoted by w_f, is computed by solving the following linear programme (Verma and Gavirneni, 2006):

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

Subject to:

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

$$\sum_{k=1}^{N} \beta_k Y_k^f - \sum_{l=1}^{M} \alpha_l X_l^f \leqslant 0 \quad f = 1, 2, \ldots, F$$

$$\alpha_l, \ \beta_k \geqslant 0$$

The basic idea of this approach is that, through the use of weights α and β, the sets of inputs and outputs are converted into 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 which result in that DMU receiving 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 programmes (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 same input or making 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 analysed cross-sectionally, with each DMU – in this case a 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 average data for the 1999-2007 period (including PISA 2006 average scores) in order to evaluate long-term efficiency measures as the effects of ICT are characterised by time lags in 27 EU and OECD countries. The program used for calculating the technical efficiencies is the Frontier Analyst 4.0 software. The data are provided by the OECD, UNESCO and the World Bank's World Development Indicators database.

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). In this analysis the data set to evaluate the efficiency of ICT includes input/output/outcome data, i.e. information and communication technology expenditure (per cent of GDP), internet users (per 100 people), teacher-pupil ratio (secondary), school enrolment, all levels (per cent gross), labour force with tertiary education (per cent of total) and the PISA 2006 average score. Up to 28 countries are included in the analysis (selected EU and OECD countries). Different inputs and outputs/outcomes are tested in four models (see Table I). In addition, to evaluate the impact of ICT on education, we calculate partial correlation coefficients for different ICT and education variables.

Table I. Input and output/outcome set for the DEA

Model	Inputs	Outputs/outcomes
I	Information and communication technology expenditure (% of GDP)[a] Internet users (per 100 people)[a]	PISA average (2006)[b]
II	Information and communication technology expenditure (% of GDP) Internet users (per 100 people)	PISA average (2006) Labour force with tertiary education (% of total)[a]
III	Information and communication technology expenditure (% of GDP)	PISA average (2006) School enrolment, secondary (% gross)[a] Teacher-pupil ratio, secondary[c]
IV	Information and communication technology expenditure (% of GDP)	PISA average (2006) School enrolment, primary (% gross)[a] School enrolment, secondary (% gross) School enrolment, tertiary (% gross)[a]

Sources: [a]World Bank (2011), [b]UNESCO (2011), [c]OECD (2010)

Empirical results

To see whether ICT has any impact on educational outputs and outcomes, we calculate the partial correlations between different variables, while controlling for the other(s) variable(s) (see Table II). All educational output and outcome variables show a weak and positive (but not statistically significant) correlation with ICT expenditures (in per cent of GDP) when controlling for the number of internet users. The impact of the number of internet users is strong and positive as the partial coefficient ranges from 0.53 to 0.71. An important ICT variable which also influences PISA scores is ICT

Table II. Partial correlation coefficients

Output/outcome variables	Input variables		
Completion rate – primary ($n=24$)	ICT (GDP)	IU	
	0.012	−0.09	
Enrolment rate –secondary ($n=27$)	ICT (GDP)	IIB	
	0.005	0.684***	
Enrolment rate – tertiary ($n=27$)	ICT (GDP)	IU	
	0.083	0.709***	
Labour force with tertiary education ($n=27$)	ICT (GDP)	IU	
	0.075	0.525***	
PISA score ($n=28$)	ICT (GDP)	IU	
	0.128	0.687***	
PISA scores ($n=27$)	ICT (p.c.)	T/P (secondary)	
	0.530***	0.292	
PISA scores ($n=26$)	ICT (p.c.)	T/P (primary)	T/P (secondary)
	0.555***	−0.268	0.339*
PISA scores ($n=23$)	ICT (GDP)	IU	T/P (primary)
	−0.014	0.701***	0.410*

Notes: ICT (GDP), information and communication technology expenditure (percent of GDP); IU, internet users (per 100 people); ICT (p.c.), information and communication technology expenditure (per capita); T/P, teacher-pupil ratio; IIB, international internet bandwidth (bits per person); COMPL, completion rate (percent of relevant age group). ***, **, *Significant at 1, 5 and 10 per cent, levels, respectively
Sources: World Bank (2011), UNESCO (2011), OECD (2010), own calculations

(per capita) as the partial coefficient reached 0.53. There are also some educational output variables which positively influence the PISA scores, such as the teacher-pupil ratio (primary and secondary). Nevertheless, the single most important related variable is the quality of the basic telecommunications infrastructure and broadband penetration. Indeed, a strong ICT infrastructure and its use alone already have an effect on perceived ICT-induced efficiency improvements but does not guarantee a good educational performance in itself. The government and policymakers should not be interested in simply introducing technology into educational institutions, but also in making sure that it is used effectively by teachers and students in order to enhance educational outputs and outcomes.

The results of the output-oriented VRSTE formulation of the DEA analysis (based on Models I-IV in Table I) suggest a relatively high level of inefficiency of ICT in selected EU and OECD countries and, correspondingly, that there is significant room to improve educational outputs and outcomes (see Table III). Indeed, the empirical results show that the total number of efficient countries varies significantly from one model to another. There are only two technically efficient countries in Model I, i.e. Finland and

No.	Country	Model I VRSTE	Model I Rank	Model II VRSTE	Model II Rank	Model III VRSTE	Model III Rank	Model IV VRSTE	Model IV Rank
1	Australia	94.7	14	95.1	18	na	na	na	na
2	Austria	94.3	15	94.3	19	94.1	12	98.6	13
3	Belgium	95.9	11	97.9	11	100.0	1	100.0	1
4	Bulgaria	85.2	26	100.0	1	83.5	24	94.8	19
5	Czech R.	99.1	4	99.1	9	94.7	11	100.0	1
6	Denmark	90.6	23	90.6	24	98.7	8	100.0	1
7	Finland	100.0	1	100.0	1	100.0	1	100.0	1
8	France	95.6	12	96.6	15	90.8	16	96.2	16
9	Germany	93.6	17	na	na	na	na	na	na
10	Greece	93.9	16	97.9	11	89.2	20	100.0	1
11	Hungary	97.6	8	97.6	14	90.3	19	100.0	1
12	Iceland	96.1	9	100.0	1	92.4	17	95.9	17
13	Italy	89.8	24	89.8	25	85.3	23	90.4	24
14	Japan	96.0	10	99.8	7	93.6	13	100.0	1
15	Korea	98.2	5	98.2	10	99.3	7	98.2	14
16	The Netherlands	94.2	16	94.2	20	97.1	10	100.0	1
17	New Zealand	95.3	13	95.3	16	100.0	1	99.8	12
18	Norway	98.1	6	100.0	1	100.0	1	100.0	1
19	Poland	99.5	3	99.5	8	100.0	1	100.0	1
20	Portugal	93.3	18	93.3	21	86.4	22	92.0	23
21	Romania	84.6	27	84.6	26	80.5	25	89.4	25
22	Slovakia	100.0	1	100.0	1	100.0	1	100.0	1
23	Slovenia	97.7	7	97.7	13	93.5	14	94.6	20
24	Spain	93.0	19	95.2	17	92.5	15	92.1	22
25	Sweden	91.2	22	91.2	23	97.6	9	97.6	15
26	UK	92.8	20	92.9	22	90.8	17	95.5	18
27	USA	87.3	25	100.0	1	88.9	21	92.4	21
Number of efficient countries		2		6		6		11	

Notes: Relative efficiency scores (Models I-IV; see Table I). In all, 27 countries are included in the analysis (Mexico is excluded as an outlier)
Sources: World Bank (2011), UNESCO (2011), OECD (2010), own calculations

Table III.
DEA results for ICT efficiency in selected OECD and EU countries

Slovakia. However, at 4.424 per cent of GDP Slovakia has the lowest level of ICT expenditure (in per cent of GDP) among all countries in the sample. The least efficient nations are Bulgaria, Romania and Greece as a result of their relatively low PISA test scores, ranging from 410 (Romania) to 464 (Greece) (for instance, the EU/OECD group average is around 494). In order to enhance the reliability of the findings, additional inputs and outputs/outcomes were introduced, resulting in Models II-IV (for details also see Table I).

Adding another output in the form (Model II) of labour force with tertiary education (per cent of total), the results show Bulgaria, Finland, Iceland, Norway, Slovakia and the USA to be the technically most efficient countries. Not surprisingly, increasing the number of outputs/outcomes in a relatively small sample leads to a higher number of efficient countries. In general, the rankings remain relatively stable in comparison to Model I (with Bulgaria and the USA being the only significant exceptions).

Model III excludes one input variable (internet users) and includes additional output/outcome variables to PISA scores, i.e. school enrolment (secondary) and teacher-pupil ratio (secondary). According to this model there are three new efficient nations, i.e. Belgium, New Zealand and Poland. Interestingly, one of the biggest improvement in the ranking is shown by Denmark, with one of the highest levels of school enrolment (secondary) averages accounting for around 125 per cent in the 1999-2007 period (the EU/OECD average is around 106 per cent). In order to become an efficient nation, selected countries should significantly increase the level of their PISA scores (particularly in Romania), the level of their school enrolment (secondary) (particularly in highly populated countries, such as Korea and the USA), and the teacher-pupil ratio (secondary) (in Japan, Sweden and the UK).

In terms of the efficiency scores for ICT in Model IV, up to 11 of the analysed countries are labelled efficient (see Table III). The average output efficiency score is 97.1, meaning that, for the level of input they are using, the countries achieve 97.1 per cent of potential outputs/outcomes (the output/outcome they should deliver if they were efficient). The worst efficiency performers are Romania, Italy, Portugal and Spain, where practically all countries are faced with below-average levels of its inputs and outputs/outcomes and therefore an increase in ICT expenditures with a significant efficiency improvement is needed in these counties. Indeed, all four countries should increase their outputs by 8.5-12.0 per cent in order to become an efficient.

According to the above empirical analysis, Finland, Norway, Belgium and Japan seem to be the most efficient countries under consideration. While the first three countries exhibit high relative efficiency due to below-average ICT expenditures (in per cent of GDP) and above average output/outcome measures (PISA scores, school enrolment, etc.), Japan shows relatively high efficiency only due to above average output/outcome (particularly PISA scores and labour force with tertiary education). On the other hand, it is obvious that the use of ICT in many other countries suffers from relatively low technical efficiency. This inefficiency is particularly highlighted in the Mediterranean countries and some less developed EU member states (see Table IV). Since most of these countries use significantly below-average ICT resources, it will be crucial for them to increase their educational outputs and outcomes. Nevertheless, the UK and Bulgaria reveal low efficiency, in particular, as both countries using a relatively high (above average) level of ICT inputs. Therefore, an improvement of the efficiency of ICT, which could significantly contribute to a country's stronger development and

Table IV. Relative Efficiency of ICT in selected OECD and EU countries

First quartile	Second quartile	Third quartile	Fourth quartile
Finland	Korea	Slovenia	Bulgaria
Slovakia	Hungary	Denmark	Spain
Norway	New Zealand	Austria	The UK
Poland	Iceland	France	Portugal
Belgium	The Netherlands	USA	Italy
Czech R.	Greece	Sweden	Romania
Japan			

Notes: Relative efficiency scores (Models I-IV; see Table II). In all, 25 countries are included in the analysis; distribution by quartiles of the ranking of efficiency scores in four models
Sources: World Bank (2011), UNESCO (2011), OECD (2010), own calculations

growth, should be a top priority in the near future for most of the considered countries, particularly those in the third and fourth quartiles.

Conclusion

The empirical results show that the efficiency of ICT, when taking educational outputs/outcomes into consideration, differs significantly across the great majority of EU and OECD countries. The analysis of the varying levels of (output-oriented) efficiency (under the VRS framework) shows that Finland, Norway, Belgium and Japan are the most efficient countries in terms of their ICT sectors (when considering educational output/outcome). The empirical results also suggest that, in general, some less developed EU countries such as Slovakia and Poland show a relatively high level of ICT efficiency due to the low level of their ICT inputs. Therefore, a significant increase in ICT expenditures is needed in those countries. On the other hand, the least efficient countries are Romania, Italy and Portugal, particularly due to relatively poor educational outputs and outcomes. All in all, the analysis finds evidence that most of the countries under consideration hold great potential for increased efficiency in ICT and for improving their educational outputs and outcomes.

References

Afonso, A. and St Aubyn, M. (2005), "Non-parametric approaches to education and health efficiency in OECD countries", *Journal of Applied Economics*, Vol. 8 No. 2, pp. 227-246.

Afonso, A. and St Aubyn, M. (2006a), "Cross-country efficiency of secondary education provision: a semi-parametric analysis with non-discretionary inputs", *Economic Modelling*, Vol. 23 No. 3, pp. 476-491.

Afonso, A. and St Aubyn, M. (2006b), "Relative efficiency of health provision: a DEA approach with non-discretionary inputs", Working Paper No. 2006/33, Department of Economics, Institute for Economics and Business Administration (ISEG), Technical University of Lisbon, Lisbon.

Amjad, R. (2006), "Why Pakistan must break-into the knowledge economy", in Chaudhry, A., Thompson Chaudhry, T. and Gera, N. (Eds), *Lahore Journal of Economics (Special Edition)*, Lahore School of Economics, Lahore, pp. 75-87.

Balanskat, A., Blamire, R. and Kefala, S. (2006), *The ICT Impact Report: A Review of Studies of ICT Impact on Schools in Europe*, European Schoolnet, Brussels.

Chalos, P. (1997), "An examination of budgetary inefficiency in education using data envelopment analysis", *Financial Accountability & Management*, Vol. 13 No. 1, pp. 55-69.

Charnes, A., Cooper, W. and Rhodes, E. (1978), "Measuring efficiency of decision-making units", *European Journal of Operational Research*, Vol. 2 No. 6, pp. 429-444.

Clements, B. (2002), "How efficient is education spending in Europe?", *European Review of Economics and Finance*, Vol. 1 No. 1, pp. 3-26.

Gupta, S. and Verhoeven, M. (2001), "The efficiency of government expenditure: experiences from Africa", *Journal of Policy Modelling*, Vol. 23 No. 4, pp. 433-467.

Hameed, T. (2006), "ICT as an Enabler for Socio-economic Development", Digital Opportunity Forum 2006, International Telecommunication Union, Seoul, available at: www.itu.int/osg/spu/digitalbridges/materials/hameed-paper.pdf (accessed 26 January 2012).

Iqbal, M.J. and Ahmad, M. (2010), "Enhancing quality of education through e-learning: the case study of Allama Iqbal Open University", *The Turkish Online Journal of Distance Education*, Vol. 11 No. 1, pp. 84-97.

Jayson, W.R. (2008), "ICT in education reform in Cambodia: problems, politics, and policies impacting implementation", *Information Technologies and International Development*, Vol. 4 No. 4, pp. 67-82.

Khan, A.M. and Shah, Q.A. (2004), *Study on Impact of Information and Communication Technology on Decent Work in Pakistan*, Pakistan Manpower Institute, Ministry of Labour Manpower & Overseas Pakistanis, Government of Pakistan, Islamabad.

Kozma, R. (2003), "Technology and classroom practices: an international study", *Journal of Research on Technology in Education*, Vol. 36 No. 1, pp. 1-14.

OECD (2010), *Education at Glance 2010: OECD Indicators*, OECD, Paris, available at: www.oecd.org/document/52/0,3343,en_2649_39263238_45897844_1_1_1_1,00.html (accessed 21 February 2012).

Ozcan, Y.A. (2007), *Health Care Benchmarking and Performance Evaluation: An Assessment Using Data Envelopment Analysis (DEA)*, Springer, New York, NY.

Pelgrum, W.J. and Anderson, R.A. (Eds) (1999), *ICT and the Merging Paradigm for Life-Long Learning: A Worldwide Assessment of Infrastructure, Goals and Practices*, International Association for the Evaluation of Educational Achievement, Amsterdam.

Shaheeda, J., Dick, N. and Laura, C. (2007), "The role of ICTs in higher education in South Africa: one strategy for addressing teaching and learning challenges", *International Journal of Education and Development Using Information and Communication Technology*, Vol. 3 No. 4, pp. 131-142.

Shaikh, Z.A. (2009), "Usage, acceptance, adoption, and diffusion of information and communication technologies in higher education: a measurement of critical factors", *Journal of Information Technology Impact (JITI)*, Vol. 9 No. 2, pp. 63-80.

St Aubyn, M. (2003), "Evaluating efficiency in the Portuguese education sector", *Economia*, Vol. 26, pp. 25-51.

UNESCO (2011), *Data Centre*, UNESCO Institute for Statistics, Montreal, available at: www.uis.unesco.org/Pages/default.aspx (accessed 20 March 2012).

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*, Vol. 29 No. 1, pp. 125-145.

World Bank (2011), *World Development Indicators*, World Bank, Washington, DC, available at: http://data.worldbank.org/data-catalog/world-development-indicators (accessed 12 March 2012).

Yusuf, M.O. and Afolabi, A.O. (2010), "Effects of computer assisted instruction (CAI) on secondary school students' performance in biology", *The Turkish Online Journal of Educational Technology*, Vol. 9 No. 1, pp. 62-69.

About the author

Aleksander Aristovnik is an Associate Professor in the Department of Public Sector Economics at the Faculty of Administration (University of Ljubljana, Slovenia). His areas of research interest encompass public sector economics, international economics, international finance and economics of the EU. Aleksander Aristovnik can be contacted at: Aleksander.Aristovnik@fu.uni-lj.si