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Efficiency of Public Expenditure on Education in Croatia

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EFFICIENCY OF PUBLIC EXPENDITURE ON EDUCATION IN CROATIA

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Summary

This paper observes technical efficiency of public expenditure on education in Croatia as a result of two non-parametric techniques, Free Disposable Hull (FDH) and Data Envelopment Analysis (DEA). Main tested hypothesis is that public expenditure on education in Croatia is being inefficient and that it can and should be improved. This hypothesis has been analytically confirmed showing that the overall waste of input resources in some cases exceeded even 40%. Furthermore, this paper goes beyond the quatification of pure technical efficiency in order to determine the reasons for such oddity, pointing out that the reasons for inefficiency in public spending on education can be explained by several facts. The number of teachers per 100 students is higher than the average of the observed 30 European countries, USA and Japan, indicating possibilities for savings by rationalization of teaching staff. According to adverse future demographic trends, these inefficiencies might become even higher. Teachers' salaries should also be revised in order to compete with those in private sector, since they indirectly influence students' performance and are very important for attracting, developing and retaining skilled and high-quality teachers. The in-depth analysis showed that mechanisms of the allocation of public resources targeted to education will inevitably have to be improved.

Keywords

Education, efficiency, expenditure, Croatia, free disposable hull (FDH), data envelopment analysis (DEA), production possibility frontier, allocation

[1] The views expressed in this paper are those of the author and should not be attributed to the PBZ.

1. Introduction

The aim of the Lisbon Agenda for the members of the European Union (EU) is to achieve knowledge-based society as well as the highest economic competence, where education is considered as one of the most important pillars in achieving these goals. The goals defined in this way are a standard in some developed EU-15 countries, real perspective in other EU members and hardly achieved objective in some other countries, particularly out of EU. In Croatia the adjustment of education process has already started, but it requires fundamental change in the process of thinking and shifting from classic "adaptive" models based on receiving information to more "creative" models of learning by improving the abilities (Mujić, 2007).

It is important to stress the relevance of the education quality and its implication to future competitiveness of the Croatian workers in the international labour market. It is also proven that education level is positively correlated with industrial development and with reduction of fertility rates, but the influence of education on industry and development acts in many ways, generally improving freedom, peace, cooperation, trust and all the institutional goodness that favours socio-economic development (Guisan, Aguayo and Exposito, 2001).

This paper will observe technical efficiency of public expenditure on education in Croatia as a result of two non-parametric techniques, that is Free Disposable Hull (FDH) and Data Envelopment Analysis (DEA). By comparing used input, i.e. public expenditure, and produced output measured by PISA scores, it will be tested the hypothesis that public expenditure on education is being inefficient and that it can and should be improved. Cross section analysis includes 33 countries, of which 31 European, and Japan and United States of America (USA), for which both Eurostat and PISA results are available[2].

After the introduction, an overview of existing and used literature relevant for this paper will be given in section 2, with the additional information on other educational aspects that might be included in further research. Definitions and educational indicators will be elaborated in section 3. Formal framework of FDH and DEA non-parametric models will be explained in details in section 4, after which follows the cross section efficiency analysis of public expenditure in section 5. Section 6 will go beyond the sole technical efficiency in order

[2] In some analyses there will be more and in some analyses less than 33 countries, depending on the availability of the data.

to determine possible sources of inefficiencies in Croatia, while section 7 will provide overall conclusion with several recommendations for key educational policy makers. After the conclusion follows the list of used literature in section 8 and table appendix in section 9.

2. Literature overview and motivation

FDH and DEA are commonly used non-parametric models in analyses of public expenditure efficiency with a cross-countries selection. Both of these methods have originally been developed and applied to decision making units (DMU), that convert inputs into outputs. These decision making units may include firms, post-offices, non-profit or public organisations such as hospitals, schools, local authorities etc. For instance, De Borger and Kerstens (1996) analysed the efficiency of Belgian local governments, Coelli (1996) assessed the efficiency performance of Australian universities, Afonso and Fernandes (2003) studied the efficiency of local municipalities in the Lisbon region, Afonso, Schuknecht and Tanzi (2003) analysed efficiency of public sector, Jemrić and Vujčić (2002) analysed efficiency of banks in Croatia etc.

FDH model was first proposed by Deprins, Simar, and Tulkens (1984) in a study of the relative efficiency of post office operations, with the aim of measuring the technical efficiency of 972 Belgian post offices. For the DEA model there are three types of model that are used in literature. First of them, sometimes also called VRS or DEA-ID, was introduced by Banker, Charnes and Cooper (1984). DEA model also noted as DEA-CD or DEA-NIRS was first proposed by Deprins and Simar (1983) and is quite similar to DEA-ID. The last one of three mentioned DEA models is also often called DEA-C or DEA-CRS, because of its constant returns to scale characteristics. This method was proposed by Charnes, Cooper and Rhodes (1978), built on the ideas of Farrell (1957), and it applied linear programming to estimate an empirical production technology frontier for the first time.

The theoretical FDH and DEA framework that will be used for analyses in this paper is explained in details in Tulkens and Vanden Eeckaut (1995), Coelli et al (2005) and Afonso and St. Aubyn (2004). The empirical part of the FDH and DEA analysis will mainly rely on Afonso and St. Aubyn (2004), who measured education and health expenditure efficiency in OECD countries. Some authors suggest the improvement of the performance of FDH and DEA estimators in terms of noise (see for example Simar, 2003), by constructing multivariate stochastic frontier model (SFA) and showing that it provides FDH and DEA estimators more robust to outliers.

It has to be noted that in none of mentioned analyses, Croatian educational system and its funding efficiency has not been included and evaluated. Recently, Aristovnik and Obadić (2011) assessed the relative technical efficiency of higher education across countries, with a particular focus on Croatia and Slovenia. They concluded that relatively high public expenditure per student in Croatia should have resulted in a better performance regarding the outputs/outcomes, i.e. a higher rate of higher education school enrolment, a greater rate of labour force with a higher education and a lower rate of the unemployed who have a tertiary education. This article will try to measure public expenditure efficiency, not only of tertiary, but of all levels of education and by using different output data.

Some criticism may be directed to the importance of expenditure in creating the output. The standard DEA models incorporate only discretionary inputs, those whose quantities can be changed at the DMU will and do not take into account the presence of environmental variables or factors, also known as non-discretionary inputs. As non-discretionary and discretionary inputs jointly contribute to each DMU outputs, there are in the literature several proposals on how to deal with this issue, implying usually the use of two-stage or even three-stage models (Afonso and St. Aubyn, 2005). Overview of such models can be seen in, for example, Ruggiero (2004) or Simar and Wilson (2005).

Barro and Lee (2001) concluded that school outcomes, i.e. comparable test scores, repetition rates and dropout rates are highly influenced by some other factors, particularly family characteristics like the income and education of parents, but also school factors like size of the class, average teachers' salary and the length of the school term. The findings from PISA 2009 (OECD, 2010a) suggest that the socio-economic background of students and schools does appear to have a powerful influence on performance. For example, students attending schools with a socio-economically advantaged intake tend to perform better than those attending schools with more disadvantaged peers, students in urban schools perform better than those in other schools, students that come from single-parent families tend to perform worse than students from other types of families, students with an immigrant background also tend to perform worse etc., but there are also proven differences among gender, i.e. boys outperformed girls in mathematics, while girls outperformed boys in reading skills. Furthermore, school factors play an important role in education performance in a way that systems prioritising higher teachers' salaries over smaller classes tend to perform better.

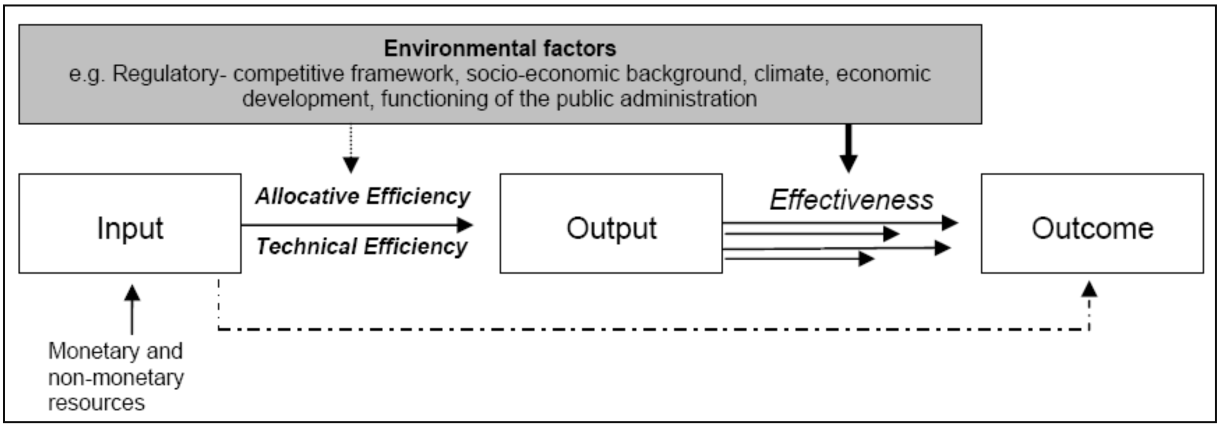
In this paper the efficiency analysis will be extended in order to determine the importance of public expenditure to output gained, since there are strong evidences that some other non-financial factors play even more important role in students' performance. Furthermore, one of the major tasks of the paper will be to identify allocation deficiencies in Croatian education system, as well as to provide the ideas for their solution and some further research. Resulting from performed analyses under the umbrella of this research, some parts within the scope of this paper were already published as an independent professional paper during the research process (see Sopek, 2011). Nevertheless, this paper provides additional scientific and professional contribution to the existing literature and extends published results by determining the size of inefficiency of public expenditure on education in Croatia, as well as by addressing the main components that lead to its existence.

3. Definitions and educational indicators

Efficiency is defined as the ratio between used input and produced output. Some activity is found more efficient if for a given input the greater output is produced or if for a given output the lower input was used. There has to be made a clear distinction between technical and allocative efficiency. Technical efficiency measures the pure relation between input and output taking the production possibility frontier into account, i.e. technical efficiency gains are movements towards this production possibility frontier. However, not every form of technical efficiency makes economic sense. Allocative efficiency reflects the link between the optimal combination of inputs taking into account costs and benefits and the output achieved (Mandl, Dierx and Ilzkovitz, 2008).

Another important term related to efficiency is effectiveness, which relates to the input or the output to the final objectives to be achieved, that is the outcome. It can be stated that efficiency is looking at how a work is done, while effectiveness looks into what is being done. It is interesting to illustrate the conceptual framework of efficiency and effectiveness, which is shown on Figure 1.

Figure 1 **Conceptual framework of efficiency and effectiveness**

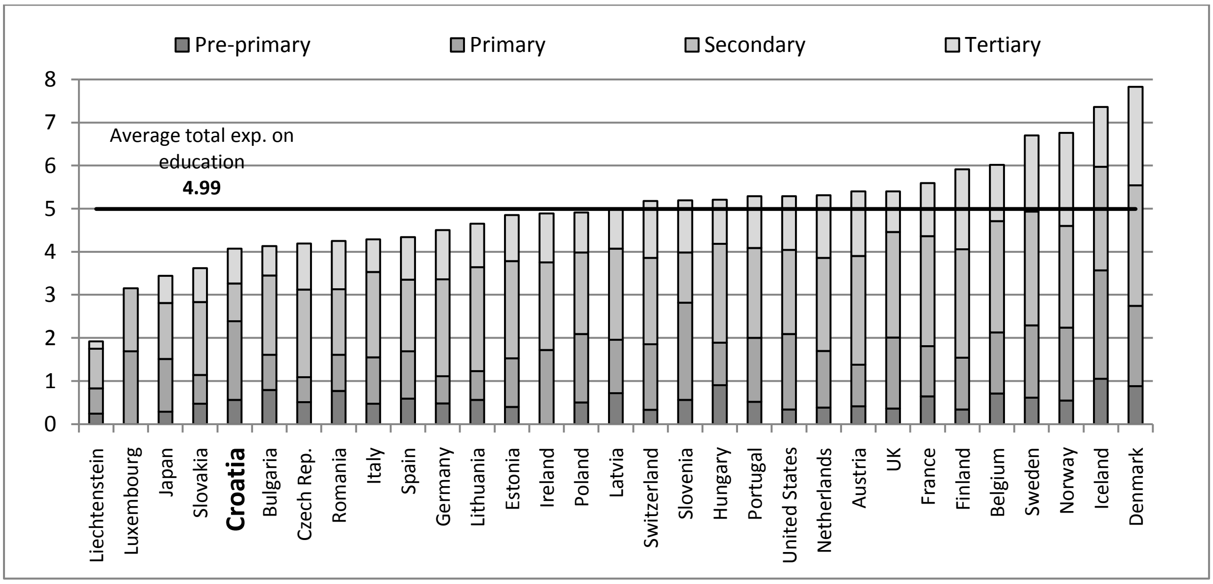


Source: Mandl, Dierx and Ilzkovitz (2008), figure 1, page 3.

For example, the output of an education system can be measured in terms of performance of pupils or students of a certain age. On the other hand, the final outcome can be understood as an educational qualification of the working-age population (Mandl, Dierx and Ilzkovitz, 2008).

This paper will specialize to both technical and allocative efficiency of Croatian public expenditure on education by analyzing its position among other countries and by determination of possible sources of inefficiencies in allocation of public funds. Figure 2 shows total public expenditure on education in 2007, differentiated by levels of education, as a percentage of GDP.

Figure 2 **Total public expenditure on education by levels of education in 2007 (% GDP)**

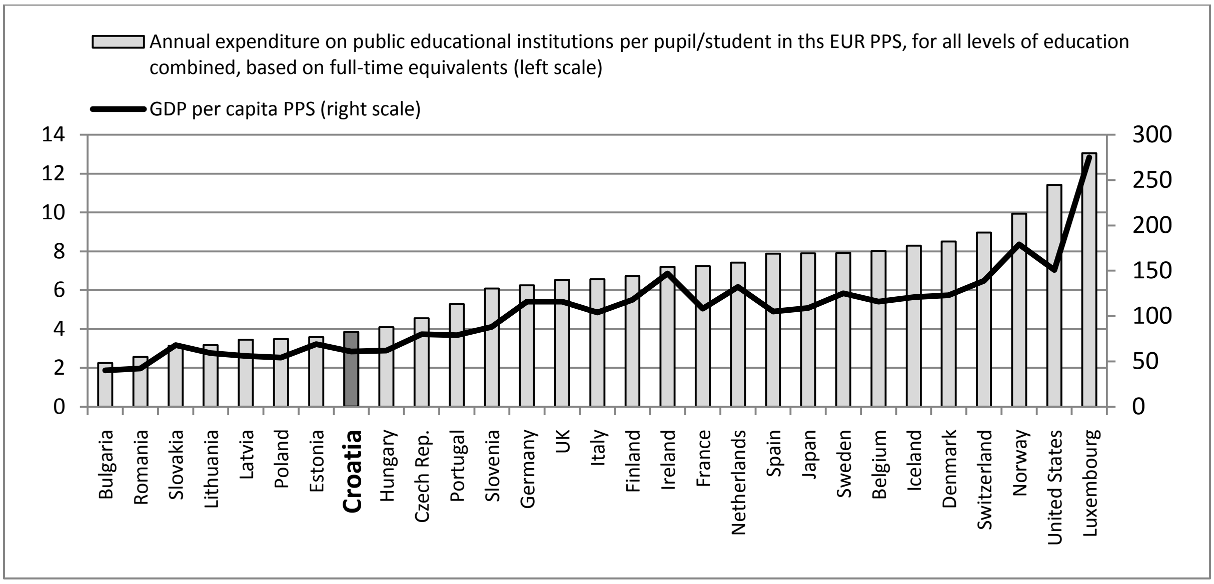


Source: Eurostat (2011a)

The average public expenditure on education in 31 observed countries of approximately 5% of GDP (straight line) was about 1 percentage point higher than total public expenditure on education in Croatia in 2007. Generally, northern European countries had the highest expenditure on education as a proportion of GDP. Denmark, whose average public expenditure on education was the highest among the observed countries, had almost two times higher proportion of GDP targeted to education than Croatia. But what is even more interesting is that expenditure on pre-primary and primary levels of education in case of Croatia accounts for about 59% of total expenditure on education, while in all other observed countries this proportion is significantly lower and averages about 37% of total expenditure on education.

Public expenditure on education as a percentage of GDP is sometimes not fully satisfactory measure for expenditure evaluation, since it does not take into account the total student population, a country's standard of living etc. Therefore it is more interesting to analyze total public expenditure on public educational institutions per pupil/student in EUR PPS[3], which is shown together with GDP per capita PPS on Figure 3.

Figure 3 **Total public expenditure on public educational institutions per pupil/student in thousand EUR PPS and GDP per capita (reference year 2007)**

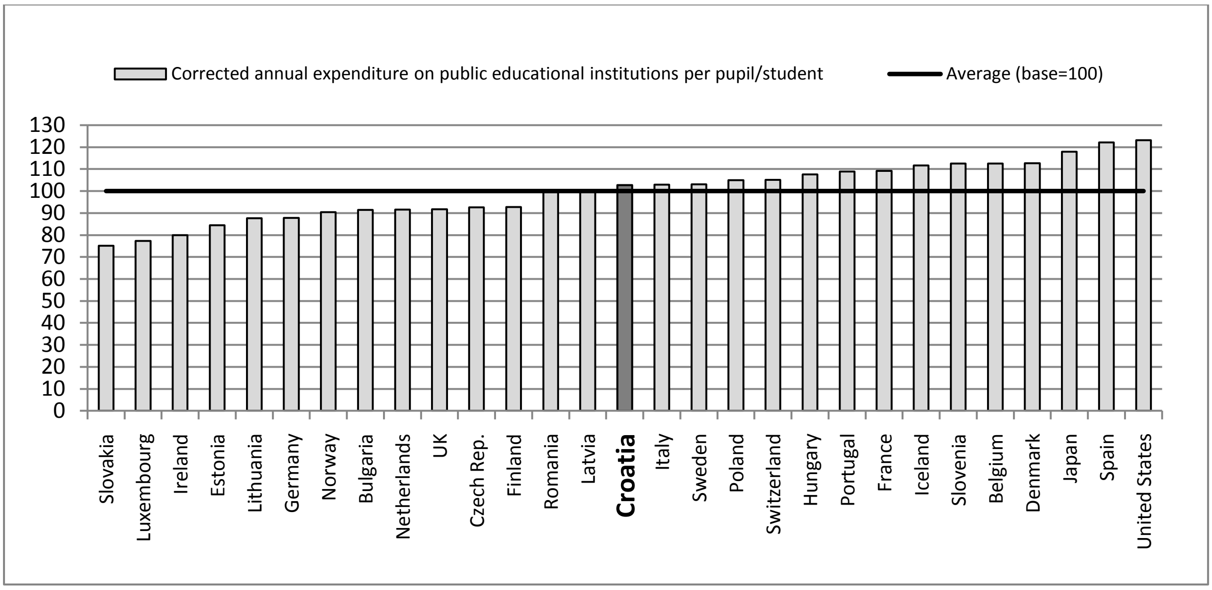


Source: Eurostat (2011b; 2011e)

[3] The purchasing power standard (PPS) is an artificial currency unit that can be interpreted as the equivalent of the euro with respect to purchasing power, i.e. as the euro in real terms. Theoretically, one PPS can buy the same amount of goods and services in each country. For that reason this indicator is used for comparisons of monetary indicators of different countries.

Croatia has relatively low expenditure on public educational institutions, about 40% lower than the average of the countries examined in Figure 3. On the other hand, it can be noted that the majority of new EU member states have even lower expenditures on education per pupil/student in EUR PPS than Croatia. The line in Figure 3 shows GDP per capita PPS, which is a very good indicator of a country's standard of living, and it shows that the public expenditure on educational institutions is positively correlated with the country's standard of living, i.e. countries with higher GDP per capita usually also have higher public expenditure per pupil/student and vice versa. Figure 4 shows total public expenditure on public educational institutions per pupil/student corrected by GDP per capita.

Figure 4 **Total public expenditure on public educational institutions per pupil/student corrected by GDP per capita (reference year 2007)**

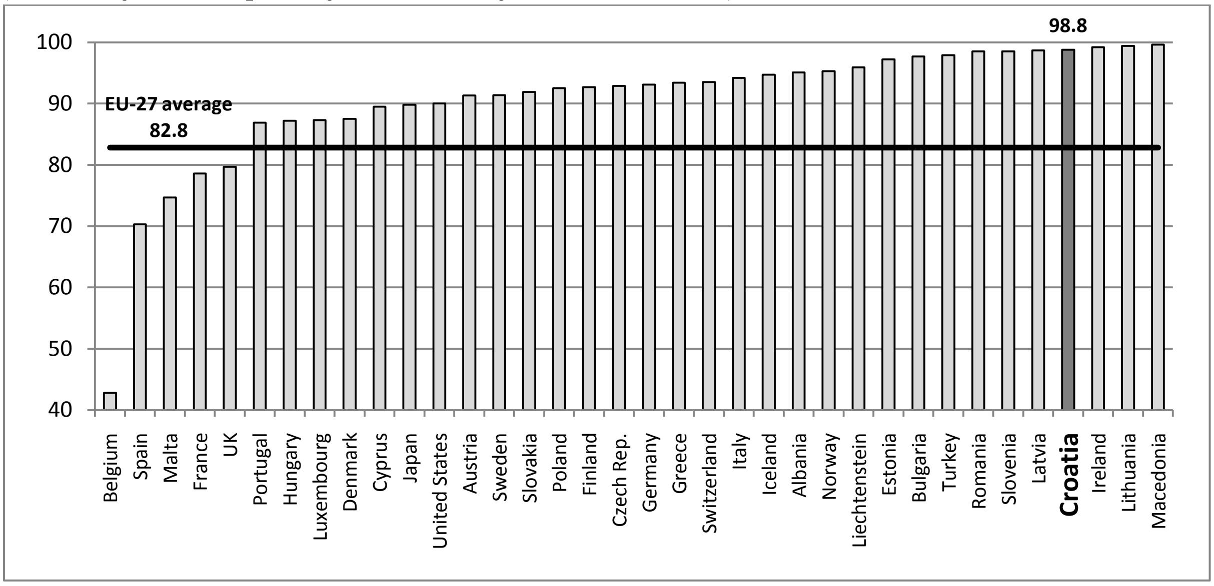


Source: author's calculation based on Eurostat (2011b; 2011e)

Indexes from Figure 4 were calculated by dividing the public expenditure from Figure 3 with GDP per capita and scaled in such a way that average corrected expenditure equals 100. Compared with the country's standard of living, Croatian expenditure on public educational institutions per pupil/student is slightly above average indexed expenditure. Even after correction, the majority of new member states had lower public education expenditures. It is interesting that some other countries, like Norway and Luxembourg, that had significantly higher uncorrected public expenditure, recorded lower corrected public expenditure on education than Croatia.

Since education can be provided by public or private sector, it is interesting to observe their shares in total educational sector. Figure 5 shows the proportion of students in public institutions as a percentage of all students in public and private institutions for primary and secondary levels of education.

Figure 5 **Students in public institutions as a percentage of all students in public and private institutions (reference year 2007, primary and secondary levels of education)**

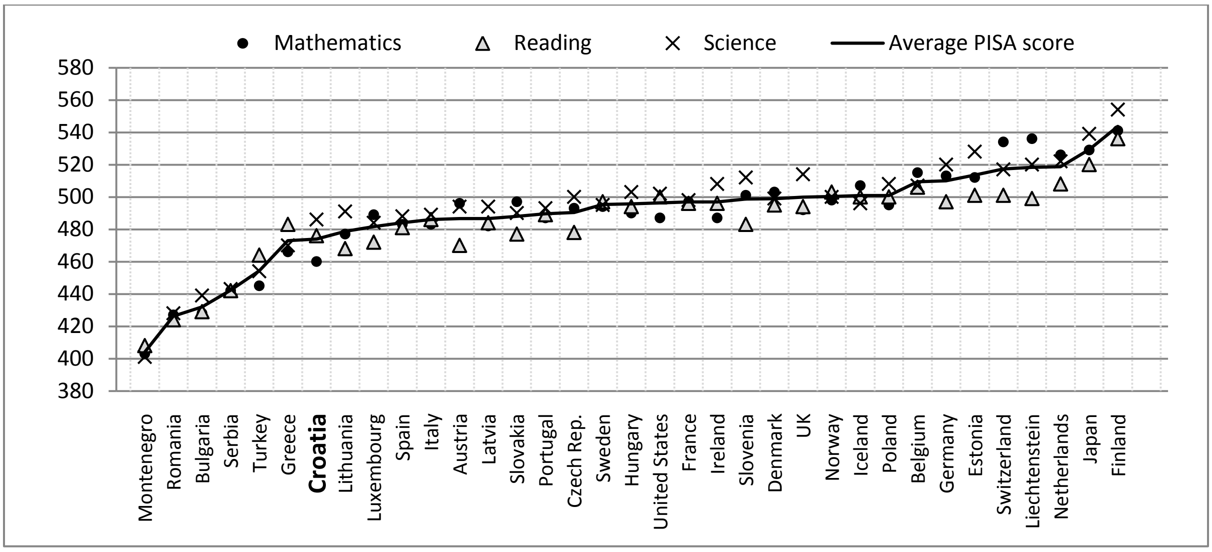


Source: Eurostat (2011d)

Croatia has the fourth highest proportion of students in public institutions among 36 observed, mainly European, countries and this proportion is about 16 percentage points higher than the EU-27 average (straight line). This indicates that the primary and secondary private educational sector may still be underdeveloped in Croatia, but it also means that the public sector has to provide more resources than it would have to if there were a more developed private sector. As Jafarov and Gunnarsson (2008) stated, private expenditure on education in Croatia is mainly targeted to the pre-primary and tertiary education. This means that a more developed private primary and secondary educational sector concurrently with an unchanged public expenditure on education may increase the quality of education, i.e. produced output.

After taking into account several educational input indicators, it is necessary to analyze gained output, which can be measured by PISA scores. PISA is an acronym taken from the Programme for International Student Assessment and it relates to a triennial OECD's international survey of the knowledge and skills of 15-year-olds, an age at which students in most countries are nearing the end of their compulsory time in school. PISA ranks countries according to their performance in reading, mathematics and science by their mean score in each area. The average PISA score is calculated as an average of mean reading, science and mathematics score. PISA scores can also be considered as direct indicators of labour force competitiveness a decade after the survey has been taken. Figure 6 shows produced educational output measured by PISA 2009 scores in mathematics, reading and science.

Figure 6 **PISA 2009 scores in mathematics, reading and science**



Source: OECD (2010a)

Croatia with the average PISA 2009 score of 474 has the highest average score with regard to its eastern neighbouring countries, but is somewhere in the middle among observed East Central and South-East Europe (CEE and SEE) region countries[4]. Best performance of Croatian pupils was recorded in science (486), followed by reading (476) and mathematics (460). Slovakia, Liechtenstein, Luxembourg and Japan, who had lower public expenditure on education proportions of GDP than Croatia, recorded better average PISA scores in 2009. This may be an indicator that Croatia faced with inefficiency in public spending on education, which is the main hypothesis of the paper. To test this hypothesis Free Disposable Hull and Data Envelopment Analysis will be used by taking different input variables and average PISA 2009 scores as an output.

4. FDH and DEA Framework

Free Disposable Hull (FDH) and Data Envelopment Analysis (DEA) are non-parametric techniques for input-output efficiency measurement. Both of these methods have originally been developed and applied to firms or even more generally „decision making

[4] East Central and South-East Europe (CEE and SEE) region generally include following countries: Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Greece, Hungary, Montenegro, Poland, Serbia, Slovakia, Slovenia, Republic of Macedonia, Turkey and Ukraine.

units” (hereinafter: DMU), that convert inputs into outputs (Afonso and St. Aubyn, 2004). The theoretical FDH and DEA framework is explained in details in Tulkens and Vanden Eeckaut (1995), Coelli et al (2005) and Afonso and St. Aubyn (2004). Here are only listed some main definitions and formulas needed for understanding the analyses in further text.

Definition 1:

Let $S = \{(x_i, y_i) \in \mathbb{R}_+^p \times \mathbb{R}_+^q, i = 1, \dots, n\}$ be a set of n actually observed production plans (DMUs) from a joint input-output space. Free Disposable Hull (FDH) of S is the smallest free disposable set containing S, which can be written as follows:

$$\mathrm{U}_{FDH}(S) = \left\{ (x, y) \in \mathbb{R}_+^{p+q} \middle| \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} x' \\ y' \end{bmatrix} + \sum_{i=1}^{p} \mu_i e_i^{p+q} - \sum_{j=1}^{q} \nu_j e_{p+j}^{p+q} \right\} \tag{1}$$

where $(x', y') \in S$, $\mu_i, \nu_j \geq 0$ and e_k^{p+q} $(p+q)$-dimensional zero vector with k-th component equal to 1.

This kind of definition satisfies two important conditions:

1. Every element from the observations set S belongs to the constructed production set $\mathrm{U}_{FDH}(S)$.
2. Every other unobserved pair of vectors $(x, y) \in \mathbb{R}_+^{p+q}$ that is weakly dominated in inputs and/or in outputs by some observation from S also belongs to the constructed production set $\mathrm{U}_{FDH}(S)$[5].

Equation (1) can also be expressed as follows:

$$\mathrm{U}_{FDH}(S) = \left\{ (x, y) \in \mathbb{R}_+^{p+q} \middle| \begin{bmatrix} x \\ y \end{bmatrix} = \sum_{k=1}^{n} \gamma_k \begin{bmatrix} x' \\ y' \end{bmatrix} + \sum_{i=1}^{p} \mu_i e_i^{p+q} - \sum_{j=1}^{q} \nu_j e_{p+j}^{p+q} \right\} \tag{2}$$

where $\gamma_k = \{0,1\}, \forall k = 1, \dots, n$ and all other notation same as in equation (1).

This kind of definition for FDH (2) is very useful for extension to definition of Data Envelopment Analysis (DEA), but with adding one condition, which can be done in several ways as follows:

[5] Some (x', y') weakly dominates (x, y) in inputs if $\exists i$: $\mu_i > 0$ and in outputs if $\exists j$: $\nu_j > 0$.

3.1. Every unobserved pair of vectors $(\mathrm{x}, \mathrm{y}) \in \mathbb{R}_{+}^{\mathrm{p+q}}$ that is a convex combination of observation from the sample S induced by condition 1. and 2. also belongs to the constructed production set.

3.2. Every unobserved pair of vectors $(\mathrm{x}, \mathrm{y}) \in \mathbb{R}_{+}^{\mathrm{p+q}}$ that is a convex combination of vectors from $S \cup O^{p+q}$, where O^{p+q} is a $(p+q)$-dimensional null vector, induced by conditions 1. and 2. also belongs to the constructed production set.

3.3. Every unobserved pair of vectors $(\mathrm{x}, \mathrm{y}) \in \mathbb{R}_{+}^{\mathrm{p+q}}$ that is a linear combination of vectors from $S \cup O^{p+q}$ induced by condition 1. and 2. also belongs to the constructed production set.

Definition 2:

Let $S = \{(x_i, y_i) \in \mathbb{R}_{+}^{p} \times \mathbb{R}_{+}^{q}, i = 1, \dots, n\}$ be a set of n actually observed production plans (DMUs) from a joint input-output space. Convex Free Disposable Hull (CFDH) of S is the smallest convex free disposable set containing S, which can be written as follows:

$$\mathrm{U}_{DEA}(S) = \left\{ (x, y) \in \mathbb{R}_{+}^{p+q} \middle| \begin{bmatrix} x \\ y \end{bmatrix} = \sum_{k=1}^{n} \gamma_k \begin{bmatrix} x' \\ y' \end{bmatrix} + \sum_{i=1}^{p} \mu_i e_i^{p+q} - \sum_{j=1}^{q} \nu_j e_{p+j}^{p+q} \right\} \tag{3}$$

where $(x', y') \in S$, $\mu_i, \nu_j \geq 0$, $\gamma_k \geq 0$, $\sum_k \gamma_k = 1$ and e_k^{p+q} $(p+q)$-dimensional zero vector with k-th component equal to 1.

This is DEA model that was induced by conditions 1., 2. and 3.1., first proposed by Banker, Charnes and Cooper (1984). The piecewise linear frontier of a set is often interpreted as exhibiting ‘variable’ returns to scale (VRS), but this is only true in the special sense that returns are increasing (I) only in the lower range of the inputs up to some point and are decreasing (D) beyond (Banker, Charnes and Cooper, 1984). Therefore, this kind of model is also sometimes noted as DEA-ID.

DEA model induced by conditions 1., 2. and 3.2. is noted as DEA-CD or DEA-NIRS (non-increasing returns to scale), since its (piecewise linear) frontier can only exhibit constant returns (in the lower range of the inputs, up to some point) and then decreasing returns to scale. It was first proposed by Deprins and Simar (1983) and is quite similar to the one in equation (3). The only difference is that in this model it will be used the smallest convex free disposable set that contains $S \cup O^{p+q}$, i.e. $(x', y') \in S \cup O^{p+q}$.

The last DEA model induced by conditions 1., 2. and 3.3. is noted as DEA-C or DEA-CRS and is a bit different than the last two DEA models. The reference production set U_{DEA-C} constructed from $U_0 = S \cup O^{p+q}$ can be expressed as follows:

$$\mathrm{U}_{DEA-C}(U_0) = \left\{(x, y) \in \mathbb{R}_+^{p+q} \middle| \begin{bmatrix} x \\ y \end{bmatrix} = \sum_{k=1}^{n} \gamma_k \begin{bmatrix} x' \\ y' \end{bmatrix} + \sum_{i=1}^{p} \mu_i e_i^{p+q} - \sum_{j=1}^{q} \nu_j e_{p+j}^{p+q} \right\} \tag{4}$$

where $(x', y') \in U_0$, $\mu_i, \nu_j \geq 0$, $\gamma_k \geq 0$ and e_k^{p+q} $(p+q)$-dimensional zero vector with k-th component equal to 1.

Because of the proportionality allowed by the weights of the linear combinations, this set is a cone, to be called the 'free disposal cone' constructed from the data. As noted by both Farrell (1957) and Charnes, Cooper and Rhodes (1978), the linearity of its frontier implies that it exhibits constant returns to scale (Tulkens and Vanden Eeckaut, 1995).

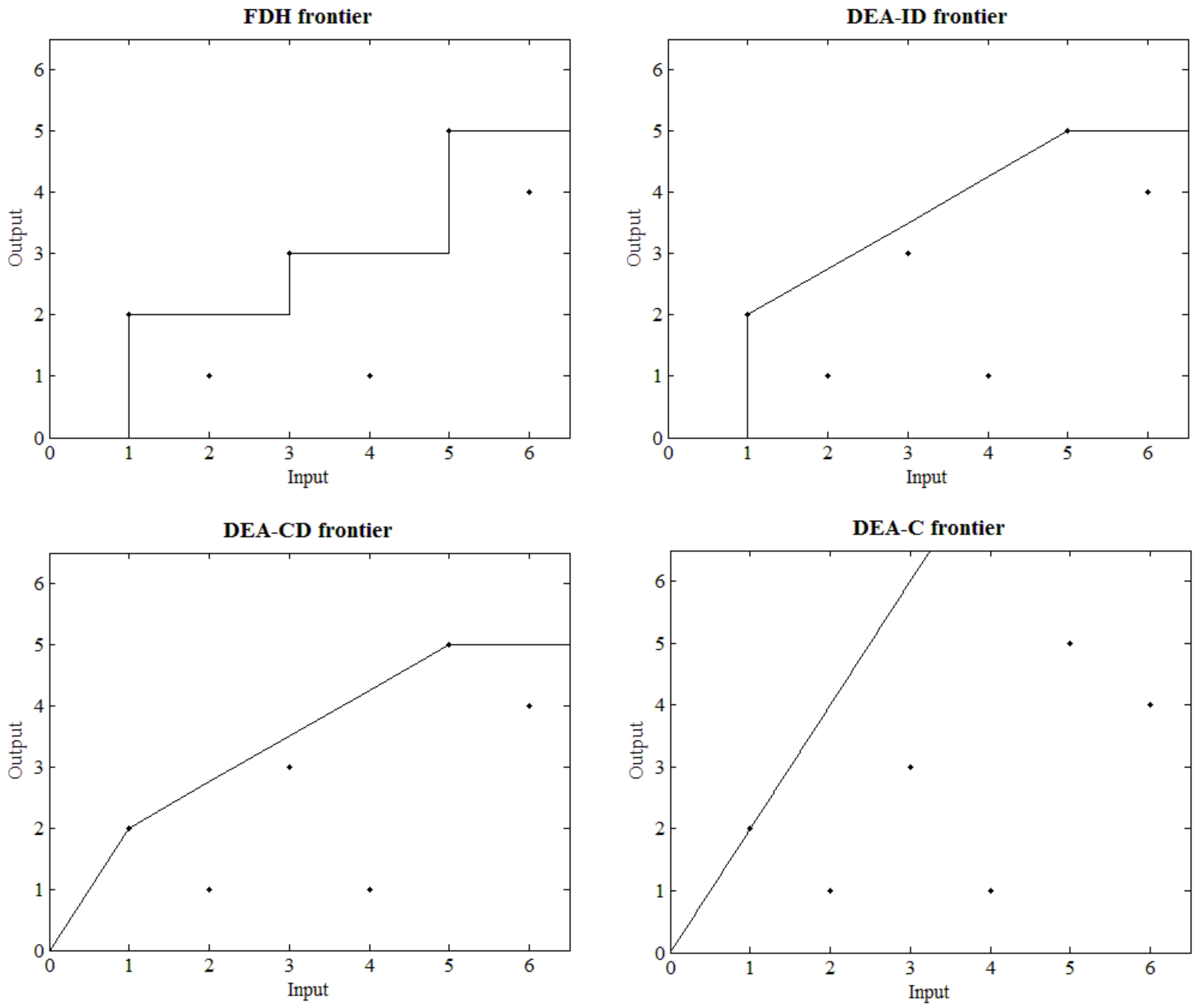
It can be easily seen that for a set of n actually observed production plans from a joint input-output space (S), the following condition is satisfied:

$$U_{FDH} \subset U_{DEA-ID} \subset U_{DEA-CD} \subset U_{DEA-C} \tag{5}$$

Borders of above mentioned sets are called the efficiency frontiers. Depending on the chosen model some of the points (production plans) may or may not be lying on a frontier. Figure 7 shows FDH, DEA-ID, DEA-CD and DEA-C frontiers of the imaginary data set in the most simplified (one input – one output) case.

All points lying on the frontier are considered fully efficient, while points below the frontier are technically inefficient. The inefficiency can be measured in two different ways. Vertical distance from any point to the frontier measures the degree of output inefficiency or the output level that could have been achieved if all input was applied in an efficient way. This means that the same input allocated differently may produce higher output. On the other hand, horizontal distance from any point to the frontier measures the degree of input inefficiency or the input level that was wasted by inefficient allocation.

Figure 7 **FDH, DEA-ID, DEA-CD and DEA-C frontiers of the imaginary data set**



Source: author

From now on, for the sake of simplification, the analysis will be restricted to FDH and DEA-ID (hereinafter: DEA) models only. These are the most commonly used FDH and DEA models in literature in evaluation of technical efficiency. Nevertheless, the extension of analysis with other two DEA models would not provide any significant added value to the analysis itself and the gained results. The next step is to define input and output efficiency scores, both for FDH and DEA models, in order to rank observed production plans. Suppose there are p input variables, q output variables and n actually observed DMUs from a joint input-output space.

For i-th DMU in FDH model, all production plans that are more efficient are to be selected, i.e. the ones that produce more of each output with less of each input. If there are no such DMUs that may be considered more efficient than the i-th DMU, then unit input and output efficiency score is to be assigned to the i-th DMU. If DMU i is not efficient, its FDH input efficiency score is equal to:

$$E_x^{FDH} = \min_{n=n_1,\dots,n_m} \max_{j=1,\dots,p} \frac{x_j(n)}{x_j(i)} \tag{6}$$

where $n_1, \dots, n_m$ are m production plans that are more efficient than production plan i.

FDH output efficiency score is calculated in a similar way and is equal to:

$$E_y^{FDH} = \min_{n=n_1,\dots,n_m} \max_{j=1,\dots,q} \frac{y_j(i)}{y_j(n)} \tag{7}$$

For the i-th DMU in DEA model, y_i is the output column vector and x_i is the column vector of the inputs. There has to be defined X as the $p \times n$ input matrix and Y as the $q \times n$ output matrix. The input-oriented DEA model is then specified with the following mathematical programming problem:

$$\begin{aligned} E_x^{DEA} &= \min_{\theta,\lambda} \theta \\ s.t. \quad & -y_i + Y\lambda \geq 0 \\ & \theta x_i - X\lambda \geq 0 \\ & \mathbb{I}_n^{\tau}\lambda = 1 \\ & \lambda \geq 0 \end{aligned} \tag{7}$$

where $0 \leq \theta \leq 1$ is a scalar, λ is n-dimensional vector of constants and $\mathbb{I}_n$ is a n-dimensional vector of ones.

θ denotes the efficiency score that measures technical efficiency of unit (x_i, y_i), i.e. the distance between a DMU and the efficiency frontier, defined as a linear combination of best practice observations. With $\theta < 1$, the decision unit is inefficient and placed inside the frontier, while $\theta = 1$ implies that the decision unit is lying on the frontier, i.e. it is considered efficient.

λ is n-dimensional vector of constants that measures the weights used to compute the location of an inefficient DMU if it were to become efficient. The inefficient DMU would be projected on the production frontier as a linear combination, using those weights, of the peers of the inefficient DMU. The peers are other DMUs that are more efficient and therefore are used as references for the inefficient DMU.

$\mathbb{I}_n$ is a n-dimensional vector of ones. The restriction $\mathbb{I}_n^\tau \lambda = 1$ imposes convexity of the frontier, accounting for variable returns to scale. Dropping this restriction would amount to admit that returns to scale were constant.

The output-oriented DEA model is very similar to its input-oriented counterparts defined in (7) and can be written as follows:

$$\begin{aligned} E_y^{DEA} &= \min_{\phi,\lambda} \frac{1}{\phi} \\ s.t. \quad & -\phi y_i + Y\lambda \geq 0 \\ & x_i - X\lambda \geq 0 \\ & \mathbb{I}_n^\tau \lambda = 1 \\ & \lambda \geq 0 \end{aligned} \tag{8}$$

where $1 \leq \phi < \infty$, such that $\phi - 1$ is the proportional increase in outputs that could be achieved by the i-th DMU, with input quantities held constant. All other notation stays the same as introduced in (7).

5. Analysis of efficiency of public spending on education

For the analysis of efficiency of public expenditure on education several different input variables were used, while the output variable measured as an average PISA 2009 score stays the same in all cases. Cross section analysis includes 33 countries, of which 31 European, and Japan and USA. Table 1 shows the list of countries to be considered in the analyses and their acronyms, which will be used for denotation in all scatter plots.

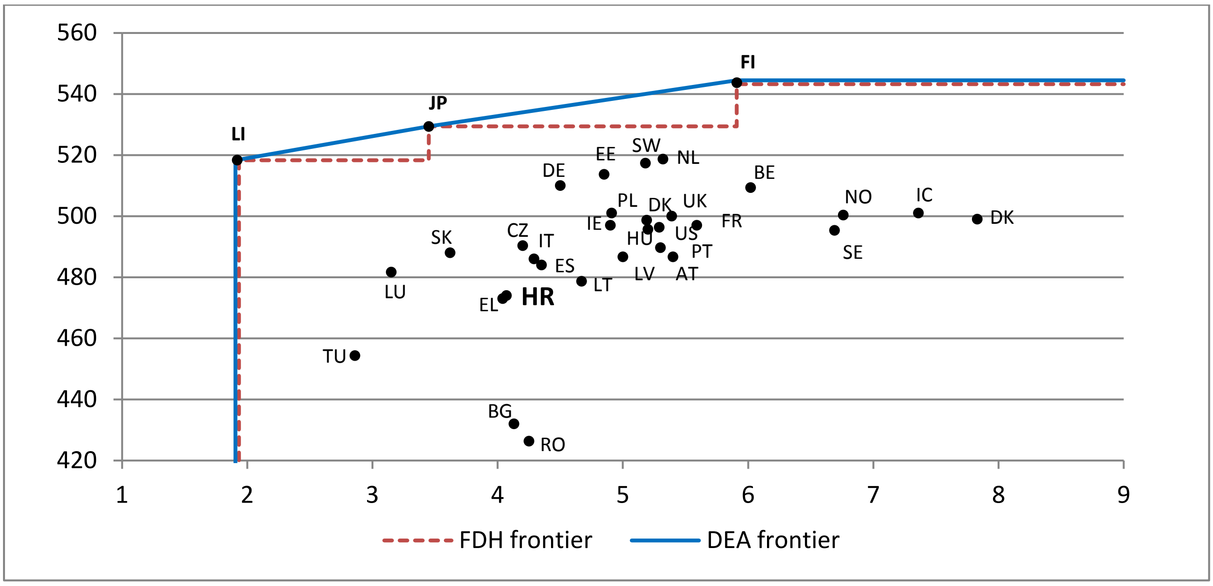
Table 1 **Country names and used country acronyms**

Country name	Acronym	Country name	Acronym	Country name	Acronym
Austria	AT	Hungary	HU	Poland	PL
Belgium	BE	Iceland	IC	Portugal	PT
Bulgaria	BG	Ireland	IE	Romania	RO
Croatia	**HR**	Italy	IT	Slovakia	SK
Czech Republic	CZ	Japan	JP	Slovenia	SI
Denmark	DK	Latvia	LV	Spain	ES
Estonia	EE	Liechtenstein	LI	Sweden	SE
Finland	FI	Lithuania	LT	Switzerland	SW
France	FR	Luxembourg	LU	Turkey	TU
Germany	DE	Netherlands	NL	United Kingdom	UK
Greece	EL	Norway	NO	United States	US

Source: author

Table A1 in Appendix shows FDH and DEA efficiency scores and country ranks in model of one input and one output variable. In this case public expenditure on education as a percentage of GDP was considered as an input variable. Figure 8 shows FDH and DEA efficiency frontiers and position of all countries in joint input-output space.

Figure 8 **FDH and DEA efficiency frontiers for public expenditure on education, as a percentage of GDP as an input and average PISA 2009 score as an output**



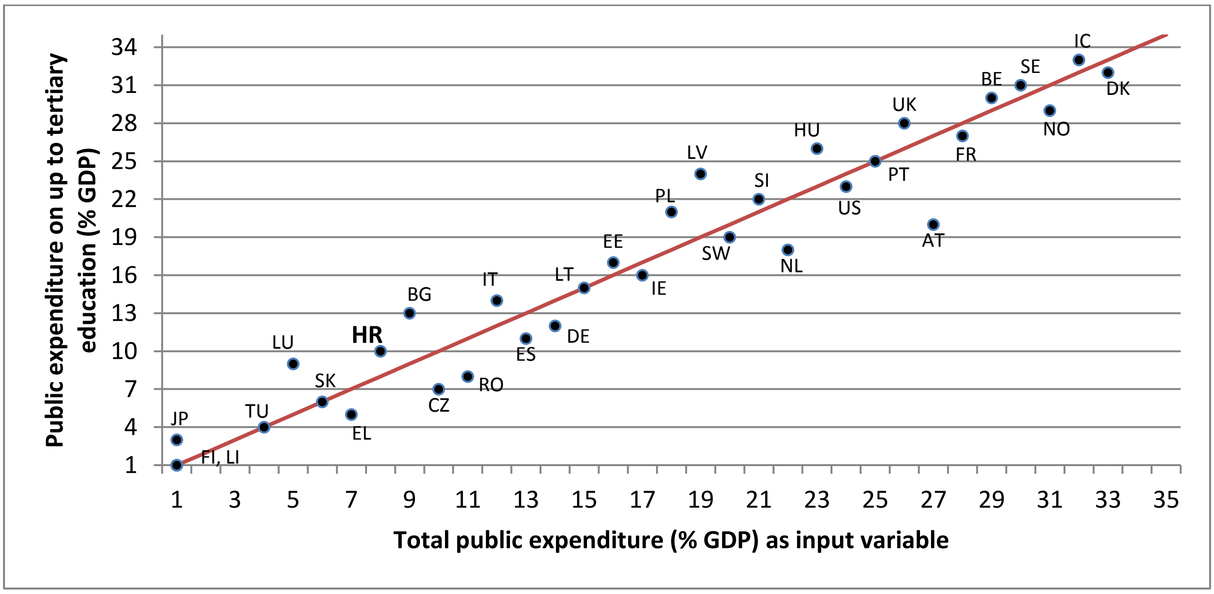
Source: author

Liechtenstein, Japan and Finland are being considered efficient in FDH and DEA analysis and have therefore assigned unit efficiency score in both cases (input oriented, output oriented) in each analysis. Liechtenstein has unit efficiency score because it had the lowest public expenditure on education as a proportion of GDP. On the other hand, Finland had the highest average PISA 2009 score and is therefore considered efficient. Denmark is being considered as the least input efficient country and Romania as the least output efficient, both in FDH and DEA analysis.

Croatia is ranked 9th in FDH and 8th in DEA with regard to its input efficiency and 29th in FDH and DEA with regard to its output efficiency. While it is above average input efficiency score both in FDH and DEA analyses, it is below average with regard to its output efficiency score. Croatian input efficiency score in FDH and DEA analysis is around 0.472 implying that Croatia might be able to achieve the same level of performance using only 47.2 percent of GDP expenditure on education it was using. In other words, this means that there is a waste of input resources of around 53.8 percent. In case of output efficiency, FDH efficiency score amounts to 0.895 and DEA efficiency score 0.889, which means that with the same level of expenditure on education, Croatia reached 89.5% of efficient PISA score in FDH and 88.9% in DEA, or equivalently there is unused output of 10.5% in FDH, i.e. 11.1% in DEA.

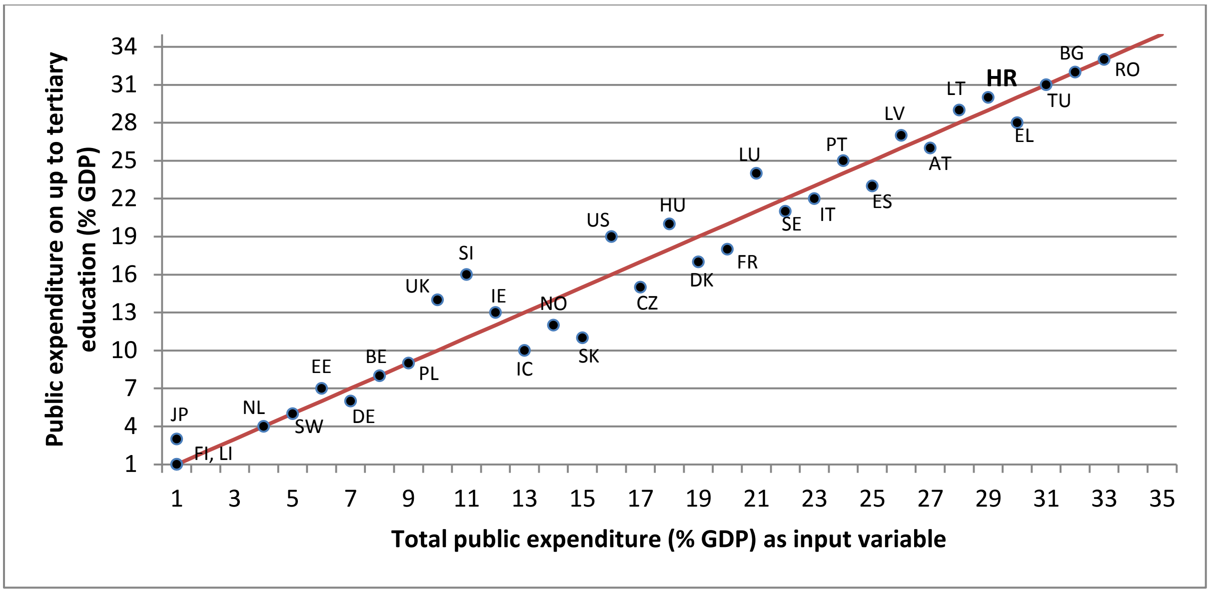
Since we consider PISA scores that were taken among 15-year-olds which were attending secondary level school, it might seem reasonable to analyse only expenditure for education up to secondary educational level, which include public expenditure on pre-primary, primary and secondary level. Figures 9 and 10 show comparison of rankings in DEA input and output oriented models with total public expenditure on all levels of education and public expenditure on pre-primary, primary and secondary education as input variables, in percentages of GDP.

Figure 9 **Comparison of rankings in DEA input oriented analysis with total public expenditure (% GDP, horizontal axis) and public expenditure on pre-primary, primary and secondary education (%GDP, vertical axis) as input variables**



Source: author

Figure 10 **Comparison of rankings in DEA output oriented analysis with total public expenditure (% GDP, horizontal axis) and public expenditure on pre-primary, primary and secondary education (%GDP, vertical axis) as input variables**



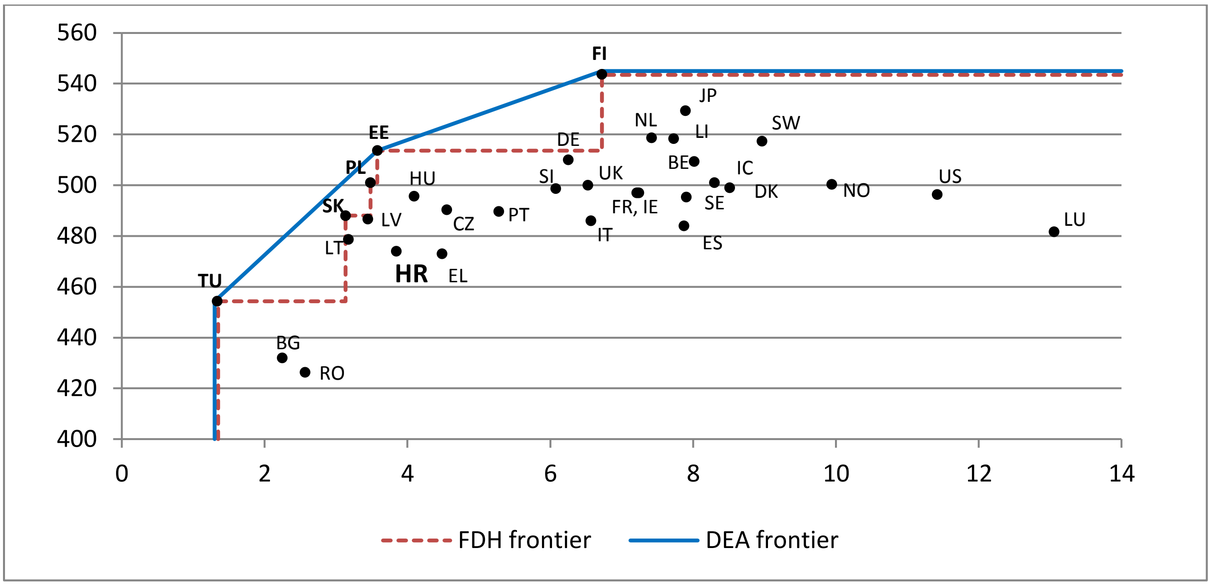
Source: author

Full results with efficiency scores and rankings of FDH and DEA analyses with public expenditure (% GDP) on up to secondary education as an input variable can be seen in Table A2 in Appendix. It can be noted that there are some minor differences between rankings in these two models. The highest difference in input oriented model is measured in case of Austria (7) and followed by Latvia (5). In output oriented model, differences are smaller and the highest ones are measured in Slovenia (5) and Slovakia and United Kingdom (both 4). In case of Croatia these differences are insignificant since they account for 2 in input oriented and 1 in output oriented model. In our further analysis, we shall consider total public expenditure which seems quite reasonable when assuming that PISA scores are direct indicators of labour force competitiveness one or two decades in advance, which can be considered as an outcome instead of output.

Public expenditure on education as a percentage of GDP does not take into account some important variables like total number of students or country standard and therefore may be unsatisfactory in efficiency measurement. Much better in this manner seems public expenditure on public educational institutions per pupil/student in EUR PPS, which measures how much central, regional and local levels of government spent per pupil/student, taking into account country standard weighted with Purchasing Power Standard (PPS). It includes expenditure for personnel, other current and capital expenditure. Table A3 in Appendix shows

FDH and DEA efficiency scores in case of one input and one output model, with public expenditure on public educational institutions per pupil/student in EUR PPS as an input variable. Figure 11 shows FDH and DEA efficiency frontiers and position of all observed countries.

Figure 11 **FDH and DEA efficiency frontiers for public expenditure on public educational institutions per pupil/student in EUR PPS as an input and average PISA 2009 score as an output**



Source: author

The same as before, the country with the lowest input (Turkey) and country with the highest output (Finland) are considered efficient. Besides these two countries, three more countries (Estonia, Poland and Slovakia) are being considered efficient in FDH and only Estonia of these three in DEA analysis, which lies on both FDH and DEA frontiers.

Croatian ranking position has changed significantly with regard to previous analysis with public expenditure on education as a percentage of GDP as an input variable and only input oriented FDH efficiency score is now above average efficiency score among observed countries. Croatian input efficiency score in FDH analysis is around 0.815 and in DEA 0.541, which means that a waste of input resources amounts to 18.5% and 45.9% respectively. In case of output efficiency, FDH efficiency score amounts to 0.923 and DEA efficiency score 0.918, which means that there is an unused output of 7.7% and 8.2%, respectively.

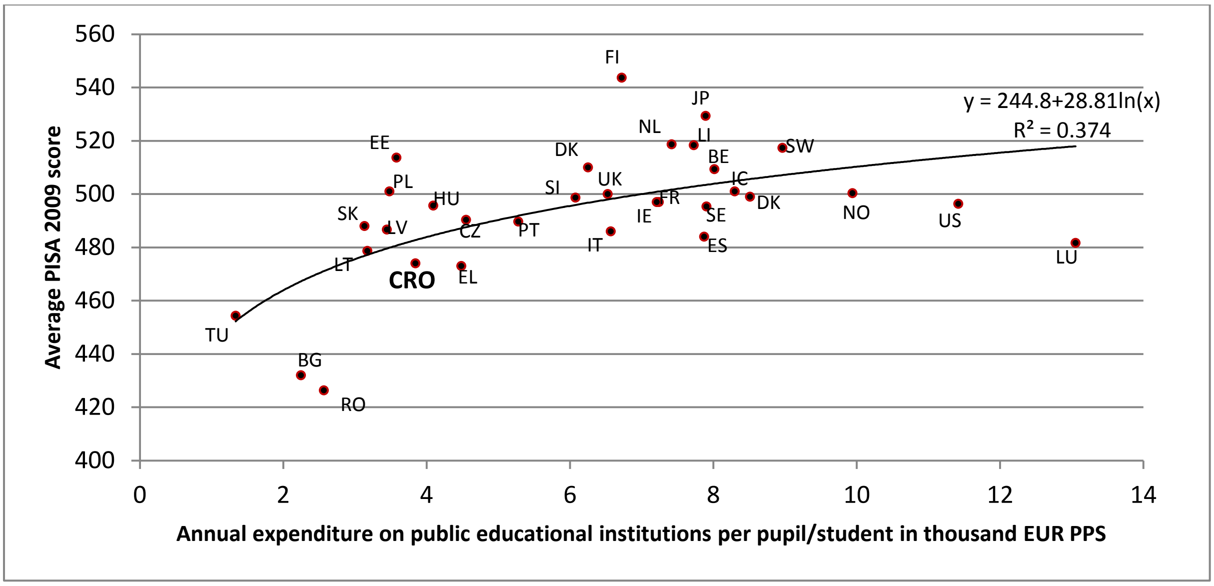
This simplified one input-one output model will now be extended to two input variables. The first variable stays the same as in the latter analysis (public expenditure on public educational institutions per pupil/student in EUR PPS) and the other one is the number of teachers per 100 students. The second variable may be also indicative because it is proven that smaller groups are usually more efficient than the large ones (Barro and Lee, 2001; OECD, 2010a). Since there are available data that show the ratio of students to teachers (ISCED 1-3), we shall transform these data into number of teachers per 100 students with the following formula:

$$TPS = \left(\frac{Students}{Teachers}\right)^{-1} \cdot 100 \qquad (9)$$

Analysis results with these two input variables are shown in Table A4 in Appendix. It can be observed that countries that were previously labelled as efficient are precisely the same as in case of a financial measure as the sole input variable, while some others also became efficient due to introduction of one new input variable. Croatian output efficiency scores have stayed the same, while the input scores have improved and amount to 0.833 in FDH and 0.662 in DEA, which means that the waste of resources amounts to 16.7%, i.e. 33.8%. All analyses are showing that funding of the Croatian education system is being inefficient and that it can and should be improved, which confirms the main hypothesis set in the beginning of the paper.

Data used for FDH and DEA analyses in previous text are relevant indicators that determine technical efficiency of government spending. However, as it was already mentioned before in the text, allocative efficiency also matters in creating the best possible output, since it reflects the link between the optimal combination of inputs taking into account costs and benefits and the output achieved. In that manner it seems reasonable to extend the analysis from the previous section to regression analysis in order to create link between public expenditure on education and PISA scores and to determine the strength of its influence. Figure 12 shows regressed scatter plot of annual expenditure on public educational institutions per pupil/student in thousand EUR PPS and average PISA 2009 score.

Figure 12 **Scatter plot and regression function of annual expenditure on public educational institutions per pupil/student in thousand EUR PPS and average PISA 2009 score**



Source: Eurostat (2011b); OECD (2010a); author's calculation

It seems that there exists relatively clear logarithmic relationship between expenditure on public educational institutions per pupil/student and performances in PISA tests. Logarithmic regression model used in this case can be expresses as follows:

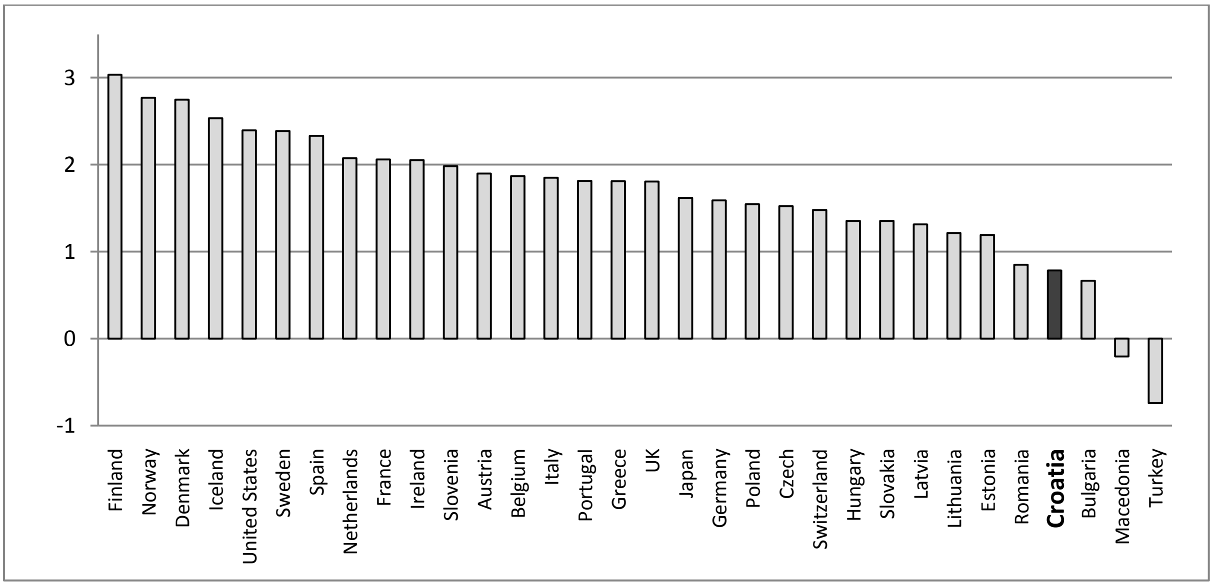
$$y = 244.8 + 28.81 \cdot \ln(x) \qquad (10)$$

where x is a level of annual expenditure on public educational institutions per pupil/student in EUR PPS and y represents estimated PISA 2009 score. Such regressed function is positive (for any $x > 2.04 \cdot 10^{-4}$, which will be always in this purpose), increasing and concave, which are good local characteristics for the needs of this analysis. Furthermore, the presented model shows a relatively satisfactory fit of 37.4%, measured by R^2, which means that over one third of students' performance can be explained with the level of public education funding. This function is also non-elastic for each level of expenditure greater than 1 EUR PPS per pupil/student, which actually means that each increase in expenditure of one percent would result with increase of PISA score of somewhere in the region of 0.05-0.07%[6]. It has to be mentioned that such kind of relationship cannot be identified between public expenditure on education as a percentage of GDP and PISA scores for a variety of reasons of which number of pupils or students and country's standard probably have influenced the most.

[6] Elasticity of regressed function with regard to expenditure on public educational institutions is a decreasing function for all levels of expenditure greater than zero and it amounts to 0.076 in case of expenditure of 100 EUR PPS per pupil/student, 0.065 for 1,000 EUR, 0.056 for 10,000 EUR and 0.054 for 20,000 EUR.

Any positive or negative deviation of the observed sample value from the estimated value shown on Figure 12 may be considered as an error, but it can actually be understood as the unobserved influence of non-financial variables like socio-economic indicators or the allocative (in)efficiency manifested in teachers' salaries, class size etc. According to logarithmic efficiency, it may be concluded that Croatia is slightly inefficient, since the Croatian average PISA score is situated below the expected value for the amount of public expenditure on education. Figure 13 shows Legatum prosperity education sub-index in 2010, as an additional source for a cross country comparison.

Figure 13 **Legatum prosperity education sub-index 2010**



Source: 2010 Legatum Prosperity Index database, author's calculation

The education sub-index demonstrates how access to education allows citizens to develop their potential and contribute productively to their society. According to the data from the Legatum Prosperity Index (2010), Croatia is situated 44th among 110 worldwide countries according to the education sub-index score which measures countries' performances in three areas: access to education, quality of education and human capital. With regard to the new EU member states, only Bulgaria had lower education sub-index than Croatia. Thus some space for progress obviously exists, and the efficiency and effectiveness of education need unremitting attention.

6. Possible sources of inefficiency of public expenditure on education in Croatia

Jafarov and Gunnarsson (2008) identified several inefficiencies of government spending on education related to size of teaching force, teachers' salaries, school infrastructure, subsidies etc. Aristovnik and Obadić (2011) showed that the relatively high public expenditure per student in Croatia in tertiary education should have resulted in a better performance in terms of outputs/outcomes, i.e. a higher rate of higher education enrolment, a greater ratio of the labour force with higher education and a lower ratio of unemployed persons who have tertiary education.

To start with analysis of possible sources of inefficiency it should be evaluated trend of number of pupils and students, institutions and teaching staff in Croatia for the period 2000-09, which is shown in Table 2.

Table 2 **Number of pupils and students enrolled in education by level, at the beginning of school year, 2000-09**

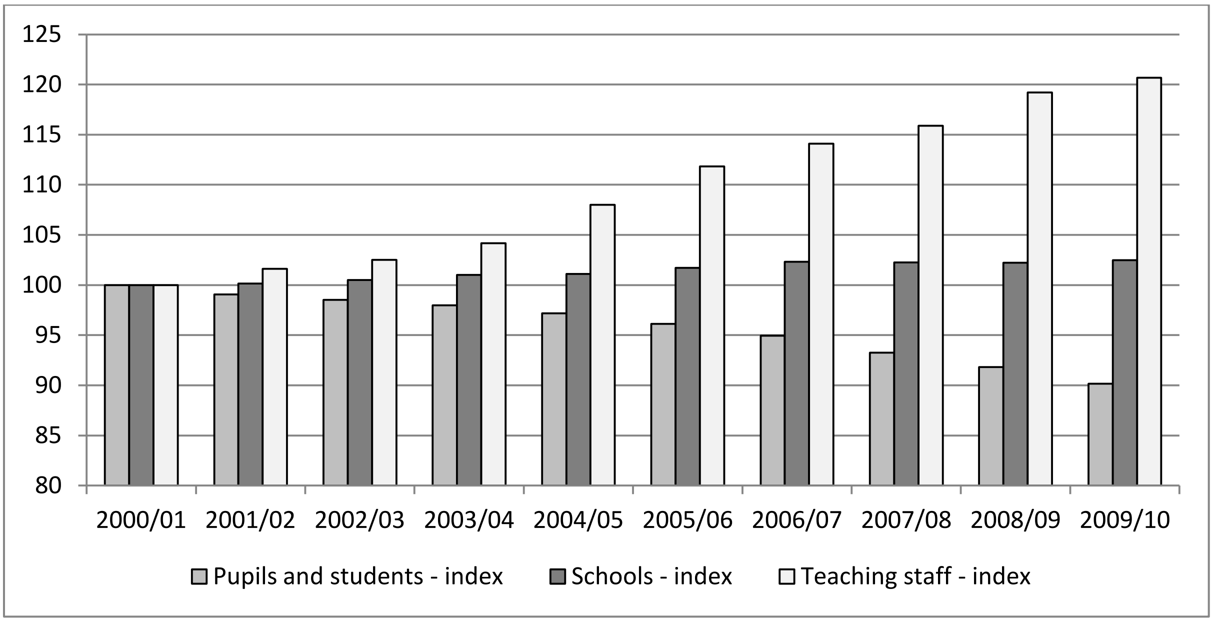
School/ academic year	**Basic education** (ISCED 1-2)			**Secondary education** (ISCED 3)			**Tertiary education** (ISCED 5)		
	Schools	Pupils	Teachers	Schools	Students	Teachers	Institutions	Students	Teaching staff*
2000/01	2,141	405,682	27,147	634	195,120	19,325	93	100,297	7,701
2001/02	2,134	400,100	27,502	645	195,000	19,718	95	107,911	7,622
2002/03	2,139	395,702	27,905	650	196,147	19,733	100	116,434	8,132
2003/04	2,138	393,421	28,335	665	195,340	20,073	102	120,822	7,917
2004/05	2,141	391,744	29,485	665	192,076	20,701	103	128,670	8,764
2005/06	2,140	387,952	30,131	683	189,661	21,835	110	132,952	9,486
2006/07	2,146	382,441	30,450	693	187,977	22,573	114	136,129	13,075
2007/08	2,133	376,100	30,877	705	184,183	22,975	115	138,126	13,866
2008/09	2,127	369,698	31,621	710	181,878	23,772	126	134,188	14,995
2009/10	2,131	361,052	32,083	713	180,582	24,004	132	145,263	15,863

Source: Croatian Bureau of Statistics (2010), page 477.

* *Since the 2006/07 academic year, the coverage of the survey has been changed and adjusted to user needs. The figure includes all members of academic staff who teach at institutions of higher education. Since members of academic staff may teach at two or more institutions of higher education, the figure shown does not correspond to the actual number of persons.*

Some evident trends of this 10-year period can be discerned from Table 2. The number of employees in education, i.e. teachers and teaching staff, has been increasing in all levels of education. On the other hand, the number of students has been rising only in tertiary education (a 45% increase), but significantly less than that of faculty (106%). Figure 14 shows trends in number of pupils and students enrolled in education, schools and teaching staff in primary and secondary education.

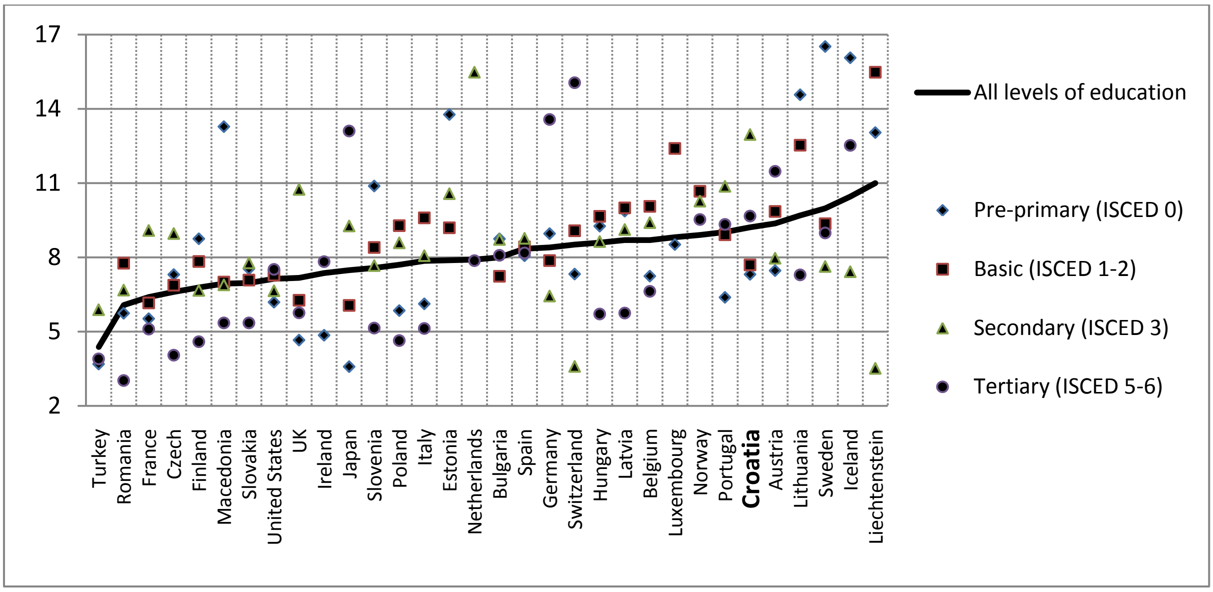
Figure 14 **Trends in number of pupils and students enrolled in education, schools and teaching staff, for primary and secondary level of education, 2000-09 (base year 2000/01 – index 100)**



Source: author based on Table 2

Following the demographic trends, the number of pupils and students has decreased by 10% since 2000. At the same time, a trend for teaching staff to increase has been recorded of about 21%. At the same time there has been an increase in the number of available schools of about 2.5%. While at the beginning of the school year 2000/01 there was an average number of 217 pupils/students per school, this number had decreased by 12% to 190 pupils/students per school in 2009/10, showing a decrease of one whole class size. At the same time, the number of teachers per school had increased from an average of 17 in 2000/01 to an average of 20 in 2009/10 implying that the student-teacher ratio had decreased by over 25%. Figure 15 shows the number of teachers per 100 pupils/students in 30 European countries, United States and Japan for all levels of education.

Figure 15 **Number of teachers per 100 pupils/students (reference year 2008)**



Source: Eurostat (2011c); author's calculation

Croatia had relatively high average number of teachers per 100 students of 9.2, about 1.2 more than the average of the observed European countries, USA and Japan. Only Austria, Lithuania, Sweden, Iceland and Liechtenstein had a higher number of teachers per 100 students and all of these countries recorded better average 2009 PISA scores than Croatia. Croatia had 4.1 teachers per 100 students more than the average of the observed countries in secondary education and 2.1 more in tertiary education, while it is slightly below average in pre-primary and basic (primary and lower secondary) education. Table 3 shows calculated discrepancies in teachers and teaching staff based on number of teachers and teaching staff per 100 pupils/students in Croatia and the averages of observed countries as the benchmark values.

Table 3 **Discrepancies in teachers and teaching staff**

	Teachers per 100 students (2008)			Number of pupils/students in Croatia (2009/10)	Teachers and teaching staff discrepancies
	Average of observed countries*	Croatia	Difference (Croatia - Average)		
Pre-primary (ISCED 0)	8.57	7.32	-1.26	99,317	-1,247
Basic (ISCED 1-2)	8.86	7.70	-1.16	361,052	-4,195
Secondary (ISCED 3)	8.88	12.96	4.08	180,582	7,367
Tertiary (ISCED 5-6)	7.59	9.67	2.08	145,263	3,017
TOTAL	**8.07**	**9.22**	**1.15**	**786,214**	**4,942**

Source: Eurostat; Croatian Bureau of Statistics (2010); author's calculation

* Observed countries include 30 European countries, USA and Japan as shown on Figure 15.

Discrepancies in teachers and teaching staff are calculated as the difference between the average number of teachers per 100 students in observed countries and number of teachers per 100 students in Croatia (Difference column) multiplied by number of pupils/students in Croatia in the academic year 2009/10. Table 3 shows that in pre-primary and basic education 5,442 teachers are needed in order to achieve an average level of teachers per 100 students as in the sample of countries observed. On the other hand, in secondary and tertiary education Croatia has 10,384 teachers more than it would have if it had the average number of teachers per 100 students. Taking all levels of education into account, it can be conclude that in Croatia there might be an excess of teaching force of 4,942 teachers. Rationalization of the teaching force to the average of observed countries could lead to declines in fiscal costs and rigidities that limit the scope for discretionary cuts in short-term education spending. This could be done by increasing the teaching hours, since teachers with a fulltime position are required to teach 16-22 hours per week (Official Gazette, 2011). Still, hours per week that teachers spend teaching in Croatia are mainly in line with OECD countries average weekly teaching hours in primary education of 21 and in lower secondary education of 19 hours (OECD, 2010b).

Nestić et all (2006) showed that demographic trends indicate that the number of school age persons (aged 7-24 years) will fall dramatically up to 2050. Their estimations show a decrease of 34% in the case of constant enrolment rates and 22% in the case of increasing enrolment rates, as compared to the numbers in 2005. Even in the case of a high fertility rate and increasing enrolment rates, which is the most optimistic scenario, the number of pupils and students will decrease by more than 7% up to 2050. Jafarof and Gunnarsson (2008) stated that future demographic trends imply significant potential for savings, if the number of teachers and overall education spending can be reduced in line. Also, as student numbers decline, schools could consider pooling resources by sharing teachers. Otherwise, further declines in the student-teacher ratio will lead to significant inefficiencies and aggravate the fiscal burden.

Although smaller groups are usually more efficient than the large ones (Barro and Lee, 2001), OECD (2010a) showed that higher teachers' salaries, but not smaller class sizes, are associated with better student performance, showing that raising teacher quality is a more effective route to improved student outcomes than creating smaller classes. Unfortunately, no comparable figures of teachers' salaries that include an assessment of Croatia are publicly available, so cross-country analysis is impossible to be made within the scope of this paper[7]. For that reason, it cannot be concluded either that the teachers in Croatia are not paid enough or that they are paid too much as compared to other countries, but this may be a very good line of enquiry for some further research.

Salaries and working conditions are important for attracting, developing and retaining skilled and high-quality teachers. In a competitive labour market, the equilibrium rate of salaries paid to different types of teachers in different regions of the country would reflect the supply of and demand for those teachers. This is often not the case in OECD countries, as salaries and other working conditions are often set centrally for all teachers (OECD, 2010b). The same problem is present in Croatia, where salaries are also set centrally for all teachers, without any consideration of demand and supply in different regions and/or teaching subjects. Salary levels at different career points may also be a bit problematic in Croatia, since the increases are mainly driven by working experience. In other words, qualified and motivated young teachers may not be adequately paid with regard to their teaching contribution. Therefore, an improvement of mechanisms of teacher assessment to bring them up to the level common in the private sector may result in high-quality teachers being attracted and motivated.

School infrastructure is used relatively intensively, but there are inequalities among regions and even among different schools in some bigger cities. According to estimates by the Ministry of Science, Education and Sports (2005), about 66% of schools had double shifts and 4% of schools had triple shifts, where 82.5% of primary school pupils and 88% of secondary school pupils attended multiple shift schools. For that reason, in 2005 the government started Education Development Project with one component, i.e. priority (of a total number of four), aiming at the elimination of triple shifts and a reduction of double shifts. According to the State Audit Office report (2011), the majority of all activities related to this priority had been accomplished by the end of 2009. Unfortunately, updated statistics on multiple shift schools and percentage of pupils that attend multiple shift schools are not publicly available. Rationalizing the school network would also help to realize potential benefits from expected declines in the number of students. This could be facilitated by increases in spending on transportation and the usage of multi-grade teaching in small schools. The government's

[7] For example, OECD Education at a Glance (2010b) includes annual teachers' salaries in public institutions (in US dollars PPP) for primary and secondary levels of education, but includes only OECD and several partner countries (Estonia, Indonesia, Israel and Slovenia).

efforts to eliminate triple shifts are welcome, but attempts to eliminate double shifts need to be well planned to avoid unnecessary spending (Jafarov and Gunnarsson, 2008).

As for tertiary education, there is some previous research that identified several inefficiencies. In 2006, the University of Rijeka found that the average time for completion of a four-year program was 6.7 years and only about a third of students did complete, implying a two-thirds dropout rate. In other words, serious internal inefficiencies at the tertiary level do not seem to have diminished in recent years. Same research showed that those students that pay fees generally complete at higher rates, in a shorter time period and with better grades (World Bank, 2008). According to Filipić (2009), inefficiency in tertiary education can also be observed in student subsidies, which are numerous, and considerable in their financial volume, but they are directed only to the maintenance or the occasional enlargement of the number of higher educated citizens. However, they do not direct students towards professions appropriate to the modern structure of the economy and society as a whole, but rather interpret the needs of society in terms of the structure and capacities of higher education and do not stimulate excellence, but only mediocrity.

Jafarov and Gunnarsson (2008) stated that public subsidies to education mostly benefit households with higher incomes, since most scholarships and rewards go to students with better academic achievements, who tend to come from families in the top-income quintile that can spend more money to support education. In order to preserve social fairness and foster excellence, scholarships should be redistributed so as to include both students with better academic achievements and those that come from lower income families. However, benefits from other subsidies, such as dormitories and transportation, should be available primarily to students from lower income families.

Croatia will also have to pay as close, if not greater, attention to the quality of learning outcomes as to sustaining the increases in schooling among its population. The most recent adult literacy rates are only 98.1%, compared to 98.7% in Albania and over 99% in the new EU member states. Life-long learning programs exist, but are little used (World Bank, 2008). In a study of the Croatian Chamber of Economics (2010) that assessed needs for education in small and medium enterprises and trades, the high importance of the future development of employees was identified. On the other hand, this analysis showed that the system of governmental support does exist, but is not fully appropriate. Thus, it is important to continue with the promotion, availability and simplicity of state support for human resources development and education.

7. Conclusion and recommendations

Dataset used in analyses included 30 (in some cases more) European countries for which PISA 2009 scores and data related to expenditure were available, but also United States and Japan as the benchmark countries. Croatia with the average PISA 2009 score of 474 has the highest average score with regard to its eastern neighbouring countries, but is somewhere in the middle among observed CEE and SEE region countries. Total public expenditure on education in Croatia in 2007 of 4% was about 1 percentage point lower than the average public expenditure on education in all observed countries.

Efficiency of public expenditure on education has been analysed by two non-parametrical approaches, FDH and DEA, by using several different input variables (expenditure as a share of GDP, expenditure per pupil/student in EUR PPS and teacher per 100 students) and average PISA 2009 score as an output variable. Main hypothesis tested was that Croatian education funding has been inefficient, which has been confirmed with all of the mentioned analyses.

Input efficiency score implies that Croatia might be able to achieve the same level of performance using only 47.2 percent of its expenditure on education expressed as a percent of GDP, while in case of output efficiency it implies that with the same level of GDP expenditure on education, there is unused output of 10.5% in FDH, i.e. 11.1% in DEA. In more realistic case, where the expenditure per pupil/student in EUR PPS was used as an input variable, Croatian input efficiency score indicates a waste of input resources of 18.5% in FDH and 45.9% in DEA. In case of output efficiency, FDH efficiency score amounts to 0.923 and DEA efficiency score 0.918, which means that an unused output amounts to 7.7% and 8.2%, respectively. With model extension of another input variable (teacher per 100 students), Croatian output efficiency scores have stayed the same as in case of only expenditure per pupil/student in EUR PPS as an input variable, while the input efficiency scores have improved and showing that the waste of input resources amounts to 16.7% in FDH, i.e. 33.8% in DEA model.

There is strong evidence that some other factors, apart from expenditure on education, play an important role in students' performance. This paper has identified several main deficiencies that may have disturbed Croatian education efficiency. The first is directed to the high share of students in public institutions as compared to other European countries, which suggests that the private primary and secondary level educational sector may still be underdeveloped, but it also means that public sector has to provide more resources than it would have to if there were a more developed private sector. Therefore, a more detailed analysis of possibilities of private education development in Croatia is suggested. Development of the private educational sector may decrease the current level of public expenditure on education and/or improve the allocation of the public funds over the long run.

The second problem is linked to the growth trends in teaching staff and number of educational institutions concomitant with declining enrolments. The number of teachers per 100 students is higher than the average of 30 European countries, USA and Japan, indicating possibilities for savings by rationalization of teaching staff. The analysis showed a possible surplus of a total of 4,942 teachers, in all levels of education. This is also consequence of the relatively modest weekly norms of 16-22 teaching hours, which can be increased.

Teachers' salaries and working conditions strongly influence student performance and are very important for attracting, developing and retaining skilled and high-quality teachers, accordingly needing special attention. Since there are no publicly available comparable figures of teachers' salaries of different countries that include an assessment of Croatia, further research into the adequacy of salary levels in Croatia as compared to that in other European countries is needed. When teacher's salaries are being determined, demand and supply in different regions and/or teaching subjects, as well as the improvement of mechanisms of teacher assessment, should be considered. At the moment, salaries in Croatia are set centrally for all teachers.

Growing urbanization, together with decreasing fertility rates, will lead to smaller class sizes particularly in the countryside, which are even now in some places too small. These should lead to the closure of schools with few pupils/students and the merging of several schools into one. Such actions may diminish current and maintenance costs of educational institutions and expenditures for teaching staff. It is recommended that the number of schools follows the trends in enrolments. All of the above mentioned may lead to better performance from Croatian pupils and students with the same level of public expenditure, i.e. the gained future educational output might outperform the current one and improve Croatian education efficiency.

The government educational subsidy system should also be revised in order to, not only foster excellence, but also help financially vulnerable groups in the education process. Therefore, scholarships and rewards should be directed both to students with better academic achievements and to those from households with lower income level. On the other hand, for programs providing subsidized transportation and dormitories, means-testing should be introduced in order to avoid such spending on students from higher income households. This would help to better target the vulnerable groups and curb education spending without sacrificing education outcomes. The existence, but under-usage of life-long learning programs underlines the importance of the promotion, availability and simplicity of state support for human resources development and education. All of these changes might help to improve the educational structure, as well as the current and future competitiveness of the Croatian labour force on the international labour market.

8. Literature

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9. Appendix

Table A1 **FDH and DEA efficiency scores – one input (Total public expenditure on education in 2007, as a percentage of GDP) and one output (average PISA 2009 score)**

Country	FDH				DEA			
	Efficiency score input oriented	Rank	Efficiency score output oriented	Rank	Efficiency score input oriented	Rank	Efficiency score output oriented	Rank
Austria	0.356	27	0.919	22	0.356	27	0.900	27
Belgium	0.319	29	0.937	14	0.319	29	0.937	8
Bulgaria	0.465	10	0.816	32	0.465	9	0.810	32
Croatia	0.472	9	0.895	29	0.472	8	0.889	29
Czech Republic	0.457	11	0.926	17	0.457	10	0.919	17
Denmark	0.245	33	0.918	25	0.245	33	0.918	19
Estonia	0.396	17	0.970	6	0.396	16	0.956	6
Finland	1.000	1	1.000	1	1.000	1	1.000	1
France	0.343	28	0.939	11	0.343	28	0.917	20
Germany	0.427	15	0.963	7	0.427	14	0.952	7
Greece[a]	0.475	8	0.894	30	0.475	7	0.888	30
Hungary	0.369	23	0.936	15	0.369	23	0.919	18
Iceland	0.261	32	0.922	20	0.261	32	0.922	13
Ireland	0.392	18	0.939	11	0.392	17	0.924	12
Italy	0.448	13	0.918	24	0.448	12	0.910	23
Japan	1.000	1	1.000	1	1.000	1	1.000	1
Latvia	0.384	20	0.919	22	0.384	19	0.904	26
Liechtenstein	1.000	1	1.000	1	1.000	1	1.000	1
Lithuania	0.411	16	0.904	28	0.411	15	0.892	28
Luxembourg	0.610	6	0.929	16	0.610	5	0.914	21
Netherlands	0.648	5	0.980	4	0.370	22	0.960	4
Norway	0.284	31	0.920	21	0.284	31	0.920	14
Poland	0.391	19	0.946	8	0.391	18	0.932	9
Portugal	0.362	25	0.925	18	0.362	25	0.907	24
Romania	0.452	12	0.805	33	0.452	11	0.798	33
Slovakia	0.530	7	0.922	19	0.530	6	0.920	15
Slovenia	0.370	22	0.942	10	0.370	21	0.924	11
Spain	0.441	14	0.914	26	0.441	13	0.905	25
Sweden	0.287	30	0.911	27	0.287	30	0.911	22
Switzerland	0.371	21	0.977	5	0.371	20	0.959	5
Turkey[b]	0.671	4	0.877	31	0.671	4	0.865	31
United Kingdom	0.356	26	0.945	9	0.356	26	0.925	10
United States	0.363	24	0.938	13	0.363	24	0.919	16
AVERAGE	0.465	-	0.929	-	0.457	-	0.919	-

Source: Eurostat (2011a); OECD (2010a); author's calculation

[a] Reference year 2005 for public expenditure on education
[b] Reference year 2006 for public expenditure on education

Table A2 **FDH and DEA efficiency scores – one input (Public expenditure on up to secondary education in 2007, as a percentage of GDP) and one output (average PISA 2009 score)**

Country	FDH				DEA			
	Efficiency score input oriented	Rank	Efficiency score output oriented	Rank	Efficiency score input oriented	Rank	Efficiency score output oriented	Rank
Austria	0.449	20	0.919	18	0.449	20	0.898	26
Belgium	0.372	30	0.937	12	0.372	30	0.937	8
Bulgaria	0.507	14	0.816	32	0.507	13	0.805	32
Croatia	0.537	11	0.895	29	0.537	10	0.886	30
Czech Republic	0.561	8	0.926	13	0.561	7	0.919	15
Denmark	0.316	32	0.918	20	0.316	32	0.918	17
Estonia	0.463	18	0.970	6	0.463	17	0.950	7
Finland	1.000	1	1.000	1	1.000	1	1.000	1
France	0.401	27	0.914	22	0.401	27	0.914	18
Germany	0.521	13	0.963	7	0.521	12	0.952	6
Greece[a]	0.651	6	0.913	23	0.651	5	0.895	28
Hungary	0.419	26	0.912	24	0.419	26	0.912	20
Iceland	0.293	33	0.922	15	0.293	33	0.922	10
Ireland	0.467	17	0.939	10	0.467	16	0.920	13
Italy	0.496	15	0.918	19	0.496	14	0.904	22
Japan	1.000	1	1.000	1	0.980	3	0.999	3
Latvia	0.430	24	0.895	30	0.430	24	0.895	27
Liechtenstein	1.000	1	1.000	1	1.000	1	1.000	1
Lithuania	0.481	16	0.904	27	0.481	15	0.888	29
Luxembourg	0.556	10	0.910	26	0.556	9	0.903	24
Netherlands	0.728	5	0.980	4	0.461	18	0.958	4
Norway	0.380	29	0.920	16	0.380	29	0.920	12
Poland	0.440	21	0.946	8	0.440	21	0.923	9
Portugal	0.428	25	0.901	28	0.428	25	0.901	25
Romania	0.559	9	0.805	33	0.559	8	0.799	33
Slovakia	0.618	7	0.922	14	0.618	6	0.920	11
Slovenia	0.440	21	0.942	9	0.440	22	0.919	16
Spain	0.522	12	0.914	21	0.522	11	0.903	23
Sweden	0.355	31	0.911	25	0.355	31	0.911	21
Switzerland	0.453	19	0.977	5	0.453	19	0.955	5
Turkey[b]	0.897	4	0.877	31	0.897	4	0.873	31
United Kingdom	0.392	28	0.920	17	0.392	28	0.920	14
United States	0.433	23	0.938	11	0.433	23	0.913	19
AVERAGE	0.532	-	0.925	-	0.524	-	0.916	-

Source: Eurostat (2011a); OECD (2010a); author's calculation

[a] Reference year 2004 for pre-primary education expenditure and 2005 for primary and secondary education expenditure

[b] Reference year 2006 for public expenditure on education

Table A3 **FDH and DEA efficiency scores – one input (Public expenditure on public educational institutions per pupil/student in EUR PPS, year 2007) and one output (average PISA 2009 score)**

Country	FDH				DEA			
	Efficiency score input oriented	Rank	Efficiency score output oriented	Rank	Efficiency score input oriented	Rank	Efficiency score output oriented	Rank
Austria	-	-	-	-	-	-	-	-
Belgium	0.447	25	0.937	21	0.426	22	0.937	15
Bulgaria	0.594	17	0.951	18	0.594	10	0.903	28
Croatia	0.815	12	0.923	22	0.541	14	0.918	21
Czech Republic	0.765	13	0.955	13	0.593	11	0.938	14
Denmark	0.409	28	0.918	26	0.355	28	0.918	22
Estonia	1.000	1	1.000	1	1.000	1	1.000	1
Finland	1.000	1	1.000	1	1.000	1	1.000	1
France	0.481	23	0.914	27	0.407	24	0.914	24
Germany	0.573	19	0.993	7	0.550	13	0.946	13
Greece[a]	0.699	15	0.921	24	0.455	20	0.906	27
Hungary	0.851	11	0.965	12	0.708	8	0.956	7
Iceland	0.420	27	0.922	23	0.374	26	0.922	19
Ireland	0.483	22	0.914	27	0.409	23	0.914	23
Italy	0.477	24	0.946	19	0.386	25	0.896	29
Japan	0.852	10	0.974	9	0.661	9	0.974	5
Latvia	0.909	7	0.997	6	0.743	6	0.954	8
Liechtenstein	0.870	9	0.953	15	0.526	15	0.953	10
Lithuania	0.987	6	0.981	8	0.711	7	0.952	11
Luxembourg	0.240	32	0.886	32	0.181	32	0.886	31
Netherlands	0.906	8	0.954	14	0.553	12	0.954	9
Norway	0.350	30	0.920	25	0.309	30	0.920	20
Poland	1.000	1	1.000	1	0.891	4	0.980	4
Portugal	0.659	16	0.953	16	0.506	17	0.924	17
Romania	0.520	21	0.938	20	0.520	16	0.876	32
Slovakia	1.000	1	1.000	1	0.833	5	0.972	6
Slovenia	0.573	18	0.971	11	0.496	18	0.928	16
Spain	0.398	29	0.890	31	0.312	29	0.890	30
Sweden	0.440	26	0.911	30	0.365	27	0.911	26
Switzerland	0.750	14	0.952	17	0.442	21	0.952	12
Turkey[b]	1.000	1	1.000	1	1.000	1	1.000	1
United Kingdom	0.533	20	0.973	10	0.469	19	0.923	18
United States	0.305	31	0.913	29	0.256	31	0.913	25
AVERAGE	0.666	-	0.951	-	0.549	-	0.935	-

Source: Eurostat (2011b); OECD (2010a); author's calculation

[a] Reference year 2005 for public expenditure on education
[b] Reference year 2006 for public expenditure on education

Table A4 **FDH and DEA efficiency scores – two inputs (Public expenditure on public educational institutions per pupil/student in EUR PPS, year 2007; Teacher per 100 students ratio, year 2008) and one output (average PISA 2009 score)**

Country	FDH				DEA			
	Efficiency score input oriented	Rank	Efficiency score output oriented	Rank	Efficiency score input oriented	Rank	Efficiency score output oriented	Rank
Austria	-	-	-	-	-	-	-	-
Belgium	0,730	23	0,937	24	0,654	21	0,937	17
Bulgaria	0,594	32	0,951	20	0,594	24	0,903	28
Croatia	0,833	19	0,923	25	0,662	20	0,918	24
Czech Republic	0,959	10	0,955	16	0,791	14	0,938	16
Denmark[c]	0,734	22	0,918	29	0,643	23	0,918	25
Estonia	1,000	1	1,000	1	1,000	1	1,000	1
Finland	1,000	1	1,000	1	1,000	1	1,000	1
France	0,863	17	0,968	14	0,805	12	0,922	21
Germany	1,000	1	1,000	1	0,989	5	0,996	5
Greece[a]	0,699	25	0,921	27	0,455	32	0,906	27
Hungary	0,874	15	0,965	15	0,708	18	0,956	10
Iceland	0,689	26	0,922	26	0,590	27	0,922	22
Ireland	0,922	12	0,975	12	0,861	10	0,940	15
Italy	0,686	27	0,946	21	0,574	29	0,896	29
Japan	1,000	1	1,000	1	1,000	1	1,000	1
Latvia	0,909	13	0,997	9	0,743	15	0,954	11
Liechtenstein	0,870	16	0,953	17	0,592	25	0,953	12
Lithuania	0,987	9	0,981	10	0,711	17	0,952	13
Luxembourg	0,617	31	0,886	32	0,536	30	0,886	31
Netherlands	1,000	1	1,000	1	0,970	6	0,987	6
Norway	0,629	30	0,920	28	0,590	26	0,920	23
Poland	1,000	1	1,000	1	0,891	8	0,980	7
Portugal	0,678	28	0,953	18	0,533	31	0,924	20
Romania	0,644	29	0,938	22	0,644	22	0,876	32
Slovakia	1,000	1	1,000	1	0,892	7	0,972	8
Slovenia	0,845	18	0,971	13	0,722	16	0,928	18
Spain	0,718	24	0,890	31	0,589	28	0,890	30
Sweden	0,791	21	0,911	30	0,704	19	0,911	26
Switzerland[d]	0,828	20	0,952	19	0,794	13	0,952	14
Turkey[b]	1,000	1	1,000	1	1,000	1	1,000	1
United Kingdom	0,958	11	0,980	11	0,889	9	0,957	9
United States	0,880	14	0,938	23	0,819	11	0,925	19
AVERAGE	0,842	-	0,958	-	0,748	-	0,941	-

Source: Eurostat (2011b; 2011c); OECD (2010a); author's calculation

[a] Reference year 2005 for public expenditure on education and 2007 for teacher per 100 students
[b] Reference year 2006 for public expenditure on education
[c] Reference year 2003 for teacher per 100 students
[d] Reference year 2005 for teacher per 100 students (http://www.childinfo.org/files/IND_Switzerland.pdf)