

Efficiency of Public Spending in Developing Countries: An Efficiency Frontier Approach¹

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Abstract

Governments of developing countries typically spend between 15 and 30 percent of GDP. Hence, small changes in the efficiency of public spending could have a major impact on GDP and on the attainment of the government's objectives. The first challenge that stakeholders face is measuring efficiency. This paper attempts such quantification and has two major parts. The first one estimates efficiency as the distance between observed input-output combinations and an efficiency frontier (defined as the maximum attainable output for a given level of inputs). This frontier is estimated for several health and education output indicators by means of the Free Disposable Hull (FDH) and Data Envelopment Analysis (DEA) techniques. Both input-inefficiency (excess input consumption to achieve a level of output) and output-inefficiency (output shortfall for a given level of inputs) are scored in a sample of 140 countries using data from 1996 to 2002. The second part of the paper seeks to verify empirical regularities of the cross-country variation in efficiency. Results show that countries with higher expenditure levels register lower efficiency scores, as well as countries where the wage bill is a larger share of the government's budget. Similarly, countries with higher ratios of public to private financing of the service provision score lower efficiency, as do countries plagued by the HIV/AIDS epidemic and those with higher income inequality. Countries with higher aid-dependency ratios also tend to score lower in efficiency, probably due to the volatility of this type of funding that impedes medium term planning and budgeting. Though no causality may be inferred from this exercise, it points at different factors to understand why some countries might need more resources than others to achieve similar educational and health outcomes.

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I. Introduction

Governments of developing countries typically spend resources equivalent to between 15 and 30 percent of GDP. Hence, small changes in the efficiency of public spending could have a significant impact on GDP and on the attainment of the government's objectives whichever these are. The first challenge faced by stakeholders is measuring and scoring efficiency. This paper attempts such quantification. Additionally it verifies statistically some empirical regularities that describe the cross country-variation in the estimated efficiency scores.

The paper has four chapters following this Introduction. The first one presents the methodology that defines efficiency as the distance from the observed input-output combinations to an efficient frontier. This frontier, defined as the maximum attainable output for a given input level, is estimated using the Free Disposable Hull (FDH) and Data Envelopment Analysis (DEA) techniques. The exercise focuses on health and education expenditure because they absorb the largest share of most countries' budgets, and because of lack of data availability for international comparisons in other types of expenditures.

The second chapter estimates the efficiency frontiers for nine education output indicators and four health output indicators, based on a sample of 140 countries and data for 1996-2002. Both input-efficiency (excess input consumption to achieve a level of output) and output-efficiency (output shortfall for a given level of inputs) are scored. The chapter presents both the single input-single-output and the multiple-inputs multiple-outputs frameworks. In addition, this chapter explores how expenditure efficiency has changed over time.

The third chapter seeks to identify empirical regularities that explain cross-country variation in the efficiency scores. Using a Tobit panel approach, this chapter shows that higher expenditure levels are generally associated with lower efficiency scores. Similarly, countries in which the wage bill is a larger share of the total budget tend to have lower efficiency scores. Three other variables that explain the cross country variation in efficiency scores are the degree of urbanization (positively correlated with efficiency), the prevalence of the HIV/AIDS epidemic (negatively associated with efficiency scores), and inequality in income distribution (higher inequality associated with lower efficiency).

The fourth and last chapter summarizes the conclusions.

II. Measuring Efficiency: Methodologies and Overview of the Literature

The object of this chapter is to briefly describe the specific empirical methods applied in this paper to measure efficiency and to survey the literature more directly related to the analysis of public expenditure efficiency. Empirical and theoretical measures of efficiency are based on ratios of observed output levels to the maximum that could have

been obtained given the inputs utilized. This maximum constitutes the efficient frontier which will be the benchmark for measuring the relative efficiency of the observations. There are multiple techniques to estimate this frontier, surveyed recently by Murillo-Zamorano (2004), and the methods have been recently applied to examine the efficiency of public spending in several counties. These are the topics of the next two sections.

II.1. Methods for Measuring Efficiency.

The origin of the modern discussion of efficiency measurement dates back to Farrell (1957), who identified two different ways in which productive agents could be inefficient: one, they could use more inputs than technically required to obtain a given level of output, or two, they could use a sub-optimal input combination given the input prices and their marginal productivities. The first type of inefficiency is termed technical inefficiency while the second one is known as allocative inefficiency.

These two types of inefficiency can be represented graphically by means of the unit isoquant curve in Figure 1. The set of minimum inputs required for a unit of output lies on the isoquant curve YY' . An agent's input-output combination defined by bundle P produces one unit of output using input quantities X_1 and X_2 . Since the same output can be achieved by consuming less of both inputs along the radial back to bundle R , the segment RP represents the inefficiency in resource utilization. The technical efficiency (TE), input-oriented, is therefore defined as $TE = OR/OP$. Furthermore, the producer could achieve additional cost reduction by choosing a different input combination. The least cost combination of inputs that produces one unit of output is given by point T , where the marginal rate of technical substitution is equal to the input price ratio. To achieve this cost level implicit in the optimal combination of inputs, input use needs to be contracted to bundle S . The input allocative efficiency (AE) is defined as $AE = OS/OR$.

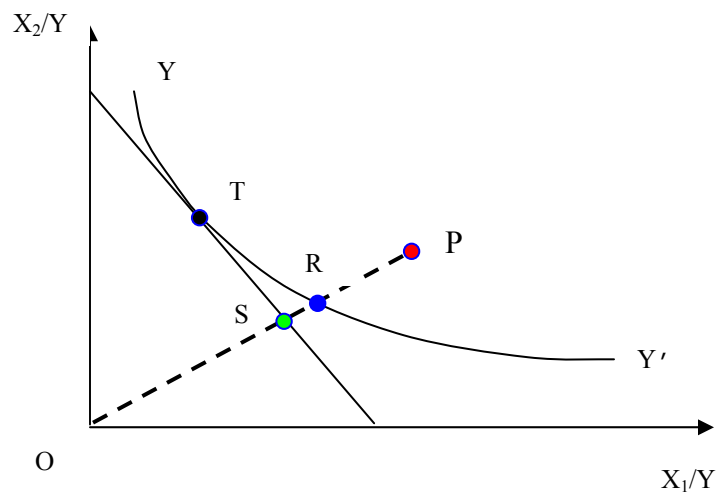


Figure 1 Technical and Allocative Inefficiency

The focus of this paper is measuring technical efficiency, given the lack of comparable input prices across the countries. This concept of efficiency is narrower than the one implicit in social welfare analysis. That is, countries may be producing the wrong output very efficiently (at low cost). We abstract from this consideration (discussed by Tanzi 2004), focusing on the narrow concept of efficiency.

Numerous techniques have been developed over the past decades to tackle the empirical problem of estimating the unknown and unobservable efficient frontier (in this case the isoquant YY''). These may be classified using several taxonomies. The two most widely used catalog methods into parametric or non-parametric, and into stochastic or deterministic. The parametric approach assumes a specific functional form for the relationship between the inputs and the outputs as well as for the inefficiency term incorporated in the deviation of the observed values from the frontier. The non-parametric approach calculates the frontier directly from the data without imposing specific functional restrictions. The first approach is based on econometric methods, while the second one uses mathematical programming techniques. The deterministic approach considers all deviations from the frontier explained by inefficiency, while the stochastic focus considers those deviations a combination of inefficiency and random shocks outside the control of the decision maker.

This paper uses non-parametric methods to avoid assuming specific functional forms for the relationship between inputs and outputs or for the inefficiency terms. A companion paper will explore the parametric approach, along the lines proposed by Greene (2003). The remainder of the section briefly describes the two methods: the Free Disposable Hull (FDH) and the Data Envelopment Analysis (DEA)

The FDH method imposes the least amount of restrictions on the data, as it only assumes free-disposability of resources. Figure 2 illustrates the single-input single-output case of FDH production possibility frontier. Countries A and B use input X_A and X_B to produce outputs Y_A and Y_B , respectively. The *input efficiency* score for country B is defined as the quotient X_A/X_B . The *output efficiency* score is given by the quotient Y_B/Y_A . A score of one implies that the country is on the frontier. An input efficiency score of 0.75 indicates that this particular country uses inputs in excess of the most efficient producer to achieve the same output level. An output efficiency score of 0.75 indicates that the inefficient producer attains 75 percent of the output obtained by the most efficient producer with the same input intake. Multiple input and output efficiency tests can be defined in an analogous way.

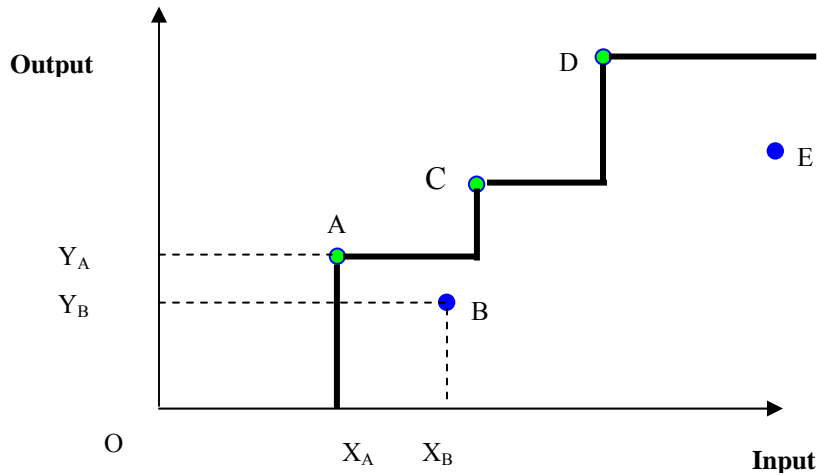


Figure 2 Free Disposal Hull (FDH) production possibility frontier

The second approach, Data Envelopment Analysis (DEA), assumes that linear combinations of the observed input-output bundles are feasible. Hence it assumes convexity of the production set to construct an envelope around the observed combinations. Figure 3 illustrates the single input-single output DEA production possibility frontier. In contrast to the vertical step-ups of FDH frontier, DEA frontier is a piecewise linear locus connecting all the efficient decision-making units (DMU). The feasibility assumption, displayed by the piecewise linearity, implies that the efficiency of C, for instance, is not only ranked against the real performers A and D, called the peers of C in the literature, but also evaluated with a virtual decision maker, V, which employs a weighted collection of A and D inputs to yield a virtual output. DMU C, which would have been considered to be efficient by FDH, is now lying below the variable returns to scale (VRS, further defined below) efficiency frontier, XADF, by DEA ranking. This example shows that FDH tends to assign efficiency to more DMUs than DEA does. The input-oriented technical efficiency of C is now defined by $TE = YV/YC$.

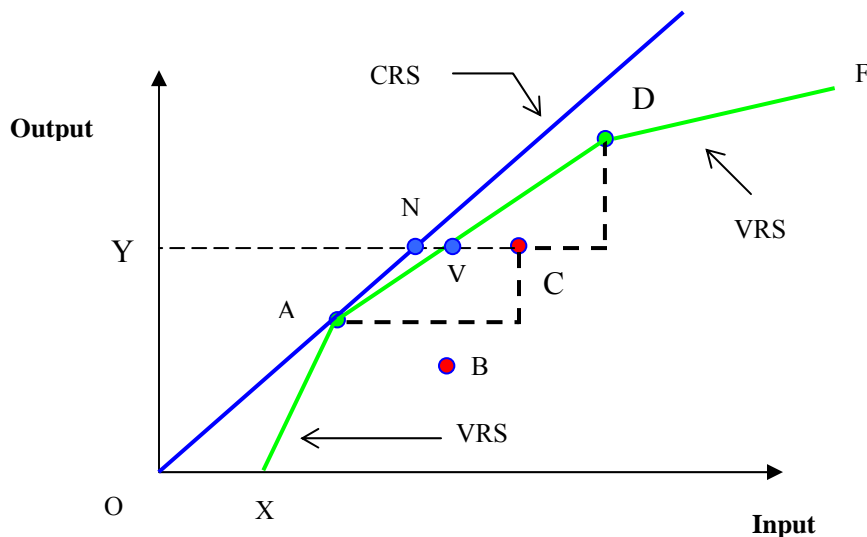


Figure 3 DEA production possibility frontier

If constant returns to scale (CRS) characterize the production set, the frontier may be represented by a ray extending from the origin through the efficient DMU (ray OA). By this standard, only A would be rated efficient. The important feature of the XADF frontier is that this frontier reflects variable returns to scale. The segment XA reflects locally increasing returns to scale (IRS), that is, an increase in the inputs results in a greater than proportionate increase in output. Segments AD and DF reflect decreasing returns to scale. It is worth noticing that constant returns to scale technical efficiency (CRSTE) is equal to the product of variable returns to scale technical efficiency (VRSTE) and scale efficiency (SE). Accordingly, DMU D is technically efficient but scale inefficient, while DMU C is neither technically efficient nor scale efficient. The scale efficiency of C is calculated as YN/YV . For more detailed exploration of returns to scale, readers are referred to Charnes, Cooper, and Rhodes (1978) and Banker, Charnes, and Cooper (1984), among others.²

The limitations of the non-parametric method derive mostly from the sensitivity of the results to sampling variability, to the quality of the data and to the presence of outliers. This has led recent literature to explore the relationship between statistical analysis and non-parametric methods (Simar and Wilson, 2000). Some solutions have been advanced. For instance, confidence intervals for the efficiency scores can be estimated using asymptotic theory in the single input case (for input-efficiency estimators) or single-output (in the output efficiency) case, given these are shown to be maximum likelihood estimators (Banker, 1993 and Goskoff, 1996). For multiple input-output cases the distribution of the efficiency estimators is unknown or quite complicated and analysts recommend constructing the empirical distribution of the scores by means of bootstrapping methods (Simar and Wilson, 2000). Other solutions to the outlier or noisy data consist in constructing a frontier that does not envelop all the data point, building an expected minimum input function or expected maximum output functions (Cazals, Florens and Simar, 2002, and Wheelock and Wilson, 2003). Another limitation of the method, at least in the context in which we will apply it, is the inadequate treatment of dynamics, given the lag between input consumption (public expenditure) and output production (health and education outcomes).

II.2. Overview of Precursor Papers

There is abundant literature measuring productive efficiency of diverse types of decision making units. For instance, there are papers measuring efficiency of museums (Bishop and Brand, 2003), container terminals (Cullinane and Song, 2003), electric generation plants (Cherchye and Post 2001), banks (Wheelock and Wilson, 2003), schools (Worthington, 2001) and hospitals (Bergess and Wilson, 1998), among others. Few papers, however, analyze aggregate public sector spending efficiency using cross-country data. These are the direct precursors of this paper and are the focus of this section's survey.

² The technical Appendix D provides more detailed exploration of the Data Envelopment Analysis, which shows how the peers are identified, how the virtual DMUs are constructed, and how weights to the different efficient DMUs and efficiency scores are calculated.

Gupta and Verhoeven (2001) employ the input-oriented FDH approach to assess the efficiency of government spending on education and health in 37 African countries in 1984-1995. Using several output indicators for health and education, they construct efficiency frontiers for each of the indicators and for each of the time periods they considered. That is, they used a single input-single output for each time period. They find that, on average, African countries are inefficient in providing education and health services relative to both Asian and the Western Hemisphere countries. They also report, however, an increase in the productivity of spending through time, as they document outward shifts in the efficiency frontier. Finally the authors report a negative relationship between the input efficiency scores and the level of public spending, which leads them to conclude that higher educational attainment and health output requires efficiency improvement more than increased budgetary allocations.

Evans and Tandon (2000) adopt a parametric approach to measure efficiency of national health systems for the World Health Organization, by estimating a fixed effects panel of 191 countries for the period 1993-1997. Health output was measured by the disability adjusted life expectancy (DALE) index, while health expenditures (public and private aggregated) and the average years of schooling of the adult population were considered as inputs. The output-efficiency score is defined as the ratio of actual performance above the potential maximum. The authors also introduce the square of the inputs (average years of schooling and expenditure), arguing it's a second-order Taylor-series approximation to an unknown functional form. The fact that the quadratic terms are significant may be an indication of the importance of non-linearity, but may also reflect neglected dynamics or heterogeneity in the sample (Haque, Pesaran and Sharma, 1999), given that both developed and developing nations were included. An interesting contribution of the paper is a construction of a confidence interval for the efficiency estimates through a Monte-Carlo procedure. These authors document a positive relationship between their efficiency scores and the level of spending. The more efficient health systems are those of Oman, Chile and Costa Rica. The more inefficient countries are all African: Zimbabwe, Zambia, Namibia, Botswana, Malawi and Lesotho.

Jarasuriya and Woodon (2002) also adopt a parametric approach to estimate efficiency of health and education provision in a sample of developing countries. The authors estimate the efficiency frontier by econometric methods. These authors consider separately an educational attainment indicator (net primary enrollment) and a health output indicator (life expectancy) and estimate a functional linear relationship between these output indicators and three inputs: per capita GDP, spending per-capita, and the adult literacy rate. Using a panel of 76 countries for the period 1990 to 1998, they found no relationship between expenditure and the educational or health output variables when they include the per-capita GDP. This led the authors to conclude that spending more is not a guarantee to obtain better education or health results. The authors do not point at the correlation between the two variables as a possible cause of this problem, which we discuss in the next section. The countries with the lowest efficiency in health indicators are all African (Malawi, Zambia, Mozambique, Ethiopia) as well as in education attainment (Ethiopia, Niger, Burkina Faso).

The authors go further by attempting to explain the cross-country variation in efficiency and find that the degree of urbanization and the quality of bureaucracy are the most relevant variables. To capture possible non-linearity, the authors introduce these variables squared. This stage of their work poses several problems. First, it is possible that the (non-linear) quadratic terms reflect heterogeneity across countries and dynamics across time. As shown by Haque, Pesaran, and Sharma (1999), this would produce inconsistent estimates. Second, the authors do not adjust for the fact that the dependent variable (efficiency scores) is censored, given that it can adopt only values between zero and one. And third, the authors do not consider the serial correlation of the efficiency scores (Simar and Wilson, 2004)

Greene (2003a) combines the previous two papers in the sense he concentrated on health efficiency only using the WHO panel data and explained inefficiency scores variation across the sample of counties. Greene's stochastic frontier estimation is much more general and flexible, as it allows for time variation of the coefficients and heterogeneity in the countries' sensitivity to the explanatory variables. The author first estimates a health production function using expenditure (public and private together) and education as inputs, and then explains inefficiency with a set of explanatory variables of which the only significant ones are the income inequality measure, GDP per capita and a dummy variable for tropical location.

Afonso, Schuknecht and Tanzi (2003) examine the efficiency of public spending using a non-parametric approach. First, they construct composite indicators of public sector performance for 23 OECD countries, using variables that capture quality of administrative functions, educational and health attainment, and the quality of infrastructure. Taking the performance indicator as the output, and total public spending as the input, they perform single-input, single-output FDH to rank the expenditure efficiency of the sample. Their results show that countries with small public sectors exhibit the highest overall performance.

Afonso and St. Aubyn (2004) address the efficiency of expenditure in education and health for a sample of OECD countries applying both DEA and FDH. This paper presents detailed results by comparing input-oriented and output-oriented efficiency measurements. The small overlap of the samples limits the comparability of these results with those presented in the next section. An apparently strange result, reported in earlier drafts of the paper, was the inclusion of Mexico as one of the benchmark countries (on the efficiency frontier). The result is strange given that the sample is the OECD countries, and it counterintuitive. This is the result of Mexico having very low spending and low education attainment results, hence it can be considered as the "origin" of the efficiency frontier. The next chapter discusses this topic and reports similar counterintuitive results but for other countries.

III. Empirical Results

III.1. Input and Output Indicators: Description, Assumptions and Limitations

Cross-country comparisons assume some homogeneity across the world in the production technology of health and education.³ There are two particular aspects in which the homogeneity assumption is important. First, the comparison assumes that there is a small number of factors of production that are the same across countries. Any omission of an important factor will yield as a result a high efficiency ranking of the country that uses more of the omitted input. Second, the comparison requires that the quality of the inputs is more or less the same, with the efficiency scores biased in favor of countries where the quality is of higher grade.

Factor heterogeneity will not be a problem, as long as it is evenly distributed across countries. It will be problematic if there are differences between countries in the average quality of a factor (Farrell, 1957). The exercise that we present suffers from this limitation, given that the main input in both production technologies is used more intensively in richer countries (with higher per-capita GDP). The main input is public spending per capita on education and health measured in constant 1995 US dollars in PPP terms. A clear positive association between this variable and per-capita GDP can be verified (Figures 4 and 5).

This positive association between expenditure and the level of economic development (as measured by per-capita-GDP) may be explained by several reasons. One of them could be the Balassa-Samuelson effect, according to which price levels in wealthier countries tend to be higher than in poorer countries.⁴ This applies to both final goods and factor prices. Thus price of the same service (health or education, for instance) will be higher in the country with higher GDP. Similarly, wages in the relatively richer countries are higher, given the higher marginal productivity of labor, which will tend to increase costs, especially in labor-intensive activities as health and education.

Figure 4 can be interpreted as evidence of the validity of Wagner's hypothesis at the cross-country level. This hypothesis, postulates that there is a tendency for governments to increase their activities as economic activity increases. Since 1890 Wagner postulated that economic development implied rising complexities that required more governmental activity, or that the elasticity of demand for publicly provided services, in particular education was greater than one. This hypothesis has been tested econometrically (Chang, 2002) in time series and cross-country settings, showing that this is nothing particular of the series used for the present study.

³ See Table B.5 in Appendix B for the list of countries included in the study.

⁴ The Balassa-Samuelson effect refers to the fact that price levels are higher in richer countries than in poorer countries. It can be shown that relative wages and relative prices are a function of the marginal productivity of labor in the traded goods. Given higher capital abundance in the richer countries, the productivity of labor tends to be higher in these countries, and hence will be wages and prices.

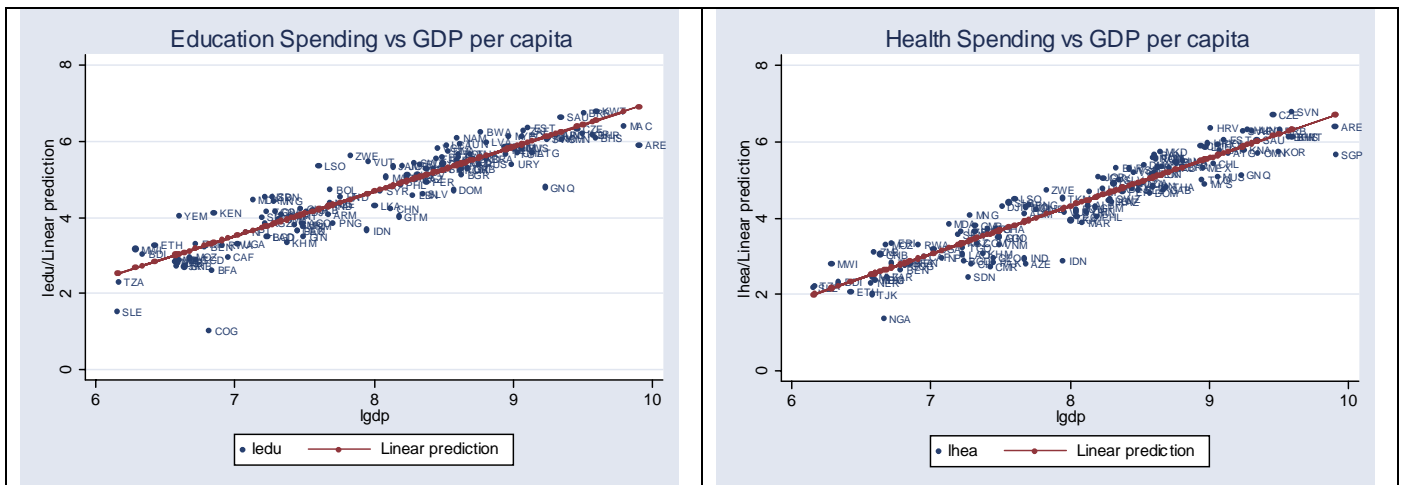


Figure 4. Public Expenditure and GDP (both per capita and in logs)

Previous studies that measured the efficiency of public spending recognized the positive association and suggested alternative solutions. One possibility is to split the sample by groups of countries (Gupta and Verhoeven, 2001). We follow this approach by excluding the industrialized nations from the sample, and by presenting most of the results clustered regionally (Africa (AFR), East Asia and Pacific(EAP), Latin America and Caribbean (LAC), Middle-East and North Africa (MNA) and South Asia (SAS)). A second alternative incorporates directly the per-capita GDP as a factor of production, jointly with expenditure and other inputs (Jarasuriya and Woodon 2002). The problem with this approach is that it combines variables derived from a production function approach, and hence with clear interpretation, with others (GDP per capita) that are difficult to interpret from any viewpoint. When the two types of variables are combined, their effects cannot be disentangled.

A third option consists in using as an input the orthogonal component of public expenditure to GDP⁵. We scored the efficiency using as input both the original expenditure variable and the orthogonalized variable. The goodness-of-fit of each model was gauged based on the frequency distribution of the inefficiency measures, as suggested by Farrell (1957) and Varian (1990). Comparing the efficiency distributions (Figures 5) it is clear that the orthogonalized expenditure version produces distributions that are not skewed towards extreme inefficient outcomes. On this basis, the paper considered the orthogonal component of expenditure on health and education.

⁵ The orthogonalized expenditure variable is the residual of the linear regression between public expenditure and GDP per capita. Since residuals may take positive and negative values, the variable was right-shifted to avoid negative values to facilitate graphical presentation of the frontiers.

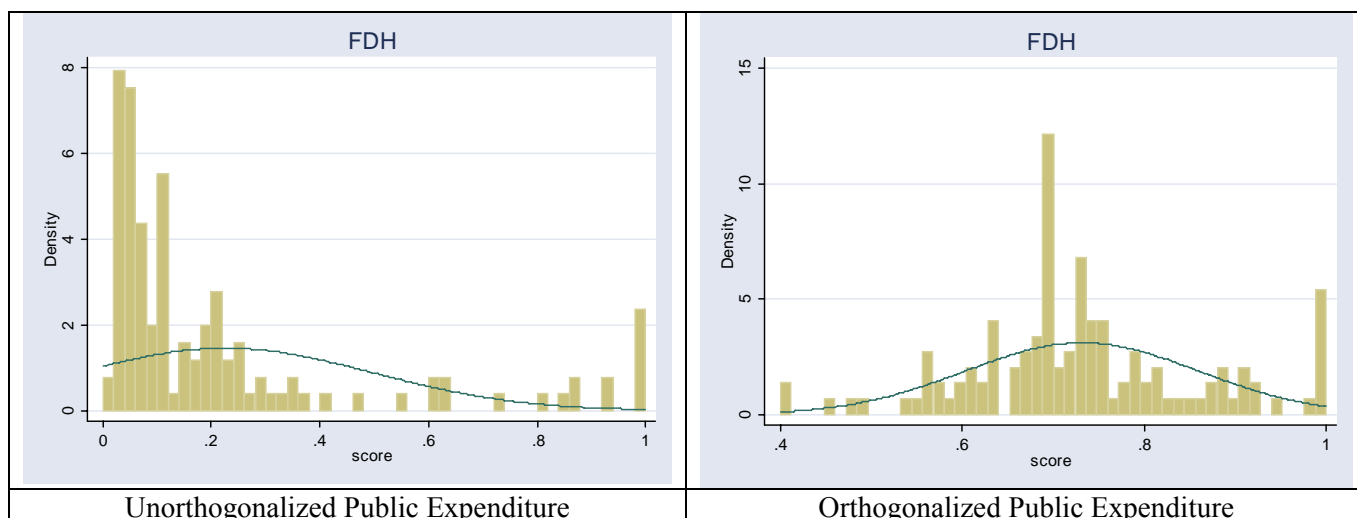


Figure 5. Density of Efficiency Scores – Gross Primary School Enrollment

This paper uses nine indicators of education output and four indicators of health output.⁶ The education indicators are: primary school enrollment (gross and net), secondary school enrollment (gross and net), literacy of youth, average years of school, first level complete, second level complete, and learning scores. Though the ideal educational output indicator are comparable learning scores, international assessments are based on samples mostly composed of developed nations, limiting the applicability to the present paper. However, Crouch and Fasih (2004) recently combined several international assessments to obtain a larger sample of comparable results.⁷ Unfortunately they only do it for one period. The correlation between the learning scores and other output variables is high (.81 with net secondary school enrollment and .76 with average years of school), as shown in Figure 6⁸. The health output indicators are: life expectancy at birth, immunization (DPT⁹ and measles), and the disability-adjusted life expectancy (DALE).

The cross-country comparisons with this set of indicators assume some form of data homogeneity, which might be problematic given the diversity of counties in the sample considered. Even for a more homogeneous group of countries, such as the OECD, there is call for caution when comparing expenditure levels in member countries (Jounard,

⁶ The data sources are: the World Bank World Development Indicators (WDI), Barro-Lee database, and Crouch and Fasih (2004) the World Health Organization (Mathers *et al*, 2000).A complete list of variables and data sources can be found in Table B.6 of Appendix B.

⁷ Crouch and Fasih (2004) consider several international tests of learning achievement in math, science and literacy applied at different levels of the school system. The tests are the following: TIMSS (Third International Mathematics and Science Survey), PIRLS (Progress in International Literacy Study), PISA (program for International Student assessment), Reading Literacy Study, LLECE (Laboratorio Latinoamericano de Evaluacion de la Calidad de la Educacion, SACMEQ (Southern Africa Consortium for Monitoring of Education Quality), MLA (Monitoring Learning Achievement)

⁸ The correlation coefficients and Figure 6 exclude developed nations for the Crouch and Fasih (2004) sample.

⁹ DPT is Diphtheria-Pertussis and Tetanus

et.al. 2003). There is very little to do to overcome this limitation, except subdivide the sample into different groups. Probably a regional aggregation can be useful, but even at that level there may be extreme heterogeneity.

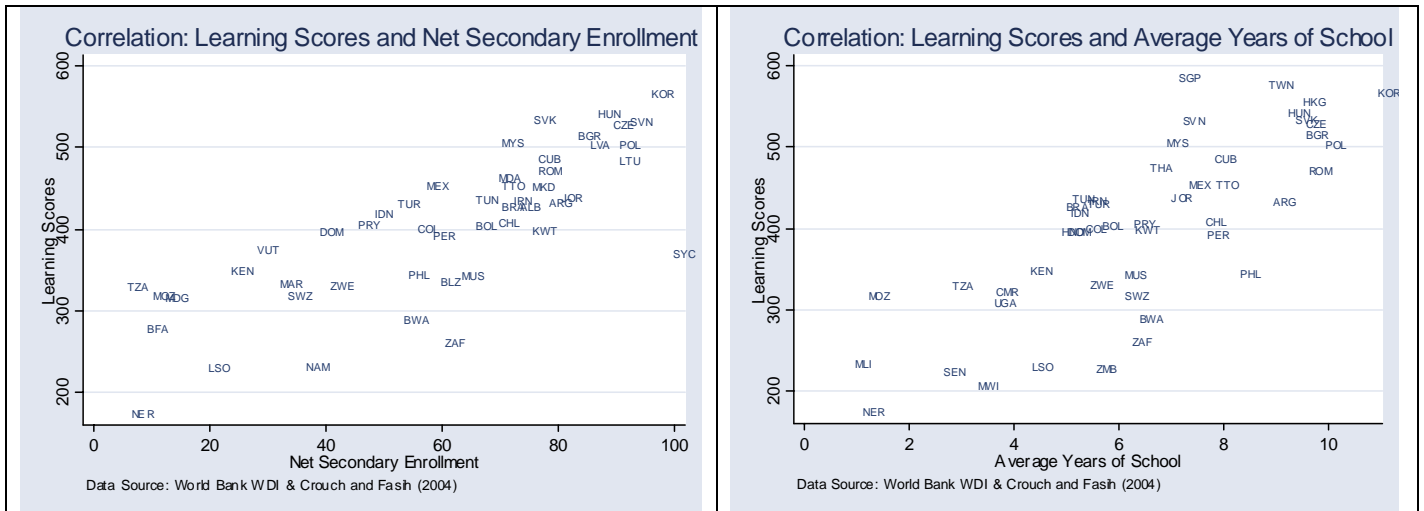


Figure 6. Correlation between Learnings Scores and Other Education Indicators

Other four limitations of the analysis arising from the particular data sources are: First, the level of aggregation. The paper uses aggregate public spending on health and education, while using disaggregate measures of output, such as primary enrollment or secondary enrollment. Ideally, the input should be use separately public spending in primary and secondary education. Similarly, health care spending could be disaggregated into primary care level care and secondary level. The data can be disaggregated even further, by analyzing efficiency at the school or hospital levels. Second, there are omitted factors of production. This is especially true in education, as the paper did not consider private spending due to data constraints for developing nations. If this factor were used more intensively in a particular group of countries, then the efficiency scores (reported in the next section) would be biased favoring efficiency in that group.

The third limitation arising from the data is the combination of monetary and non-monetary factors of production. The paper uses together with public expenditure, other non-monetary factors of production such as the ratio of teachers to students, in the case of education, or literacy of adults in the case of health and education. Other factors of production that could have been used were the physical number of teaching hours (in education) or the number of doctors or in-patient beds, as Afonso and St. Aubyn did for the OECD countries. However, inexistent data for a large number of developing countries constrained the options.

A fourth limitation arising from the selected indicators, is that these don't allow for a good differentiation between outputs and outcomes. For instance, most of the indicators of education, such as completion and enrollment rates do not measure how much learning is taking place in a particular country. In education, this paper advances by considering the learning scores as one of the indicators. In health, other outcomes such as the number

of sick-day leaves or the number of missed-school days because of health-related causes could be better reflections of outcomes. Two of the selected health output indicators, DPT and measles immunization are delivered in vertical programs, that is, in campaigns that are relatively independent of basic health systems and therefore may not be good indicators of the actual quality of the health system. Finally, the fact that life expectancy is influenced by diet, lifestyle, and a clean environment, that to the extent that are not included as factors of production may bias the efficiency scores.

III.2. Single Input-output Results

III.2.1. FDH and DEA analysis: Education

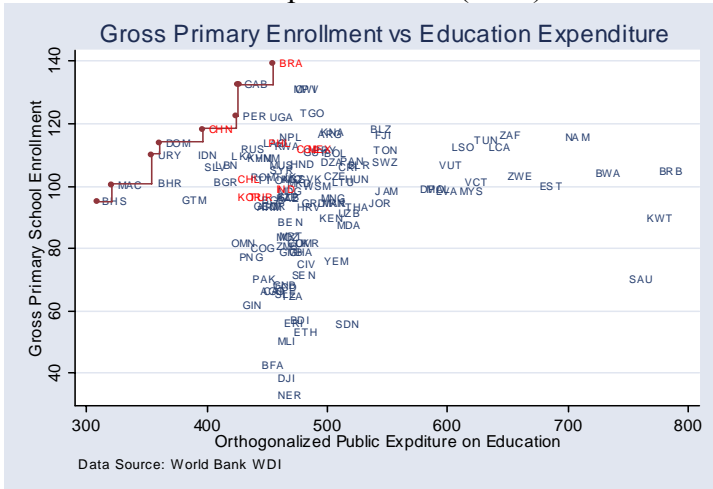
Figures 7a-c show both FDH and DEA estimation of the efficiency frontier for three of the nine output indicators: gross primary school enrollment, first level complete and learning scores. Individual country efficiency scores for the three indicators are reported in Table B.1-3 of Appendix B¹⁰. The graphical efficiency frontiers for other output indicators can be found in Appendix B (Figure B.1).

Figure 7.d illustrates the efficiency frontier for the learning scores if the developed countries are included in the sample, demonstrating the sensitivity of the results to the sample definition. This fact is particularly acute in the case of learning scores which capture the quality of education dimension that no other indicator captures. While in the sample of developing countries Chile, Hungary and the Czech Republic are on the frontier; once the developed nations are included they appear as inefficient. The complete set of efficiency scores (including and excluding the set of developed countries can be found in Table B.2 and B.3 in Appendix B¹¹.

¹⁰ The efficiency scores of all the indicators can be found at the PRMED website indicated in footnote 1.

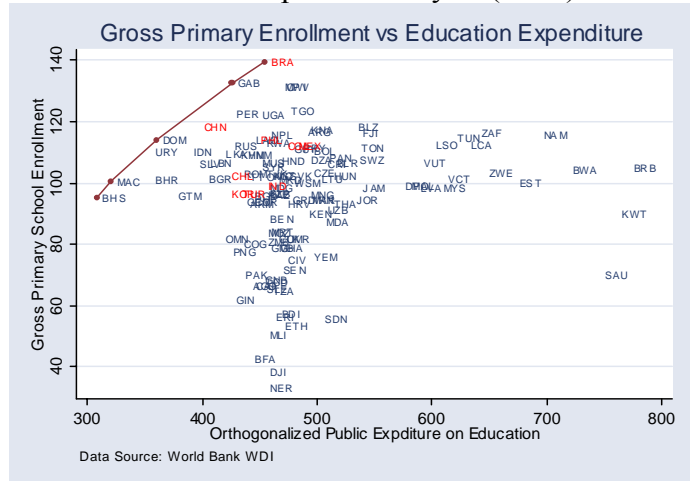
¹¹ The frontier depicted in Figure 7.d. excludes Japan, Korea, Ireland and Belgium to facilitate comparisons with the frontier without developed nations.

Free Disposable Hull (FDH)



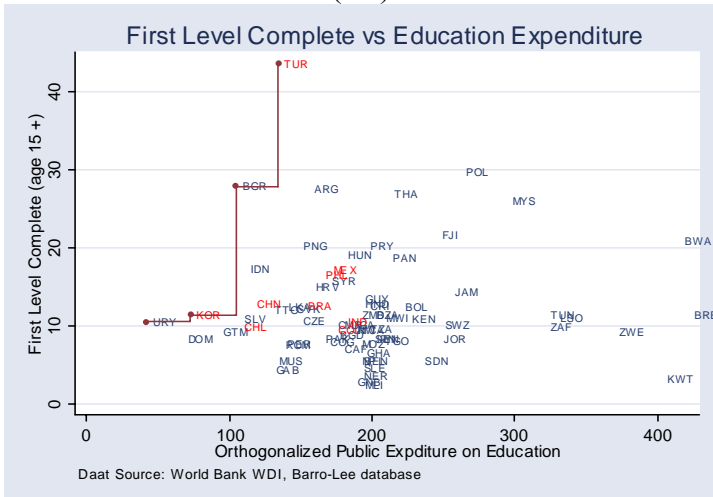
(a.1)

Data Envelopment Analysis (DEA)



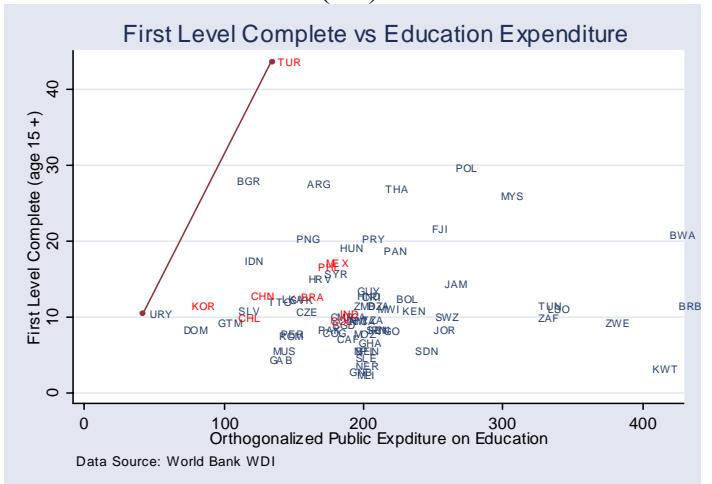
(a.2)

First Level Complete vs Education Expenditure



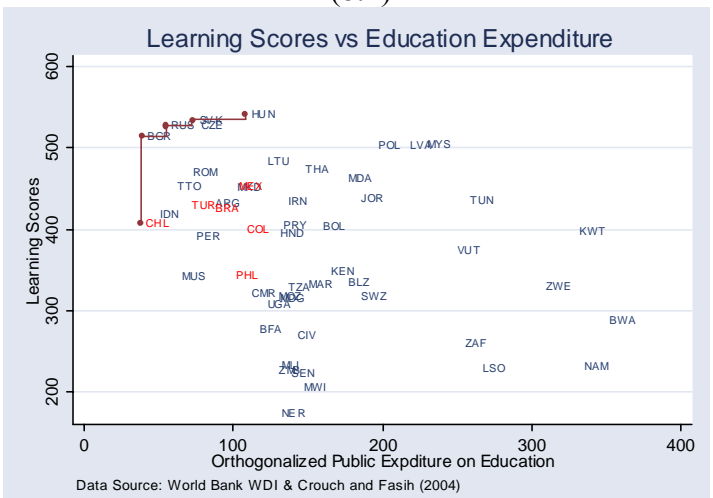
(b.1)

First Level Complete vs Education Expenditure



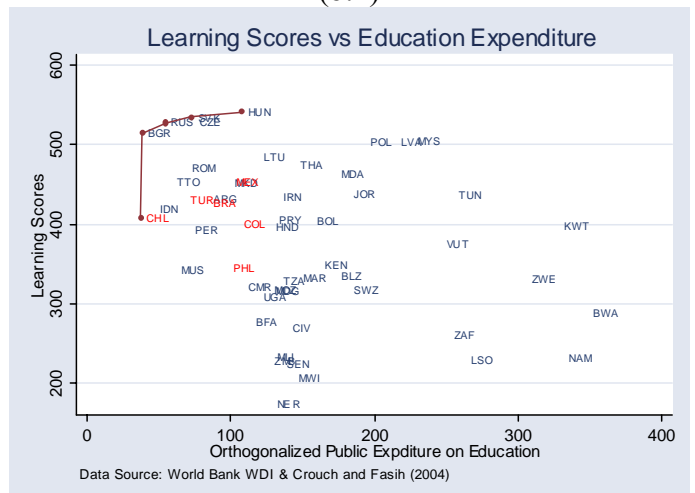
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Learning Scores vs Education Expenditure

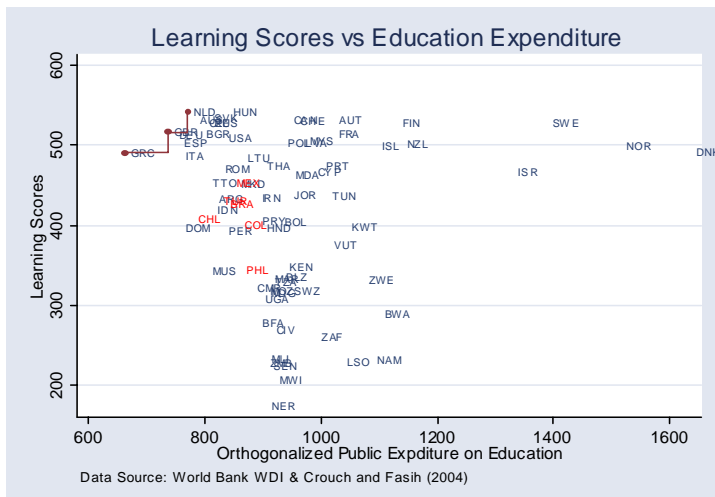


(c.1)

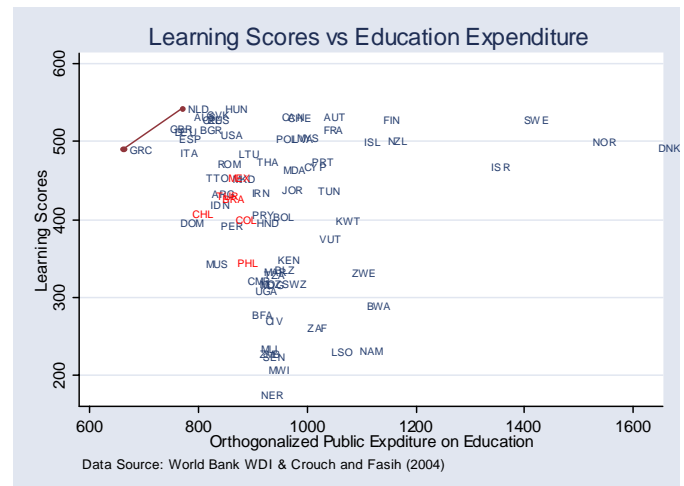
Learning Scores vs Education Expenditure



(c.2)



(d.1)



(d.2)

Figure 7 Education Efficiency Frontier: Single Input and Single Output

Several results may be highlighted:

- In general, the rankings are robust to the output indicator selected. This can be can be verified by the Spearman rank-correlation coefficient (see Tables C.1 and C.2 in Appendix C), that are all positive, significant and high. The range oscillates from a minimum of .53 to a maximum of .94, with the mean of .70. This result implies that countries appearing as efficient (or inefficient) according to one indicator, are ranked similarly when other output indicator is used.
- Despite the orthogonalization by GDP, the relatively rich countries tend to be in the less efficient group, i.e. countries with higher per-capita GDP spend more than other countries in attaining similar education outcomes. Higher spending may reflect the higher cost of tertiary education. This is one factor that may help explain the stand-out of Estonia, Latvia, and Poland. Oil-rich countries, such as Kuwait and Saudi Arabia, tend to be in the group of relatively more inefficient producers.
- Another group of relatively inefficient producers are those with “average” expenditure levels but extremely low education attainment. Among those are mostly African counties (Angola, Niger, Burkina Faso, Sudan, and Ethiopia), some Middle Eastern countries (Djibouti, and Yemen) and South Asia (Bangladesh and Pakistan). Table B.1-3 in Appendix B list the output-efficiency scores for three of the indicators.
- Output-efficiency rankings also vary with the selected output indicators. The spearman correlation coefficient of the output-efficiency scores (see Tables C.3 and C.4 in Appendix) show that these are robust to the selected indicator, though the mean of the correlation coefficients is lower (.52) and the range is somewhat higher (.30 to .95) than those registered in the input-efficiency rankings.
- In an attempt to identify clusters of more efficient countries and more inefficient countries, the top (and bottom) 10 percent of the efficiency ranking were selected for each of the indicators. If a country appeared in the efficient (inefficient) tail in three or more of the indicators, it was included in Table 1.

Table 1. Education Attainment: Single Input, Single Output

	Input-Efficient	Output Efficient
More efficient	Uruguay, Korea, Dominican Republic, Indonesia, Guatemala, China, Bahamas, Bahrain, El Salvador	Uruguay, Korea, Bahrain, Bahamas
Least efficient	Botswana, South Africa, Kuwait, Tunisia, Lesotho, Barbados, Saudi Arabia, Zimbabwe, Namibia, Malaysia, St, Lucia, Jamaica, St, Vincent, Latvia,	Niger, Mali, Tanzania, Burkina Fasso, Gunea-Bissau, Ethiopia, Guinea, Burundi, Sudan, Sierra Leone, Chad

- f. This clustering exercise reveals (Table 1) a group of African countries as the most inefficient. Two oil-rich countries are included in this group as well. Among the more efficient group of countries we consistently find Uruguay, Korea, Bahamas, and Bahrain. Explaining why these particular sets of countries appear in each cluster requires more in-depth analysis. The last section of this paper attempts to associate efficiency results with some explanatory variables.
- g. To grasp the order of magnitudes of the deviations from the efficiency frontier, we computed an average for all indicators for the inefficient countries. The input-efficiency estimations indicate that the most inefficient decile could reach the same educational attainment levels by spending approximately 50 percent less. The output efficiency estimators indicate that, on average, with the expenditure level this group could reach educational attainment levels four times as high.
- h. It is critical to note that even if a country appears as efficient, there might still be a significant discrepancy between the observed output level and the desired or target output level. For instance, Bahamas, Bahrain, Dominican Republic and Guatemala appear as efficient countries on the efficiency frontier or very close to it (Figure 7 a.1). However, these countries are still far away from where Gabon or Brazil are, and could consider desirable to achieve those target enrollment rates. Both Guatemala and Dominican Republic spend two percent of GDP on education but have (net) secondary enrollment rates below 40 percent. And net primary enrollment is about 80 percent. It would be difficult to argue that that is a desirable outcome, though it is an efficient one. Similarly, though Chile appears as efficient with learning scores of about 400, the country could still achieve higher learning scores of over 500 points at the cost of additional public spending. The important thing is that the country moves along the efficiency frontier to the higher target output level. Countries can even improve efficiency by exploiting scale economies if they are operating in the increasing returns to scale zone of the production possibility frontier (output levels smaller than that of point A, Figure 3)
- i. The regional aggregation of the efficiency scores by each individual output indicator shows that scores are lower when they are input oriented (Table 2) than

when they are output oriented (Table 3).¹²This is especially true for ECA. In general, we observe higher efficiency scores when primary enrollment is considered as the output indicator. Scores are lower for secondary enrollment, especially when output-oriented measures are considered. Africa and MNA have similar levels of input-inefficiency: in most cases, both regions use public spending in excess of 35 percent than the benchmark cases. EAP, ECA, LAC and SAS spend in excess between 20-30 percent of the benchmark level. The output efficiency scores are lower in Africa

**Table 2. Educational Attainment: Input-Efficiency scores by regions across the world
- Single Input, Single Output**

	AFR	EAP	ECA	LAC	MNA	SAS
Gross primary enrollment	.69	.74	.67	.74	.65	.75
Net primary enrollment	.68	.78	.72	.77	.68	.71
Gross Secondary enrollment	.65	.69	.67	.69	.63	.70
Net secondary enrollment	.64	.71	.71	.69	.64	.72
Average years of school	.21	.36	.37	.32	.18	.25
First level complete	.21	.43	.48	.36	.20	.26
Second level complete	.22	.37	.33	.32	.19	.27
Literacy of youth	.66	.73	.86	.72	.63	.72

**Table 3. Educational Attainment: Output-Efficiency scores by regions across the world
- Single Input-Single Output**

	AFR	EAP	ECA	LAC	MNA	SAS
Gross primary enrollment	.62	.79	.72	.82	.67	.72
Net primary enrollment	.64	.93	.90	.93	.79	.78
Gross Secondary enrollment	.23	.50	.70	.61	.54	.39
Net secondary enrollment	.26	.58	.84	.66	.60	.44
Average years of school	.32	.63	.79	.60	.53	.38
First level complete	.19	.49	.50	.36	.22	.20
Second level complete	.09	.37	.38	.24	.26	.22
Literacy of youth	.72	.95	.99	.94	.88	.66

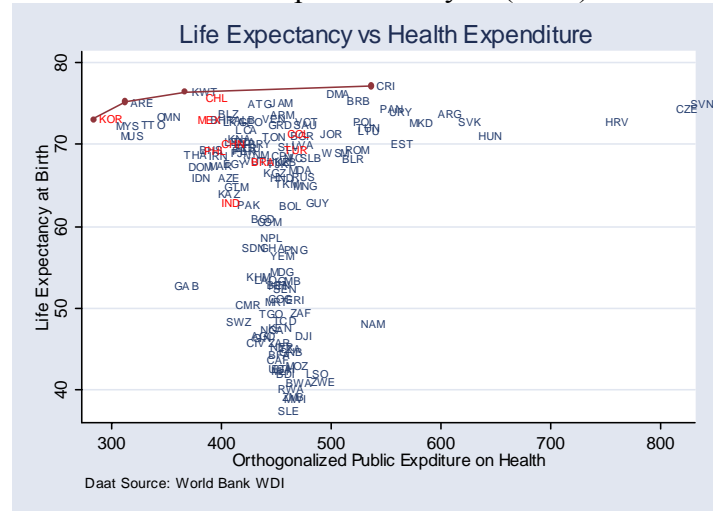
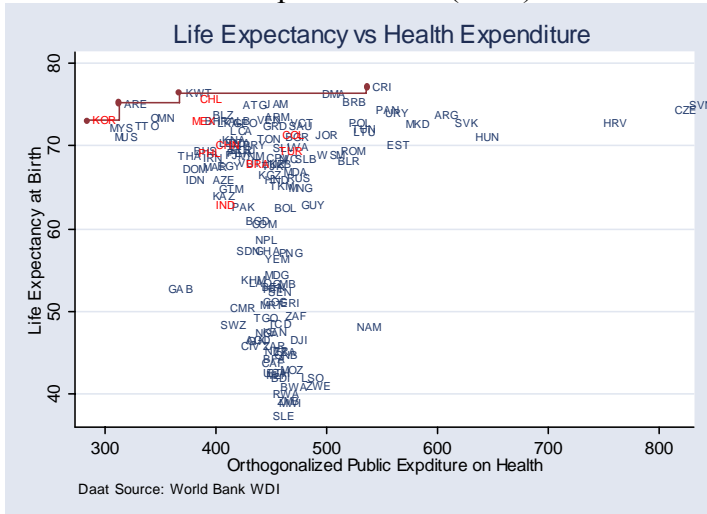
¹² The regional aggregation is for illustrative purposes only and was computed as the simple average of the individual country scores obtained for the whole sample. The scores were not computed by constructing separate efficiency frontiers for each region. Hence, they do not reflect the heterogeneity in the individual country scores and possibly do not reflect adequately variations across regions.

III.2.2. FDH and DEA Analysis: Health

This section considers the case of one input (public expenditure on health per capita in PPP terms) and four alternative output indicators: life expectancy at birth, DPT immunization, measles immunization, and the disability adjusted life expectancy (DALE) index which takes into account both mortality and illness. The efficiency frontiers for each indicator are computed using both the FDH and DEA methodologies. Figures 8a-d show the efficiency frontier for one indicator. The specific country rankings for two of the health indicators are listed in Table B.4 of Appendix B.

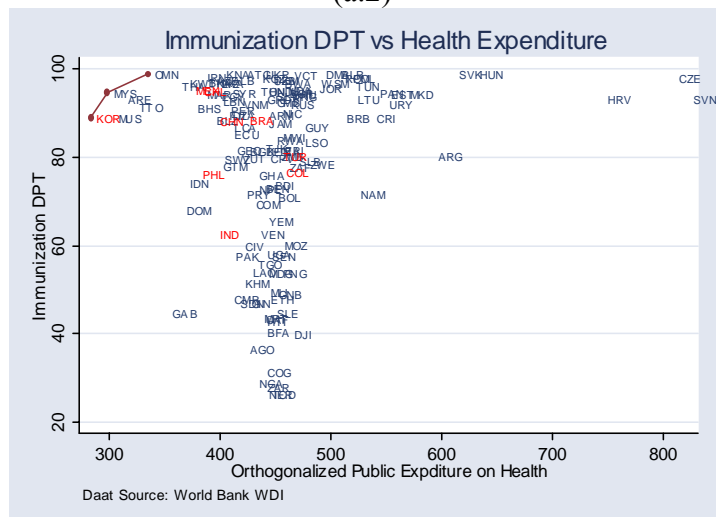
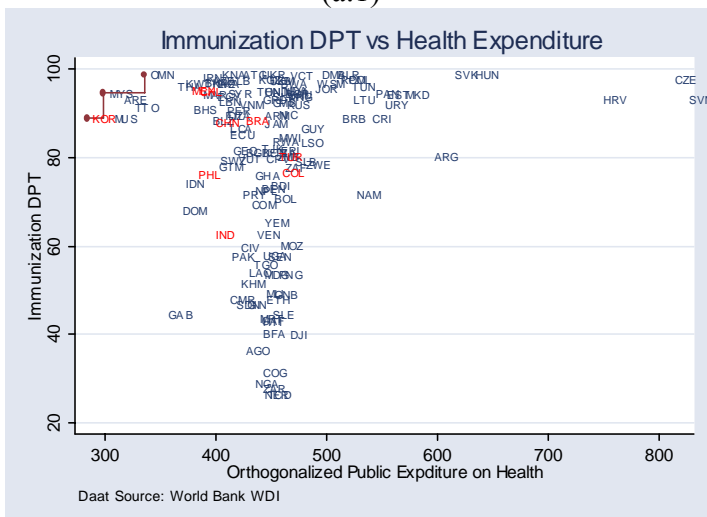
Free Disposable Hull (FDH)

Data Envelopment Analysis (DEA)



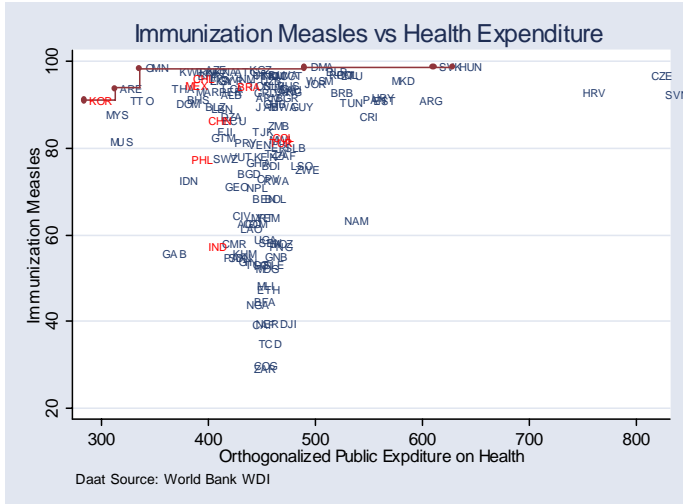
(a.1)

(a.2)

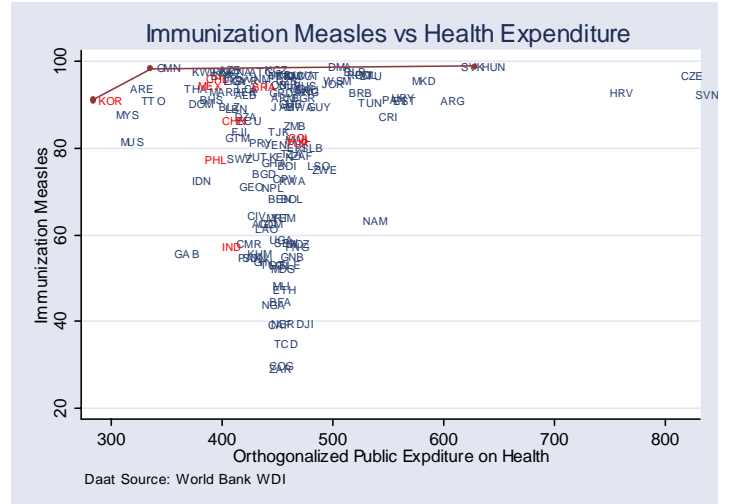


(b.1)

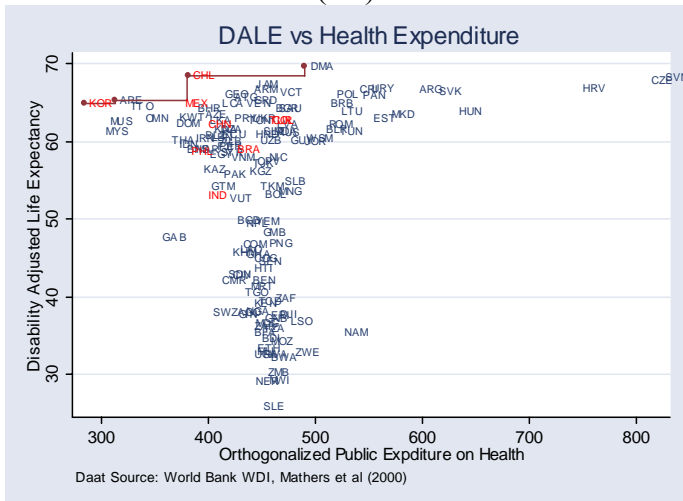
(b.2)



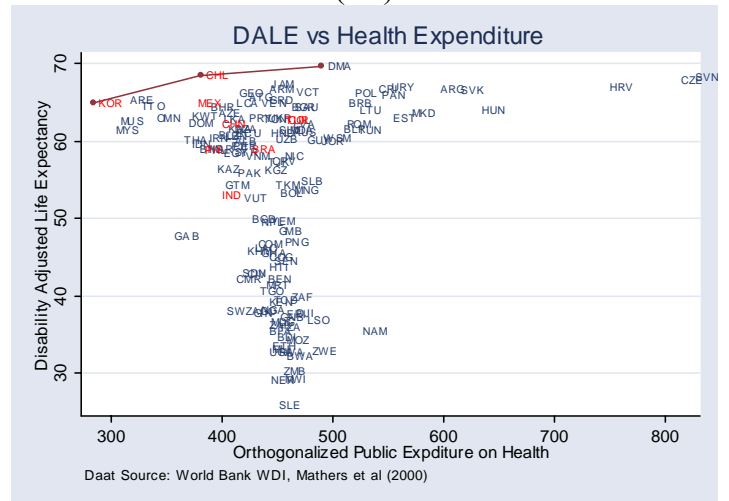
(c.1)



(c.2)



(d.1)



(d.1)

Figure 8. Health Efficiency Frontier: Single Input and Single Output

Several results may be highlighted:

- a. The input efficiency scores obtained for each of the output indicators are highly correlated. The Spearman rank-order correlation coefficient oscillates between .66 and .94, with a mean of 0.81 (see Tables C.1 and C.2 in Appendix C). This indicates that the efficiency ranking is very similar regardless of the output indicator being used.
- b. Despite the orthogonalization by GDP the relatively rich countries tend to be in the less efficient group. The group of inefficient producers tend to concentrate in two groups of countries: one group of relatively rich countries like the Czech Republic, Croatia, Slovenia, and Hungary that have big expenditure levels and not extremely high output (input inefficiency) and other group of countries that spend relatively little but their output indicators could be substantially larger, like Sierra Leone, Namibia, Zimbabwe, and Lesotho

- c. To capture this difference, it is convenient to examine the output- efficiency scoring (see Tables C.3 and C.4 in Appendix C). The rankings between input and output orientations are highly correlated.
- d. With the four output indicators deciles, more efficient and least efficient countries are listed in Table 4. The group of least efficient countries could, on average, increase output significantly for a given expenditure level. For instance, the decile of most inefficient countries could almost double the disability-adjusted life expectancy (DALE) index to achieve the same efficiency as the benchmark. Similarly the DPT immunization would have to triple to achieve the same efficiency level than the benchmark developing countries.
- e. The regional aggregation of the efficiency scores, by each individual output indicator shows that input efficiency scores (Table 5) are lower than output efficiency scores (Table 6). This is especially true in ECA, LAC and MNA, and to a lesser extent in EAP and SAS. In Africa, both scores are strikingly similar, indicating that, on average, the region spend about 35 percent in excess of the benchmark cases to achieve the same output level. Alternatively, the output level is 35 percent below comparable efficient countries that use the same input (expenditure) level.

Table 4. Health Attainment: Single Input, Single Output

	Input-Efficient	Output Efficient
More efficient	Korea, Malaysia, Thailand, Trinidad & Tobago, Oman, United Arab Emirates, Mauritius, Kuwait, Chile	Korea, Dominica, Oman, United Arab Emirates, Anigua and Barbuda
Least efficient	Argentina, Estonia, Czech Republic, Slovenia, Macedonia, Croatia, Namibia, Tunisia, Latvia, Hungary, Barbados	Sierra Leone, Ethipia, Burkina Fasso, Central African Republic, Mali

**Table 5. Health Attainment: Input-Efficiency scores by regions across the world
- Single Input, Single Output**

	AFR	EAP	ECA	LAC	MNA	SAS
Life Expectancy at birth	.65	.72	.58	.69	.73	.69
Immunization DPT	.66	.73	.63	.68	.76	.71
Immunization Measles	.65	.73	.67	.69	.76	.71
DALE	.65	.72	.60	.70	.71	.69

**Table 6. Health Attainment: Output-Efficiency scores by regions across the world
- Single Input-Single Output**

	AFR	EAP	ECA	LAC	MNA	SAS
Life Expectancy at birth	.63	.87	.91	.92	.90	.83
Immunization DPT	.62	.83	.95	.87	.90	.75
Immunization Measles	.63	.83	.95	.91	.90	.71
DALE	.56	.83	.90	.90	.86	.79

III.3. Multiple Inputs and Multiple Outputs

Both education and health attainment are not solely determined by public spending. Other inputs, such as private spending also affect the output indicators. For health, the World Bank WDI database reports a comparable statistic across countries. Unfortunately, a comprehensive database of this variable does not exist for education: For the education production technology we have multiple indicators of educational attainment, and three inputs (public spending, teachers per pupil, and adult literacy rate). In health, besides public spending, two other inputs were included: private spending and the education level of adults. The analysis was limited to include up to three outputs. Too many output indicators will complicate the analysis, biasing efficiency scores towards one, increasing the variance of the estimators, and reducing their speed of convergence to the true efficiency estimators (Simar and Wilson, 2000; Groskopf, 1996)

In education, the selected input-output combinations produce ranking that are somewhat similar: the average rank correlation coefficient is .53. The frequency distribution of the efficiency estimators is similar in all the models, and as the model shifts from a basic two-input two-output model to a more complex three-input three-output model, the frequency distribution shifts to the right, that is, more concentrated around more efficient results.

The multi-input output model results (Table 7) in general confirm the results of Table 1. Some new countries that appear as efficient are Bangladesh, Congo and Argentina. In the case of Bangladesh and Congo, this is the result of considering literacy of adults as a factor of production, that in these countries is low, and hence, appearing as very efficient. Congo has also extremely low ratio of teachers per student, the other factor of production, reinforcing the bias towards the efficient score. Within the least efficient countries, the models point at Zimbabwe, Lesotho, Botswana, Malaysia, and Saudi Arabia as the single-input models. In addition, Costa Rica and Swaziland appear as input inefficient.

Table 7. Educational Attainment: Multiple Inputs, Multiple Outputs

	Input-Efficient	Output Efficient
More efficient	Bangladesh, Bahrain,, Dominican Republic, Argentina, Estonia	Argentina, Bangladesh,, Chile, Brazil, Bahrain, Dominican Republic, Congo
Least efficient	Zimbabwe, Lesotho, Botswana, Costa Rica, Swaziland, Saudi Arabia, Malaysia	Sudan, Ghana, Tanzania, Ethiopia, Kenya, Niger

The regional aggregation for input and output efficiency scores using the multiple input-output framework show (Tables 8 and 9) that as the model becomes more complex (adding inputs or outputs), scores tend to show more efficient regions. The input efficiency regional aggregation allows several interesting comparisons across the regions on the impact of an additional input on the efficiency scores. For instance, the first two rows of Table 8 allow examination of the impact of adding literacy of adults as an additional input. The biggest impact is in the MNA region, followed by ECA and LAC while the others the increase in efficiency scores is more marginal¹³. Output efficiency scores change substantially in MNA and Africa.

**Table 8. Education Attainment: Input-Efficiency scores by regions across the world
- Multiple Inputs, Multiple Outputs**

	AFR	EAP	ECA	LAC	MNA	SAS
2 inputs (public expenditure, teachers per pupil) – 2 outputs (gross primary and secondary enroll.)	.88	.83	.72	.82	.73	.91
3 inputs (public expenditure, teachers per pupil, literacy of adult) – 2 outputs (gross primary and secondary enroll.)	.92	.89	.86	.89	.92	.96
3 inputs (public expenditure, teachers per pupil, literacy of adult) – 2 outputs (net primary and secondary enroll.)	.87	.94	.93	.93	.92	1.0
2 inputs (public expenditure, literacy of adult)- 3 outputs (first complete, second level complete, avg yrs of school)	.78	.92	.95	.84	.80	.91
3 inputs (public expenditure, literacy of adult, teachers per pupil)- 3 outputs (first complete, second level complete, avg yrs of school)	.91	.97	.94	.89	.81	.95
3 inputs (public expenditure, teachers per pupil, literacy of adult) – 3 outputs (literacy of youth, first level complete, second level complete)	.91	.97	.94	.89	.80	.95

¹³ The statistical significance of these changes has yet to be determined. The tests developed by Banker , and used in previous sections do not apply to the multiple-output cases we are analyzing here (Simar and Wilson, 2000)

Table 9. Education Attainment: Output-Efficiency scores by regions across the world

- Multiple Inputs, Multiple Outputs

	AFR	EAP	ECA	LA	MNA	SAS
2 inputs (public expenditure, teachers per pupil) – 2 outputs (gross primary and secondary enroll.)	.68	.83	.80	.85	.71	.79
3 inputs (public expenditure, teachers per pupil, literacy of adult) – 2 outputs (gross primary and secondary enroll.)	.82	.88	.89	.89	.91	.90
3 inputs (public expenditure, teachers per pupil, literacy of adult) – 2 outputs (net primary and secondary enroll.)	.79	.97	.96	.96	.92	1.0
2 inputs (public expenditure, literacy of adult)- 3 outputs (first complete, second level complete, avg yrs of school)	.64	.87	.94	.80	.79	.83
3 inputs (public expenditure, literacy of adult, teachers per pupil)- 3 outputs (first complete, second level complete, avg yrs of school)	.86	.94	.93	.86	.80	.89
3 inputs (public expenditure, teachers per pupil, literacy of adult) – 3 outputs (literacy of youth, first level complete, second level complete)	.98	1.0	1.0	.98	.99	.99

Rows 4 and 5 of Table 8 allow comparing the impact of adding the variable teachers per pupil as an additional input. In Africa the change is dramatic, while in ECA and MNA there is no significant change. Further analysis is required to explain this differential response to the inclusion of this input.

In health there are multiple combinations of inputs (public expenditure, private expenditure, and literacy of adults) and outputs (life expectancy at birth, immunization DPT, immunization measles, and Disability Adjusted life expectancy (DALE)). The combinations we selected produce rankings that are more homogeneous. The rank correlation is in the range of .65 to .98 (Tables 10-12). Bangladesh appears as efficient, as well as Niger, mainly due to the inclusion as of the (low) levels of literacy of adults as an input, and hence, making these countries to appear as efficient.

Table 10. Health Attainment: Multiple Inputs, Multiple Outputs

	Input-Efficient	Output Efficient
More efficient	Bangladesh, Malaysia, Costa Rica, Kuwait, Morocco, Oman, Mauritius, Niger	Bangladesh, Costa Rica, Kuwait, Malaysia, Morocco, Mauritius, Oman, Niger
Least efficient	Russia, Belarus, Namibia, Romania, Estonia, Croatia, Lituania,, Hungary, Jordan	Namibia, Togo, Ethiopia, Mozambique, Cote d'Ivoire, Cameroon, Congo, Central African Republic, Nigeria, Uganda

Table 11. Health Attainment: Input-Efficiency scores by regions across the world**- Multiple Inputs, Multiple Outputs**

	AFR	EAP	ECA	LA	MNA	SAS
2 inputs (public expenditure, literacy of adult) – 2 outputs (life expectancy, immunization DPT.)	.85	.82	.72	.82	.91	.93
3 inputs (public expenditure, private spending, literacy of adult) – 2 outputs (life expectancy, immunization DPT.)	.86	.82	.74	.83	.91	.94
3 inputs (public expenditure, private spending, literacy of adult) – 2 outputs (life expectancy, immunization measles.)	.86	.82	.77	.83	.91	.94
3 inputs (public expenditure, private spending, literacy of adult) – 3 outputs (life expectancy, immunization DPT., DALE)	.86	.82	.80	.87	.93	.94

Table 12. Health Attainment: Output-Efficiency scores by regions across the world**- Multiple Inputs, Multiple Outputs**

	AFR	EAP	ECA	LA	MNA	SAS
2 inputs (public expenditure, literacy of adult) – 2 outputs (life expectancy, immunization DPT.)	.81	.91	.97	.93	.97	.96
3 inputs (public expenditure, private spending, literacy of adult) – 2 outputs (life expectancy, immunization DPT.)	.81	.91	.97	.94	.97	.96
3 inputs (public expenditure, private spending, literacy of adult) – 2 outputs (life expectancy, immunization measles.)	.80	.91	.96	.94	.98	.96
3 inputs (public expenditure, private spending, literacy of adult) – 3 outputs (life expectancy, immunization DPT., DALE)	.82	.91	.97	.95	.98	.97

Tables 9 and 12 show that, on average, developing nations score between .85 and .95 in output efficiency in the multiple input-output framework. This figures imply that developing countries could raise their output levels by an average of 10 percent with the same input consumption, if they were as efficient as the comparable benchmark countries. This figure is simply indicative, as the precise estimate varies with the country and with the selected indicator, and has a large variance across countries: for instance, the bottom decile of (output) efficiency scores is about .66, implying that the scope for increasing health and education attainment levels is between 3 or 4 times higher than for the whole sample average.

III.4. Efficiency Change Over Time

To examine the evolution of input and output efficiency over time, we computed the efficiency scores in two different time periods: 1975-1980 and 1996-2002 for education study, and 1997-99 and 2000-02 for health study, the construction of which is driven by data availability. Appendix D reports the results on a regional basis¹⁴.

Comparison of different input-output bundles in different time periods has to be done carefully because the frontier can be shifting outward through time. In some cases the frontier displacement can be parallel (such as in the life expectancy case of Figure 9). In others, the frontier displacement can be very uneven (biased frontier shift in Figure 9) reflecting biased technological change (see Appendix D for detailed discussion).

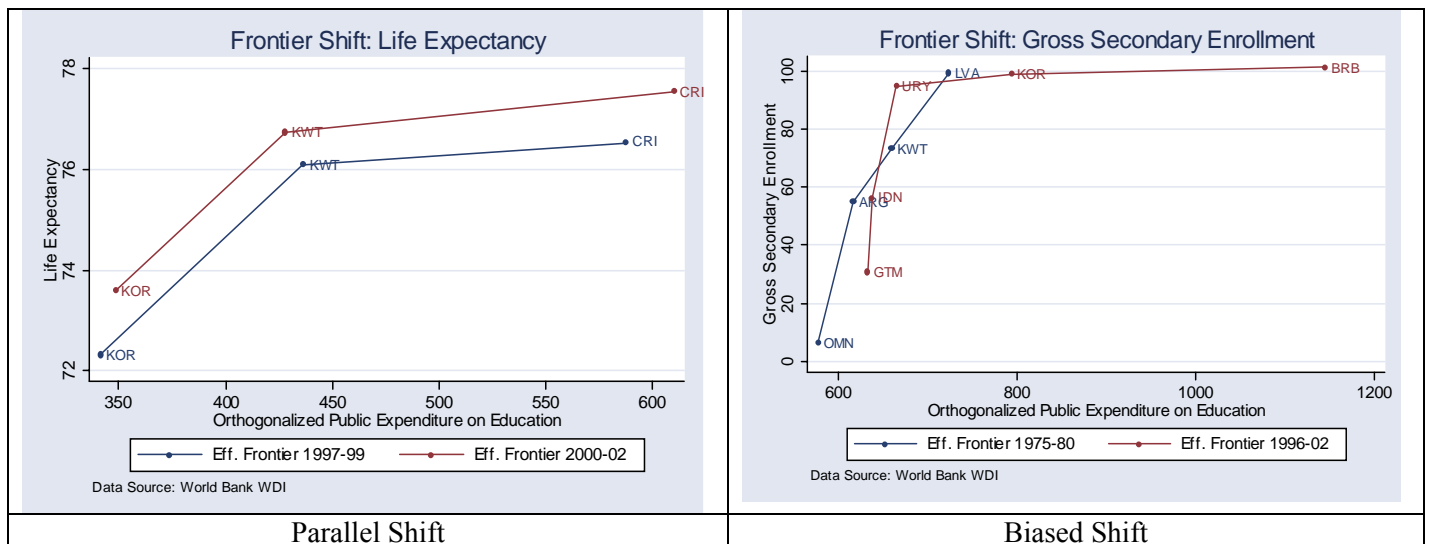


Figure 9. Efficiency Frontier Shift Over Time

The detailed comparison between observed input-output combinations in different time periods distinguishes whether variations in the levels of input utilization or output production levels are due to changes in efficiency or changes in technology. This testing is possible with observed levels of inputs and outputs, and are based on the concept of a Malmquist Index (Fare, Grosskopf, Norris and Zhang, 1994). This method has been used to study productivity change in the OECD economies, as well as productivity in agriculture across the world (Coelli and Rao, 2003; Nin, Arndt, and Preckel, 2003). Appendix D describes details of the method that uses some of the efficiency scores calculated in previous sections, and the index that will facilitate the analysis of productivity change through time.

¹⁴ Scores for individual countries are available at the PRMED website indicated in footnote 1.

Results show that over the two decades output-efficiency growth was faster in the most inefficient countries, showing that there is a “catching-up” phenomenon. However, when measuring input-efficiency, the previous results do not hold: most regions increased expenditure levels without increasing output. Appendix D summarizes, on a regional basis, the change in productivity of public spending decomposed into efficiency change and technological change.¹⁵

IV. Explaining Inefficiency Variation Across Countries

This chapter seeks to identify factors correlated with inefficiency scores variation across countries. This two-stage approach attempts to identify statistically significant regularities common to efficient or inefficient countries using the more basic statistical techniques. This exercise does not try to identify supply or demand factors that affect health and education outcomes, such as those described by Filmer (2003). The scope is limited to verifying statistical association between the efficiency scores and environmental variables.

IV.1. Method, Variables and Data Description

Given that the dependent variable, the efficiency scores, is continuous and distributed over a limited interval (between zero and one), it is appropriate to use a censored (Tobit) regression model to analyze the relationships with other variables. The panel consist of a large numebr of countries (varying from 70 to 140 depending on the output indicator) and only two time periods. The literature on panel estimation has shown that in panels with this configuration, that is, a large number of cross-section units (countries) and a relatively short time dimension (2 periods), the fixed-effects estimators of the coefficients will be inconsistent (Maddala, 1987) and their variance will be biased downward (Greene, 2003b). Hence the random effects panel estimation method was preferred.

The dependent variable in the Tobit panel is the input efficiency score calculated by DEA method in the first stage. The input-oriented estimator reflects the consideration that input choices are more under the policymaker’s control. The independent variables reflect environmental effects included in precursor papers, as well as suggested by others recently. We included the following independent variables¹⁶.

a. The size of government expenditure. Most of the papers surveyed in the previous section explore the relationship between the size of the government (or expenditure as a percentage of GDP) and efficiency levels. The objective is to verify if additional pubic spending is associated with better education and health outcomes. While some papers have found a negative association between efficiency and expenditure levels (Gupta-Verhoeven 2001, Jarasuriya-Woodon 2003, and Afonso et.al. 2003), others have found a positive association (Evans et.al. 2003) and others have found no significant impact (Filmer and Pritchett, 1999)

¹⁵ The results on country-by-country basis can be found at the PRMED website indicated in footnote 1.

¹⁶ The precise definition and sources is can be found in Appendix B, Table B.6.

b. A government budget composition variable. Given that both education and health are labor-intensive activities, the government's labor policies will determine the efficiency with which outputs are delivered. We choose a budget composition indicator to reflect this, in particular, the ratio of the wage bill to the total budget. A higher ratio is expected to be negatively correlated with efficiency.

c. Per-capita GDP. We included the per-capita GDP to control for the Balassa-Samuleson effect in comparing across countries. If richer countries tend to be more inefficient (given higher wages in these countries), a negative sign is expected. However, it must be recalled that to obtain the efficiency scores in the "first stage" we constructed an auxiliary variable (the orthogonalized public expenditure). Hence the inclusion of this variable in the second stage is an attempt to control for any remaining Balassa-Samuleson effects.

d. Urbanization. The clustering of agents make it cheaper to provide services in urbanized areas rather than in rural. Higher degree of urbanization should reflect in higher efficiency, making positive as the expected sign of the coefficient on this variable.

e. Prevalence of AIDS. Based on WHO mappings of the disease, we included a dummy variable in the most severely affected countries to control for the role of this epidemic in the poor health outcomes. Evans *et. al.* (2000) report that AIDS lowers the Disability adjusted life expectancy (DALE) by 15 years or more. Aids also affects education outcomes both directly and indirectly (Drake, *et. al.* 2003): directly because school-age children are affected: UNAIDS estimates that almost 4 million children have been infected since the epidemic began, and two thirds have died. However, the indirect channel is relatively more important: AIDS leaves orphaned children that are more likely to drop-out of school or repeat. All these factors reflect how AIDS affect the demand for education. But the supply is also affected by the decreasing teacher labor force due to illness or death, or the need to care for family (Pigozzi, 2004). Prevalence of HIV/AIDS should be negatively associated with education and health outcomes. Consequently, efficiency scores should be negatively associated with the dummy variable.

f. Income distribution inequality. Ravallion (2003) argues that, besides the mean income, its distribution affects social indicators because their attainment is mostly determined by the income of the poor. Hence, we controlled for the distribution of income by including the Gini coefficient as an explanatory variable. Higher inequality is expected to be associated with lower educational and health attainments, making negative the expected sign of this variable.

g. Share of public sector in the provision of service. Services can be provided by both the public and private sectors, and efficiency indicators will differ across countries depending on the relative productivities of both sectors. Previous studies have included this variable to explain differences in outcomes (Le Grand, 1987; Berger and Messer, 2002) or efficiency scores (Greene, 2003a). The specific variable we included was the ratio of publicly financed service over the total spending (sum of private and public spending).

h. External Aid. To the extent that countries do not have to incur the burden of taxation, they may not have the incentive to use resources in the most cost-effective way. Another channel through which aid-financing may affect efficiency is through the volatility and unpredictability of its flows. Given that this financing source is more volatile than other types of fiscal revenue (Bulir and Hamann, 2000), it is difficult to undertake medium-term planning with in activities funded with aid resources. If this is the case, we would expect a negative association between aid-dependence and efficiency in those activities funded with aid, mostly health services. To our knowledge there are no previous attempts to establish a relationship between efficiency and the degree to which activities are financed by external aid. There is, however, recent evidence of a negative association between donor financing and some health outcomes (Bokhari, Gottret, and Gai, 2005)

i. Institutional Variables. Countries with better institutions, more transparency, and less corruption are expected to have higher efficiency scores. Similarly, countries that have suffered wars or state failures are expected to register lower efficiency scores. To capture these effects we included different indicators: the ICRG International Country Risk Indicators, the Worldwide Governance Research Indicators, in particular the Control of Corruption component (Kaufmann, et.al, 2002). We also included a dummy variable if there had been some type of state failure, such as internal wars, from the State Failure Task force database.

The data on educational and health indicators are not available on a continuous annual basis for many countries. Thus, averages of the variables were computed over sub-periods both in the first stage calculation of efficiency score and in the second stage of regression analysis. Specifically, educational indicators are averaged over two periods (1975-80 and 1996-2002) and health indicators over two periods (1996-99 and 2000-02). This discrepancy in the sub-period construction is due exclusively to the lack of data for earlier years. The averages are treated as separate observations. The advantages of this approach are threefold. First, the averages may serve as a better measure of the educational and health attainment, which can hardly be substantially improved on a yearly basis; Second, the averaging maximizes the coverage of countries for each period, since one observation of a certain year is sufficient to help the country survive in the cross sectional comparison; Third, the time series thus constructed for each country, although short, facilitates the implementation of econometric techniques on panel data to explore the efficiency variations across countries and through time.

IV.2. Results

The Tobit estimation on panel data is defined as follows.

$$VRSTE_{it} = f(WAGE_{it}, GOVEXP_{it}, PUBTOT_{it}, \\ GDPPC_{it}, URBAN_{it}, AIDS_{it}, GINI_{it}, EXTAID_{it}, INST_{it}, CONS)$$

where $VRSTE_{it}$ = Variable returns to scale DEA efficiency score for single output and multiple output cases.

$WAGE_{it}$ = Wages and salaries (% of total public expenditure)

$GOVEXP_{it}$ = Total government expenditure (% of GDP)

$PUBTOT_{it}$ = Share of expenditures publicly financed (public/total)

$GDPPC_{it}$ = GDP per capita in constant 1995 US dollars

$URBAN_{it}$ = Urban population (% of total)

$AIDS_{it}$ = Dummy variable for HIV/AIDS

$GINI_{it}$ = Gini Coefficient

$EXTAID_{it}$ = External aid (% of fiscal revenue)

$INST_{it}$ = Institutional indicators including ICRG country risk, World Governance Research Indicators (Corruption Control), or a dummy for state failures from the State Failure Task Force database.

$CONS$ = Constant

Tables 13 and 14 report the results for the single-input single-output case and the multiple-input multiple-output case, respectively. The more interesting findings are:

- a. We find that countries with larger expenditure levels also register the more inefficient scores. This result is robust to changes in the output indicator selected, to considering health or education, and to adopting either the single –output or multiple output frameworks. The trade-off between size of expenditure and efficiency is quite robust.
- b. Countries in which the wage bill represents a higher fraction of total expenditure tend to be more inefficient. This result does not hold for health in the multiple output framework. This difference could be due partly to the relatively decreasing number of health care professionals in the world, especially in the poorer countries (Liese, et.al., 2003). Further investigation would be required to examine why this is not the case in education.
- c. Countries in which public financing is a larger share of total expenditure on the service also register lower efficiency scores. This is probably due to differential productivity rates in the provision of services. Further research would be needed to explain why this is the case in health services. Recent case studies of water

- companies in Argentina show that private companies were more efficient than public ones and provided better service quality leading to lower child mortality rates (Galiani, Gertler and Schargrotsky, 2005). In education, there is some evidence that efficiency scores are lower in public schools (Alexander and Jaforullah, 2004), though the evidence regarding the impact of privatizing education on outcomes is mixed (World Bank, 2003).
- d. Urbanization is positively associated with efficiency scores in both education and health. However, when life expectancy is included as an output, the relationship is non-significant (single output) or negative (multiple-output). Possibly the urbanization variable is capturing other effects such as crime. There is ample literature studying the relationship between urbanization and crime (Glaeser E. and B. Sacerdote, 1999). Alternatively, as urbanization intensifies, communicable diseases are more difficult and costly to control, hence the negative association found between both variables in health.
 - e. The effect of the HIV/AIDS is clearly negative affecting health efficiency scores in the multiple-output models. However, its effect on education is less clear, as the expected negative sign is significant in few cases and has the opposite sign in equal number of cases. This confirms the difficulty of empirically verifying this relationship, reported in previous work (Wobst and Arndt, 2003).
 - f. Income distribution has the expected negative effect on the educational and health efficiency scores. The impact of inequality on health scores is less robust than in education, but confirms Greene's findings (2003). Other papers (Berger and Messer, 2002), have found a positive association between income inequality and health outcomes.
 - g. Results showed a negative relationship between some of the efficiency scores and the external aid dependency ratio. Only in one of the multiple-output cases is the external aid associated with higher efficiency, but with border-line statistical significance. Though no causality relationship can be inferred from the exercise, this is one of the results that merit more detailed research. This result might be explained by the volatility of aid as a funding source that limits medium term planning and effective budgeting. Probably this is why the negative sign is more robust in health than in education, given that donor funding is mostly directed towards the first. Recent research (Bokhari, Gottret, Gai, 2005) show a negative association between some health outcomes and the degree of donor funding, pointing in this same direction. This result also coincides with research showing that the quality of policies is not only unrelated to donor financing, but that highly indebted countries with "bad" policies received more net transfers as a share of GDP (Birdsall, et.al. 2003).
 - h. None of the institutional variables proved to be statistically significant. We interpret this result as due to the data limitations, as some of the most crucial information, for instance the corruption index is only available since 1996 and the panel exercise was limited to a cross-section. The state-failure dummy variable or

the ICRG indicators did not prove to be significant either. Hence, these results are not reported in any of the tables.

To investigate the possibility of slope heterogeneity across countries, we followed the approach used in Haque, Pesaran, and Sharma (1999). Specifically, the slope coefficients in each country are assumed to be fixed over time, but varying across countries linearly with the individual sample mean of GDP per capita. The final results (Tables 15 and 16) only include the statistically significant interaction terms, in order to avoid co linearity arising from the correlation between original explanatory variables and the auxiliary variable capturing the interaction of these with the sample mean of GDP per capita. Hence the estimated model is:

$$VRSTE_{it} = f(WAGE_{it}, GOVEXP_{it}, GDPPC_{it}, URBAN_{it}, AIDS_{it}, GINI_{it}, WAGEG_{it}, GOVG_{it}, GINIG_{it}, CONS)$$

where $VRSTE_{it}$ = Variable returns to scale DEA efficiency score for single output and multiple output cases

$WAGE_{it}$ = Wages and salaries (% of total public expenditure)

$GOVEXP_{it}$ = Total government expenditure (% of GDP)

$PUBTOT_{it}$ = Share of expenditures publicly financed (public/total)

$GDPPC_{it}$ = GDP per capita in constant 1995 US dollars

$URBAN_{it}$ = Urban population (% of total)

$AIDS_{it}$ = Dummy variable for HIV/AIDS

$GINI_{it}$ = Gini Coefficient

$CONS$ = Constant

$WAGEG_{it} = WAGE_{it} * \overline{GDPPC_i}$

$GOVG_{it} = GOVEXP_{it} * \overline{GDPPC_i}$

$GINIG_{it} = GINI_{it} * \overline{GDPPC_i}$

$\overline{GDPPC_i} = T^{-1} \sum_{t=1}^T GDPPC_{it}$

Results show that the interaction terms are significant, especially for the health regression, implying that there is a heterogeneous response of efficiency scores to the different explanatory variables. This confirms Greene's (2003) results on the WHO data. One of the key results of this section is that the negative association between the size of government expenditure and efficiency is stronger in countries with higher per-capita GDP. Similarly, this happens with the wage variable. Results are somewhat similar to those of the homogeneous slopes, though statistical significance of many of the coefficients is lower. This is the result of co-linearity between the auxiliary variables and the original set of explanatory variables. This problem deserves further work in the future.

Interpretation of these results requires caution due to several limitations. First, education and health outcomes are explained by multiple supply and demand factors (Filmer, 2003) that are not included here. This is not the object of the present paper. The omission of one of these factors in the health or education production functions in the previous stage could explain some of the cross-country co-variation of the efficiency results (Ravallion, 2003). The goodness-of-fit analysis of the first stage indicated that no important factor seemed to be omitted. Of course, there can always be additional factors that could be included but the curse of dimensionality¹⁷ is particularly pressing in non-parametric statistical methods (even if the data were available)

The second limitation derives from the intuitive question why the set of explanatory variables used in the second stage were not included in the first stage. The answer lies in that most of these variables are environmental and outside the control of the decision-making unit. The inclusion of these environmental variables would have had little justification from the production function perspective. Additionally, by maintaining the production function as simple as possible the dimensionality curse is avoided.

Finally, the third limitation arises from the fact that if the variables used in the first stage to obtain the efficiency estimator are correlated with the second stage explanatory variables, the coefficients will be inconsistent and biased (Simar and Wilson, 2004; Grosskopf, 1996; Ravallion, 2003). To examine the extent of this potential problem we calculated correlation coefficients between the “first-stage” inputs and the second stage explanatory variables. The largest correlation coefficients were between GDP per capita and the teachers per pupil ratio and the literacy of the adult. To examine the sensitivity of the results to the inclusion of GDP per capita, all the estimations were performed without this variable and none of the results changed.

V. Concluding Remarks and Directions for Future Work

The paper presented an application of non-parametric methods to analyze the efficiency of public spending. Based on a sample of more than 140 countries, the paper estimated efficiency scores for nine education output indicators and four health output indicators. Our results indicate that countries could achieve substantially higher education and health output levels: on average, developing countries score output efficiency of about .9 (in the multiple input-output framework) or around .7 (in the single input-single output model), implying that they could increase health and education attainment between by 10 percent or 30 percent while consuming the same input level, if they were as efficient as the comparable benchmark countries. This is just an indicative figure, as the figures vary across countries and with the selected output indicator. It is crucial to identify what are the institutional or economic factors that cause some countries to be more efficient than others in the service delivery.

¹⁷ As the number of outputs increase, the number of observations must increase exponentially to maintain a given mean-square error of the estimator. See Simar and Wilson (2000).

In terms of policy implications, it is vital to differentiate between the technically efficient level and the optimal or desired spending level. Even if a country is identified as an “efficient” benchmark country, it may very well still need to expand its public spending levels to achieve a target level of educational or health attainment indicators. Such is the case of countries with low spending levels and low attainment indicators, close to the origin of the efficient frontier.. The important thing is that countries expand their scale of operation along the efficient frontier.

The methods used in the paper can be interpreted as tools to identify extreme cases of efficient units and inefficient cases. Once the cases have been identified, more in-depth analysis is required to explain departures from the benchmark, as proposed and done by Sen (1981). Given that the methods are based on estimating the frontier directly from observed input-output combinations they are subject to sampling variability and are sensitive to the presence of outliers. Recent advances allow dealing with these problems such as in Wilson (2004). Additionally, it would be useful to contrast these results with those obtained with the use of parametric stochastic frontier estimation.

In a “second stage” the paper verified statistical association between the efficiency scores and environmental variables that are not under the control of the decision-making units. The panel Tobit regressions showed that the variables, which are negatively associated with efficiency scores, include the size of public expenditure, the share of the wage bill in the total public budget, the proportion of the service that is publicly financed, the prevalence of HIV/AIDS epidemic on health efficiency scores, income inequality on education efficiency scores, and external aid-financing on some of the efficiency scores. This last impact is probably due to the volatility of aid that impedes effective medium term planning and budgeting, and probably explains why the result is more robust in health than in education where most of the donor-funding is directed. This result point in the same direction of previous research showing that donor financing is unrelated to the quality of domestic policies and that, in the case of highly indebted counties, those with worse policies received more transfers. A positive association between urbanization and efficiency outcomes is also identified in education but some of the health efficiency scores are negatively associated. This last result probably is due to higher crime rates in the cities or the effect of communicable diseases that spread with agglomeration. These are topics for further research in case studies.

Table 13. Explaining cross-country variation in efficiency, Single Input-Single Output

Independent Variable	Gross Primary Enrollment	Net Primary Enrollment	Gross Secondary Enrollment	Net Secondary Enrollment	Literacy of Youth	Average Years of School	First Level Complete	Secondary Level Complete	Life Expectancy	Immuni-zation DPT	Immuni-zation Measles
WAGE	-.00117***	-.00357*	-.00172**	-.00680*	-.00189**	-.00570*	-.00470**	-.00546*	.00065	-.00052	-.00049
GOVEXP	-.00387*	-.00546*	-.00340*	-.00455**	-.00387*	-.00696*	-.00566*	-.00765*	-.00269**	-.00078	-.00227***
PUBTOT	--	--	--	--	--	--	--	--	-.00213*	-.00150*	-.00135***
GDPPC	-.00002*	-.00002*	-.00001*	.00002**	-.00002*	-1.5e-6	-.00001	-7.7e-6	7.6e-7	-.00001*	-.00001*
URBAN	.00167*	.00143***	.00168*	.00037	.00187*	.00532*	.00551*	.00555*	-.00018	.00099**	.00088
AIDS	-.04471**	-.08731**	-.02204	.01243	-.02974	.12717***	.1211***	.11041	-.05473	-.01108	-.02730
GINI	-.06688	.01507	-.19326**	-.42311	-.18484***	-.44658**	-.34402	-.45870**	.22118	.09510	.08692
EXTAID	-.00094	-.00196**	-.00021	-.00106	-.00054	.00089	-.00025	-.00006	-.00224***	-.00155	-.00324**
CONS	1.02996*	1.1282*	1.0472*	.84138*	1.0697*	.76791*	.70009*	.81705*	.79193*	.78734*	.84384*
# of Obs	79	44	79	34	72	71	71	71	118	118	118
(# of Countrs)	(51)	(30)	(51)	(20)	(46)	(45)	(45)	(45)	(69)	(69)	(69)
Wald Chi2(6)	83.91	66.09	46.72	55.31	44.27	64.13	45.53	61.94	50.83	123.97	35.01
(Prob > Chi2)	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)

Note: * 0.01 significance level, ** 0.05 significance level, *** 0.10 significance level, and insignificant otherwise

Table 14. Explaining cross-country variation in efficiency, Multiple Inputs-Multiple Outputs

Independent Variable	EDU2-2	EDU2-2n	EDU3-2	EDU3-2n	EDU3-3	EDU3-3bl	HEA2-2	HEA3-2	HEA3-2m	HEA3-3
WAGE	-.00212**	-.00767*	-.00219**	-.00425	-.001000	-.00340***	.00126*	.00205*	.00203***	.00203***
GOVEXP	-.00321*	-.00365	-.00203***	.00099	-.00123***	-.00316***	-.0012***	-.00273*	-.0009	-.00090
PUBTOT	--	--	--	--	--	--	-.00151*	-.00142*	-.00159***	-.00151***
GDPPC	-.00001**	-6.6e-7	-.00001***	-.00003	-4.2e-6	1.98e-6	-2.7e-6	4.2e-6*	-7.1e-7	-9.3e-7
URBAN	.00138***	-.00045	.00191**	.001997	.00127*	.00091	-.00095*	-.00148*	-.00106	-.00105
AIDS	-.03295	-.05843	-.00956	-.14763	.01797	.06022	-.04815*	-.033147**	-.07162	-.06999
GINI	-.06485	.43602	-.14717	.27058	-.17237**	-.15697	-.03997	-.07958***	-.01015	-.01387
EXTAID	.00010	-.00622	.00152	-.00274	-.00066	.00123	.00087	.00128***	-.00095	-.00106
CONS	1.0655*	1.0223	1.0642*	1.0124*	1.06570*	1.1218*	1.0098	1.0117*	.98891*	.98787*
# of Obs (# of Countrs)	76 (49)	34 (20)	69 (44)	32 (19)	69 (44)	63 (40)	97 (55)	98 (56)	98 (56)	98 (56)
Wald Chi2(6) (Prob > Chi2)	24.48 (.00)	11.69 (.11)	20.84 (.00)	7.44 (.38)	18.72 (.01)	9.18 (.24)	185.21 (.00)	229.98 (.00)	19.25 (.01)	18.62 (.02)

Note:

* 0.01 significance level, ** 0.05 significance level, *** 0.10 significance level, and insignificant otherwise

EDU2-2: Inputs: orthogonalized public spending on education per capita, teachers per pupil

Outputs: gross primary and secondary enrollments

EDU2-2n: same inputs as EDU2-2, outputs: net primary and secondary enrollment

EDU3-2: literacy of adult is added to EDU2-2 as input

EDU3-2n: literacy of adult is added to EDU2-2n as input

EDU3-3: literacy of youth is added to EDU3-2 as output

EDU3-3bl: same inputs as in EDU3-2,

outputs: average years of school, first level complete, and second level complete (Barro-Lee education indicators)

HEA2-2: Inputs: orthogonalized public spending on health per capita, literacy of adult

Outputs: life expectancy at birth, and immunization DPT

HEA3-2: orthogonalized private spending on health per capita is added to HEA2-2 as input

HEA3-2m: Immunization Measles is in place of DPT in HEA3-2 as output

HEA3-3: Immunization Measles is added to HEA3-2 as output

Table 15. Explaining cross-country variation in efficiency, Single Input and Single output - Heterogeneous Slopes

Independent Variable	Gross Primary Enrollment	Net Primary Enrollment	Gross Secondary Enrollment	Net Secondary Enrollment	Literacy of Youth	Average Years of School	First Level Complete	Secondary Level Complete	Life Expectancy	Immuni- zation DPT	Immuni- zation Measles
WAGE	-.00006	.00076	-.00035	-.00228	-.00056	-.00200	-.00120	-.00419	-.00306***	-.00079	-.00241
GOVEXP	-.00363*	-.00255***	-.00377*	-.00727***	-.00552*	-.00595***	-.00453	-.00611***	.00337**	.00168***	.00221
PUBTOT	--	--	--	--	--	--	--	--	-.00162*	-.00162*	-.00097
GDPPC	-.00002*	-.00002*	-5.4e-6	.00003*	-.00002***	.00004*	.00003***	.00003***	.00002**	-.00002*	-.00001
URBAN	.00179*	.00132**	.00193*	.00139	.00212*	.00566*	.00601*	.00593*	-.00080	-.00117*	.00021
AIDS	-.03866***	-.06603**	-.03153	.01010	-.02177	.05491	.06656	.06464	-.02321	-.04147**	-.00826
GINI	-.14230	-.42098*	-.14976	-.29395	-.13107	-.09995	-.15463	-.24762	-.12865	-.38851*	-.42162**
WAGG	-4.4e-6***	-1.2e-6*	-4.6e-7***	-9.4e-7	-4.5e-7	-8.1e-7	-8.8e-7	-2.4e-7	8.9e-7**	6.95e-8	5.1e-7
GOVG	-8.6e-8	-5.2e-7***	4.3e-8	3.6e-7	4.0e-7	-4.3e-7	-4.4e-7	-5.3e-7	-1.4e-6*	-5.4e-7*	-9.4e-7*
GINIG	.00003	.00011*	-2.4e-6	-.00003	2.0e-6	-.00006	-.00005	-.00006	.00001	.00009*	.00006***
CONS	1.0156*	1.1036*	1.0098*	.74603*	1.0365*	.60371*	.53977*	.68648*	.82665*	1.0119*	.93820*
# of Obs (# of Countrs)	82 (52)	47 (31)	82 (52)	36 (21)	75 (47)	74 (46)	74 (46)	74 (46)	120 (70)	121 (71)	121 (71)
Wald Chi2(6) (Prob > Chi2)	87.32 (.00)	93.98 (.00)	62.74 (.00)	105.34 (.00)	58.40 (.00)	94.00 (.00)	69.32 (.00)	82.38 (.00)	74.33 (.00)	450.54 (.00)	52.71 (.00)

Note: * 0.01 significance level, ** 0.05 significance level, *** 0.10 significance level, and insignificant otherwise

Table 16. Explaining cross-country variation in efficiency, Multiple Inputs and Multiple Outputs - Heterogeneous Slopes

Independent Variable	EDU2-2	EDU2-2n	EDU3-2	EDU3-2n	EDU3-3	EDU3-3bl	HEA2-2	HEA3-2	HEA3-2m	HEA3-3
WAGE	.00051	-.00140	.00005	.00494	-.00018	-.00045	-.00063	-.00065	-.00093	-.00092
GOVEXP	-.00323**	.00501	-.00385**	.00520	-.00256**	-.00459	.00122***	.00063	-.00070	-.00064
PUBTOT	--	--	--	--	--	--	-.00180*	-.00145**	-.00149***	-.00141***
GDPPC	-8.6e-6	.00002	1.7e-6	.00003	-1.8e-6	-2.1e-6	-.00001**	-.00001	-.00003**	-.00003**
URBAN	.00137**	.00079	.00166**	.00096	.00134*	.00064	-.00246*	-.00167***	-.00160	-.00159
AIDS	-.04139	-.06211	-.04744	-.20362*	.00646	.04633	-.06289*	-.04001	-.07217	-.07025
GINI	-.14418	-.18676	.07096	-.02601	-.07474	-.20029	-.32844*	-.45695**	-.29885	-.30857
WAGG	-8.3e-7**	-1.2e-6	-6.4e-7***	-1.9e-6	-2.0e-7	-7.9e-7	7.8e-7*	7.2e-7	6.0e-7	6.0e-7
GOVG	-6.3e-8	-2.6e-6***	3.5e-7	-1.2e-6	3.0e-7	3.5e-7	-5.98e-7*	-4.9e-7	2.7e-8	1.4e-8
GINIG	.00003	.00012	-.00003	.00005	-.00002	.00003	.00005*	.00005***	.00006	.00006***
CONS	1.0515*	.89986*	1.0021*	.84756*	1.0464	1.1257*	1.1494*	1.1457*	1.1512*	1.1495*
# of Obs (# of Countrs)	79 (50)	36 (21)	72 (45)	34 (20)	72 (45)	66 (41)	101 (58)	101 (58)	101 (58)	101 (58)
Wald Chi2(6) (Prob > Chi2)	41.93 (.00)	18.57 (.03)	31.15 (.00)	18.71 (.22)	23.89 (.00)	13.22 (.15)	600.70 (.00)	37.22 (.00)	25.33 (.00)	24.74 (.01)

Note:

- * 0.01 significance level, ** 0.05 significance level, *** 0.10 significance level, and insignificant otherwise
- EDU2-2: Inputs: orthogonalized public spending on education per capita, teachers per pupil
Outputs: gross primary and secondary enrollments
EDU2-2n: same inputs as EDU2-2, outputs: net primary and secondary enrollment
EDU3-2: literacy of adult is added to EDU2-2 as input
EDU3-2n: literacy of adult is added to EDU2-2n as input
EDU3-3: literacy of youth is added to EDU3-2 as output
EDU3-3bl: same inputs as in EDU3-2,
outputs: average years of school, first level complete, and second level complete (Barro-Lee education indicators)
HEA2-2: Inputs: orthogonalized public spending on health per capita, literacy of adult
Outputs: life expectancy at birth, and immunization DPT
HEA3-2: orthogonalized private spending on health per capita is added to HEA2-2 as input
HEA3-2m: Immunization Measles is in place of DPT in HEA3-2 as output
HEA3-3: Immunization Measles is added to HEA3-2 as output

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Appendix A. Data Envelopment Analysis (DEA) Model

A measure of production efficiency, perhaps the simplest one, is defined as the ratio of output to input. It is, however, inadequate to deal with the existence of multiple inputs and outputs. The relative efficiency for all decision-making units (DMU), $j=1, \dots, n$, is then modified as the ratio of weighted outputs to weighted inputs, more precisely,

$$\text{Relative efficiency} = \frac{\sum_{r=1}^s u_r y_{rj}}{\sum_{i=1}^m v_i x_{ij}} \quad (\text{A.1})$$

where x and y are inputs and outputs, respectively, and u and v are the common weights assigned to outputs and inputs, respectively. A challenge of this measure immediately follows: it is difficult to justify the common weights given that DMUs may value inputs and outputs differently.

The seminal paper by Charnes, Cooper and Rhodes (1978) proposed the following ratio form to allow for difference in weights across DMUs, which establishes the foundation of data envelopment analysis (DEA).

$$\begin{aligned} \text{Max } h_0 &= \frac{\sum_{r=1}^s \mu_r y_{r0}}{\sum_{i=1}^m v_i x_{i0}} \\ \text{subject to:} \\ \frac{\sum_{r=1}^s \mu_r y_{rj}}{\sum_{i=1}^m v_i x_{ij}} &\leq 1, \quad j = 1, \dots, n \\ \mu_r &\geq \varepsilon, \quad r = 1, \dots, s \\ v_i &\geq \varepsilon, \quad i = 1, \dots, m \\ \varepsilon &> 0 \end{aligned} \quad (\text{A.2})$$

In the model, there are $j=1, \dots, n$ observed DMUs which employ $i=1, \dots, m$ inputs to produce $r=1, \dots, s$ outputs. One DMU is singled out each time, designated as DMU_0 , to be evaluated against the observed performance of all DMUs. The objective of model (A.2) is to find the most favorable weights, μ_r and v_i , for DMU_0 to maximize the relative efficiency. The constraints are that the same weights will make ratio for every DMU be less than or equal to unity. The optimal value of the ratio must be $0 \leq h_0^* \leq 1$ and DMU_0 is efficient if and only $h_0^* = 1$, otherwise it is considered as relatively inefficient. One problem with the ratio formulation is that there are an infinite number of solutions: if μ_r and v_i are solutions to (A.2), so are $\alpha\mu_r$ and αv_i , $\forall \alpha > 0$.

It is worth observing one important feature of model (A.2). In maximizing the objective function it is the relative magnitude of the numerator and the denominator that really matters and not their individual values. It is thus equivalent to setting the denominator to a constant, say 1, and maximizing the numerator. This transformation will not only lead

to the uniqueness of solution but also convert the fractional formulation of model (A.2) into a linear programming problem in model (A.3).

$$\begin{aligned}
 & \text{Max} && \sum_{r=1}^s \mu_r y_{r0} \\
 & \text{subject to :} && \\
 & && \sum_{i=1}^m v_i x_{i0} = 1 \\
 & && \sum_{r=1}^s \mu_r y_{rj} - \sum_{i=1}^m v_i x_{ij} \leq 0, \quad j = 1, \dots, n \\
 & && -\mu_r \leq -\varepsilon, \quad r = 1, \dots, s \\
 & && -v_i \leq -\varepsilon, \quad i = 1, \dots, m
 \end{aligned} \tag{A.3}$$

Model (A.3) facilitates straightforward interpretation in terms economics. The objective is now to maximize the weighted output per unit weighted input under various conditions, the most critical one of which is that the virtual output does not exceed the virtual input for any DMU.

Since model (A.3) is a linear programming, we can convert the maximization problem into a minimization problem, e.g. a *dual* problem, by assigning a dual variable to each constraint in the *primal* (A.3). Specifically, dual variables $\theta, \lambda_j, s_r^+, s_i^-$ are assigned as follows.

<i>Max</i>	$\sum_{r=1}^s \mu_r y_{r0}$	Dual Variable
<i>subject to :</i>		
	$\sum_{i=1}^m v_i x_{i0} = 1$	θ
	$\sum_{r=1}^s \mu_r y_{rj} - \sum_{i=1}^m v_i x_{ij} \leq 0, \quad j = 1, \dots, n$	λ_j
	$-\mu_r \leq -\varepsilon, \quad r = 1, \dots, s$	s_r^+
	$-v_i \leq -\varepsilon, \quad i = 1, \dots, m$	s_i^-

A *dual* minimization problem is thus derived as model (A.4). It is clear that model (A.4) has $m+s$ constraints while model (A.3) has $n+m+s+1$ constraints. Since n is usually considerably larger than $m+s$, the dual DEA significantly reduces the computational burden and is easier to solve than the primal.

$$\begin{aligned}
\text{Min} \quad & \theta - \varepsilon \left[\sum_{i=1}^m s_i^- + \sum_{r=1}^s s_r^+ \right] \\
\text{subject to:} \quad & \\
& \theta x_{i0} - \sum_{j=1}^n x_{ij} \lambda_j - s_i^- = 0 \\
& y_{r0} = \sum_{j=1}^n y_{rj} \lambda_j - s_r^+ \\
& \lambda_j \geq 0, \quad s_r^+ \geq 0, \quad s_i^- \geq 0 \\
& i = 1, \dots, m, \quad r = 1, \dots, s, \quad j = 1, \dots, n
\end{aligned} \tag{A.4}$$

More importantly, the duality theorem of linear programming states that the solution value to the objective function in (A.4) is exactly equal to that in (A.3). And, the dual variables, $(\lambda_1, \lambda_2, \dots, \lambda_n)$, have the interpretation of Lagrange multipliers. That is, the value of a dual variable is equal to the shadow price of Lagrange Multiplier. It is also known that, from constrained optimization problem, $\lambda_j > 0$ normally when the constraint in (A.3') is binding and $\lambda_j = 0$ if not. Note that the binding constraint in (A.3) implies that the corresponding DMU is efficient. In another word, efficient units are identified by positive λ 's while inefficient units are given λ 's of zero. The DMU in question in model (A.4) is thus compared with the efficient DMUs only, named as comparison *peers* in the literature. The solution values of λ 's reflect the exact weights assigned to each peer in the evaluation of DMU₀.

Since only efficient DMUs exert effective constraints in model (A.4), as argued above, the input-output bundle, $(\sum_{j=1}^n x_{ij} \lambda_j, \sum_{j=1}^n y_{rj} \lambda_j)$, is the most efficient combination for $i = 1, \dots, m$ and $r = 1, \dots, s$. To achieve an output level y_{r0} , which is as close as possible to $\sum_{j=1}^n y_{rj} \lambda_j$, DMU₀ has to use an input bundle to meet the minimum requirement, $\sum_{j=1}^n x_{ij} \lambda_j$. This further implies that the solution θ^* is the lowest proportion of the current input bundle, x_{i0} used by DMU₀, that is actually required to meet the minimum input requirement and produce target output y_{r0} . The solution θ^* is defined as the efficiency score for DMU₀. For instance, $\theta^* = 0.60$ implies that 40 percent of current input is a waste of resources.

Model (A.4) also offers the explanation why the data envelopment analysis is so named. The first constraint in (A.4) defines a lower limit of inputs and the second constraint an upper limit of outputs for DMU₀, and within the limits θ is minimized. The set of solutions to all DMUs forms an upper bound that envelops all observations.

Appendix B.
Table B.1 Efficiency Score for Selected Education Indicators

Country	Primary School Enrollment				Secondary School Enrollment			
	<i>Input Efficiency</i>		<i>Output Efficiency</i>		<i>Input Efficiency</i>		<i>Output Efficiency</i>	
	FDH	DEA	FDH	DEA	FDH	DEA	FDH	DEA
AGO	0.702	0.702	0.502	0.490	0.702	0.702	0.157	0.132
ARG	0.813	0.761	0.838	0.838	0.726	0.651	0.922	0.711
ARM	0.707	0.707	0.703	0.690	0.707	0.707	0.883	0.746
AZE	0.709	0.690	0.729	0.695	0.682	0.682	0.793	0.650
BDI	0.665	0.665	0.410	0.410	0.665	0.665	0.087	0.070
BEN	0.678	0.678	0.668	0.635	0.678	0.678	0.217	0.177
BFA	0.700	0.700	0.324	0.315	0.700	0.700	0.098	0.082
BGD	0.727	0.702	0.722	0.702	0.699	0.699	0.404	0.338
BGR	0.883	0.807	0.857	0.809	0.769	0.769	0.932	0.809
BHR	0.999	0.907	0.915	0.901	0.999	0.941	0.998	0.954
BHS	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
BLR	0.692	0.663	0.766	0.766	0.603	0.603	0.667	0.667
BLZ	0.747	0.707	0.846	0.846	0.581	0.581	0.496	0.496
BOL	0.732	0.712	0.794	0.794	0.626	0.626	0.549	0.549
BRA	1.000	1.000	1.000	1.000	0.779	0.709	0.932	0.761
BRB	0.460	0.433	0.752	0.752	0.636	0.472	0.786	0.786
BWA	0.494	0.463	0.747	0.747	0.430	0.430	0.551	0.551
CAF	0.697	0.697	0.500	0.485	0.697	0.697	0.097	0.081
CHL	0.842	0.776	0.866	0.782	0.733	0.733	0.813	0.707
CHN	1.000	0.949	1.000	0.953	0.778	0.778	0.693	0.607
CIV	0.656	0.656	0.538	0.538	0.656	0.656	0.234	0.186
CMR	0.699	0.699	0.708	0.689	0.699	0.699	0.284	0.238
COG	0.715	0.715	0.607	0.601	0.715	0.715	0.423	0.361
COL	0.768	0.754	0.801	0.801	0.657	0.657	0.692	0.550
COM	0.668	0.668	0.585	0.585	0.668	0.668	0.251	0.202
CPV	0.910	0.902	0.942	0.942	0.659	0.659	0.620	0.495
CRI	0.703	0.670	0.761	0.761	0.612	0.612	0.426	0.426
CZE	0.719	0.670	0.743	0.743	0.626	0.626	0.680	0.680
DJI	0.680	0.680	0.292	0.278	0.680	0.680	0.170	0.139
DMA	0.561	0.556	0.710	0.710	0.620	0.550	0.702	0.702
DOM	1.000	1.000	1.000	1.000	0.856	0.856	0.609	0.574
DZA	0.723	0.698	0.772	0.772	0.629	0.629	0.519	0.519
ERI	0.671	0.671	0.404	0.404	0.671	0.671	0.251	0.203
EST	0.478	0.476	0.717	0.717	0.731	0.586	0.835	0.835
ETH	0.661	0.661	0.383	0.383	0.661	0.661	0.156	0.125
FJI	0.741	0.690	0.835	0.835	0.577	0.577	0.596	0.596
GAB	1.000	1.000	1.000	1.000	0.724	0.724	0.487	0.419
GEO	0.711	0.711	0.708	0.697	0.711	0.711	0.763	0.647
GHA	0.666	0.666	0.564	0.564	0.666	0.666	0.363	0.292
GIN	0.726	0.726	0.507	0.469	0.726	0.726	0.136	0.118
GMB	0.677	0.677	0.566	0.566	0.677	0.677	0.320	0.261
GNB	0.686	0.686	0.516	0.495	0.686	0.686	0.145	0.120

Table B.1 (continued)

Country	Primary School Enrollment				Secondary School Enrollment			
	<i>Input Efficiency</i>		<i>Output Efficiency</i>		<i>Input Efficiency</i>		<i>Output Efficiency</i>	
	FDH	DEA	FDH	DEA	FDH	DEA	FDH	DEA
GRD	0.651	0.651	0.678	0.678	0.651	0.651	0.633	0.500
GTM	0.857	0.829	0.840	0.812	0.824	0.824	0.324	0.297
GUY	0.758	0.740	0.796	0.796	0.649	0.649	0.826	0.650
HND	0.762	0.731	0.767	0.767	0.663	0.663	0.323	0.259
HRV	0.657	0.657	0.669	0.669	0.657	0.657	0.878	0.699
HUN	0.696	0.642	0.735	0.735	0.826	0.681	0.757	0.757
IDN	0.913	0.900	0.966	0.904	0.795	0.795	0.593	0.528
IND	0.709	0.702	0.747	0.713	0.682	0.682	0.478	0.392
IRN	0.625	0.625	0.677	0.677	0.625	0.625	0.634	0.634
JAM	0.599	0.591	0.708	0.708	0.576	0.576	0.622	0.622
JOR	0.583	0.583	0.679	0.679	0.583	0.583	0.613	0.613
KAZ	0.708	0.687	0.726	0.692	0.681	0.681	0.894	0.733
KEN	0.631	0.631	0.643	0.643	0.631	0.631	0.296	0.228
KGZ	0.775	0.713	0.733	0.733	0.675	0.675	0.843	0.686
KHM	0.827	0.809	0.824	0.821	0.720	0.720	0.212	0.182
KNA	0.809	0.759	0.840	0.840	1.000	1.000	1.000	1.000
KOR	0.762	0.741	0.815	0.736	1.000	0.839	1.000	0.870
KWT	0.406	0.406	0.645	0.645	0.406	0.406	0.666	0.666
LAO	0.897	0.817	0.861	0.837	0.698	0.698	0.347	0.291
LBN	0.880	0.840	0.900	0.846	0.766	0.766	0.840	0.726
LCA	0.573	0.565	0.805	0.805	0.490	0.490	0.642	0.642
LKA	0.852	0.835	0.926	0.845	0.742	0.742	0.808	0.681
LSO	0.602	0.594	0.807	0.807	0.515	0.515	0.248	0.248
LTU	0.710	0.647	0.725	0.725	0.710	0.654	0.722	0.722
LVA	0.548	0.541	0.707	0.707	0.527	0.527	0.684	0.684
MAC	1.000	1.000	1.000	1.000	0.962	0.962	0.889	0.863
MAR	0.628	0.628	0.679	0.679	0.628	0.628	0.304	0.304
MDA	0.613	0.613	0.626	0.626	0.613	0.613	0.572	0.572
MDG	0.708	0.697	0.742	0.707	0.680	0.680	0.152	0.124
MEX	0.752	0.740	0.802	0.802	0.644	0.644	0.700	0.548
MKD	0.766	0.694	0.722	0.722	0.667	0.667	0.798	0.643
MLI	0.679	0.679	0.382	0.363	0.679	0.679	0.128	0.104
MNG	0.655	0.634	0.688	0.688	0.630	0.630	0.647	0.497
MOZ	0.682	0.682	0.629	0.601	0.682	0.682	0.108	0.088
MRT	0.677	0.677	0.603	0.603	0.677	0.677	0.197	0.161
MUS	0.792	0.759	0.806	0.776	0.690	0.690	0.738	0.611
MWI	0.911	0.901	0.941	0.941	0.660	0.660	0.175	0.140
MYS	0.530	0.523	0.707	0.707	0.509	0.509	0.526	0.526
NAM	0.572	0.531	0.832	0.832	0.446	0.446	0.469	0.469
NER	0.680	0.680	0.249	0.237	0.680	0.680	0.067	0.055
NIC	0.773	0.712	0.734	0.734	0.673	0.673	0.526	0.427
NPL	0.871	0.807	0.830	0.830	0.678	0.678	0.401	0.328
OMN	0.742	0.742	0.692	0.632	0.742	0.742	0.763	0.643

Table B.1 (continued)

Country	Primary School Enrollment				Secondary School Enrollment			
	<i>Input Efficiency</i>		<i>Output Efficiency</i>		<i>Input Efficiency</i>		<i>Output Efficiency</i>	
	FDH	DEA	FDH	DEA	FDH	DEA	FDH	DEA
PAK	0.712	0.712	0.528	0.522	0.712	0.712	0.261	0.222
PAN	0.701	0.678	0.774	0.774	0.610	0.610	0.527	0.527
PER	1.000	0.919	1.000	0.926	0.727	0.727	0.775	0.670
PHL	0.890	0.810	0.860	0.831	0.692	0.692	0.789	0.655
PNG	0.732	0.732	0.654	0.590	0.732	0.732	0.205	0.178
POL	0.554	0.549	0.710	0.710	0.727	0.608	0.766	0.766
PRY	0.747	0.732	0.800	0.800	0.639	0.639	0.555	0.432
ROM	0.821	0.758	0.774	0.767	0.715	0.715	0.806	0.687
RUS	0.852	0.837	0.945	0.849	0.729	0.729	0.875	0.758
RWA	0.800	0.792	0.851	0.815	0.685	0.685	0.130	0.107
SAU	0.414	0.414	0.504	0.504	0.414	0.414	0.519	0.519
SDN	0.616	0.616	0.398	0.398	0.616	0.616	0.220	0.220
SEN	0.663	0.663	0.513	0.513	0.663	0.663	0.171	0.137
SLB	0.708	0.690	0.731	0.696	0.680	0.680	0.181	0.148
SLE	0.684	0.684	0.492	0.470	0.684	0.684	0.167	0.137
SLV	0.902	0.858	0.930	0.861	0.785	0.785	0.518	0.457
SVK	0.752	0.692	0.733	0.733	0.655	0.655	0.881	0.699
SWZ	0.666	0.642	0.771	0.771	0.580	0.580	0.387	0.387
SYR	0.792	0.748	0.794	0.764	0.690	0.690	0.428	0.354
TCD	0.686	0.686	0.510	0.489	0.686	0.686	0.107	0.088
TGO	0.901	0.834	0.885	0.885	0.653	0.653	0.328	0.259
THA	0.605	0.605	0.667	0.667	0.605	0.605	0.513	0.513
TJK	0.784	0.724	0.775	0.740	0.683	0.683	0.790	0.649
TON	0.675	0.662	0.801	0.801	0.788	0.659	0.766	0.766
TTO	0.810	0.743	0.769	0.753	0.705	0.705	0.785	0.662
TUN	0.643	0.590	0.824	0.824	0.500	0.500	0.565	0.565
TUR	0.746	0.725	0.728	0.723	0.717	0.717	0.677	0.579
TZA	0.676	0.676	0.467	0.467	0.676	0.676	0.059	0.048
UGA	0.949	0.869	0.921	0.886	0.690	0.690	0.129	0.107
UKR	0.659	0.659	0.585	0.585	0.899	0.724	0.968	0.772
URY	1.000	0.986	1.000	0.985	1.000	0.945	1.000	0.957
UZB	0.612	0.612	0.655	0.655	0.835	0.678	0.748	0.748
VCT	0.581	0.532	0.728	0.728	0.506	0.506	0.548	0.548
VNM	0.813	0.794	0.823	0.808	0.708	0.708	0.638	0.540
VUT	0.603	0.578	0.766	0.766	0.525	0.525	0.203	0.203
WSM	0.675	0.671	0.716	0.716	0.649	0.649	0.729	0.574
YEM	0.627	0.627	0.544	0.544	0.627	0.627	0.324	0.324
ZAF	0.621	0.577	0.833	0.833	0.555	0.484	0.693	0.693
ZMB	0.682	0.682	0.610	0.582	0.682	0.682	0.259	0.212
ZWE	0.549	0.510	0.741	0.741	0.478	0.478	0.344	0.344

Table B.2. Efficiency Score for Selected Education Indicator - Learning scores
– Excluding Developed Countries

Country	Learning	<i>Input Efficiency</i>		<i>Output Efficiency</i>		Country	Learning	<i>Input Efficiency</i>		<i>Output Efficiency</i>	
	Score	FDH	DEA	FDH	DEA		Score	FDH	DEA	FDH	DEA
HUN	542	1.000	1.000	1.000	1.000	HND	396	0.294	0.294	0.731	0.731
SVK	535	1.000	1.000	1.000	1.000	PER	392	0.525	0.525	0.742	0.733
CZE	530	0.972	0.800	0.991	0.990	VUT	375	0.152	0.152	0.692	0.692
RUS	528	1.000	1.000	1.000	1.000	KEN	349	0.232	0.232	0.644	0.644
BGR	515	1.000	1.000	1.000	1.000	PHL	345	0.382	0.382	0.645	0.639
MYS	506	0.169	0.169	0.934	0.934	MUS	342	0.606	0.606	0.648	0.644
LVA	504	0.178	0.177	0.930	0.930	BLZ	335	0.216	0.216	0.618	0.618
POL	504	0.198	0.198	0.930	0.930	MAR	334	0.255	0.255	0.616	0.616
LTU	485	0.321	0.319	0.895	0.895	ZWE	331	0.122	0.122	0.611	0.611
THA	475	0.265	0.262	0.876	0.876	TZA	329	0.282	0.282	0.607	0.607
ROM	472	0.552	0.547	0.894	0.884	CMR	322	0.345	0.345	0.594	0.594
MDA	464	0.220	0.218	0.856	0.856	MOZ	318	0.297	0.297	0.587	0.587
MEX	455	0.382	0.377	0.850	0.842	SWZ	317	0.206	0.206	0.585	0.585
TTO	454	0.652	0.644	0.860	0.857	MDG	315	0.293	0.293	0.581	0.581
MKD	453	0.386	0.381	0.847	0.838	UGA	309	0.315	0.315	0.570	0.570
JOR	439	0.211	0.208	0.810	0.810	BWA	288	0.107	0.107	0.531	0.531
TUN	437	0.150	0.148	0.806	0.806	BFA	277	0.329	0.329	0.511	0.511
IRN	435	0.289	0.284	0.803	0.803	CIV	269	0.269	0.269	0.496	0.496
ARG	432	0.456	0.449	0.807	0.804	ZAF	261	0.149	0.149	0.482	0.482
TUR	431	0.565	0.556	0.816	0.809	MLI	233	0.291	0.291	0.430	0.430
BRA	428	0.456	0.448	0.800	0.797	NAM	232	0.113	0.113	0.428	0.428
IDN	419	0.826	0.811	0.814	0.804	LSO	230	0.142	0.142	0.424	0.424
CHL	407	1.000	1.000	1.000	1.000	ZMB	228	0.295	0.295	0.421	0.421
PRY	406	0.288	0.288	0.749	0.749	SEN	223	0.277	0.277	0.411	0.411
BOL	405	0.239	0.239	0.747	0.747	MWI	207	0.261	0.261	0.382	0.382
COL	400	0.354	0.354	0.748	0.739	NER	173	0.292	0.292	0.319	0.319
KWT	398	0.114	0.114	0.734	0.734						

Note: Data for learning scores are reproduced from Table 1.2. in Crouch and Fasih (2004). Sorted by learning scores.

Table B.3. Efficiency Score for Selected Education Indicator - Learning scores
– Including Developed Countries

Country	Learning	<i>Input efficiency</i>		<i>Output efficiency</i>		Country	Learning	<i>Input efficiency</i>		<i>Output efficiency</i>	
	Scores	FDH	DEA	FDH	DEA		Scores	FDH	DEA	FDH	DEA
NLD	543	1.000	1.000	1.000	1.000	IRN	435	0.747	0.747	0.801	0.801
HUN	542	0.918	0.916	0.998	0.998	ARG	432	0.814	0.814	0.796	0.796
SVK	535	0.956	0.936	0.985	0.985	TUR	431	0.806	0.806	0.794	0.794
AUS	533	0.987	0.961	0.982	0.982	BRA	428	0.795	0.795	0.788	0.788
AUT	533	0.755	0.735	0.982	0.982	IDN	419	0.815	0.815	0.772	0.772
CAN	532	0.818	0.794	0.980	0.980	CHL	407	0.850	0.850	0.750	0.750
CHE	531	0.807	0.781	0.978	0.978	PRY	406	0.745	0.745	0.748	0.748
CZE	530	0.967	0.933	0.976	0.976	BOL	405	0.716	0.716	0.746	0.746
SWE	529	0.555	0.534	0.974	0.974	COL	400	0.771	0.771	0.737	0.737
FIN	528	0.682	0.654	0.972	0.972	KWT	398	0.636	0.636	0.733	0.733
RUS	528	0.957	0.918	0.972	0.972	DOM	397	0.877	0.877	0.768	0.741
GBR	517	1.000	0.972	1.000	0.981	HND	396	0.740	0.740	0.729	0.729
BGR	515	0.931	0.899	0.948	0.948	PER	392	0.797	0.797	0.722	0.722
FRA	515	0.724	0.699	0.948	0.948	VUT	375	0.655	0.655	0.691	0.691
DEU	514	0.991	0.955	0.994	0.969	KEN	349	0.708	0.708	0.643	0.643
USA	509	0.888	0.842	0.937	0.937	PHL	345	0.769	0.769	0.635	0.635
MYS	506	0.760	0.715	0.932	0.932	MUS	342	0.826	0.826	0.630	0.630
ESP	505	0.977	0.917	0.977	0.943	BLZ	335	0.712	0.712	0.617	0.617
LVA	504	0.765	0.715	0.928	0.928	MAR	334	0.727	0.727	0.615	0.615
POL	504	0.790	0.739	0.928	0.928	ZWE	331	0.617	0.617	0.610	0.610
NZL	501	0.648	0.601	0.923	0.923	TZA	329	0.728	0.728	0.606	0.606
NOR	500	0.486	0.449	0.921	0.921	CMR	322	0.753	0.753	0.593	0.593
ISL	499	0.674	0.620	0.919	0.919	MOZ	318	0.735	0.735	0.586	0.586
DNK	493	0.451	0.407	0.908	0.908	SWZ	317	0.703	0.703	0.584	0.584
GRC	491	1.000	1.000	1.000	1.000	MDG	315	0.733	0.733	0.580	0.580
ITA	486	0.876	0.876	0.940	0.906	UGA	309	0.742	0.742	0.569	0.569
LTU	485	0.768	0.768	0.893	0.893	BWA	288	0.603	0.603	0.530	0.530
THA	475	0.739	0.739	0.875	0.875	BFA	277	0.746	0.746	0.510	0.510
PRT	474	0.663	0.663	0.873	0.873	CIV	269	0.727	0.727	0.495	0.495
ROM	472	0.804	0.804	0.869	0.869	ZAF	261	0.668	0.668	0.481	0.481
CYP	468	0.674	0.674	0.862	0.862	MLI	233	0.732	0.732	0.429	0.429
ISR	467	0.498	0.498	0.860	0.860	NAM	232	0.610	0.610	0.427	0.427
MDA	464	0.700	0.700	0.855	0.855	LSO	230	0.641	0.641	0.424	0.424
MEX	455	0.785	0.785	0.838	0.838	ZMB	228	0.734	0.734	0.420	0.420
TTO	454	0.825	0.825	0.836	0.836	SEN	223	0.730	0.730	0.411	0.411
MKD	453	0.777	0.777	0.834	0.834	MWI	207	0.720	0.720	0.381	0.381
JOR	439	0.702	0.702	0.808	0.808	NER	173	0.733	0.733	0.319	0.319
TUN	437	0.657	0.657	0.805	0.805						

Note: Data for learning scores are reproduced from Table 1.2. in Crouch and Fasih (2004). Sorted by learning scores.

Table B.4 Efficiency Score for Selected Health Indicators

Country	Life Expectancy at Birth				Immunization DPT			
	<i>Input Efficiency</i>		<i>Output Efficiency</i>		<i>Input Efficiency</i>		<i>Output Efficiency</i>	
	FDH	DEA	FDH	DEA	FDH	DEA	FDH	DEA
AGO	0.671	0.671	0.609	0.607	0.671	0.671	0.368	0.368
ALB	0.697	0.697	0.955	0.953	0.826	0.792	0.984	0.984
ARE	1.000	1.000	1.000	1.000	0.956	0.942	0.983	0.967
ARG	0.527	0.492	0.955	0.955	0.478	0.478	0.811	0.811
ARM	0.712	0.663	0.963	0.959	0.681	0.651	0.906	0.906
ATG	0.744	0.736	0.980	0.978	0.800	0.794	0.997	0.997
AZE	0.724	0.724	0.862	0.861	0.857	0.822	0.984	0.984
BDI	0.638	0.638	0.549	0.547	0.638	0.638	0.746	0.746
BEN	0.649	0.649	0.693	0.690	0.649	0.649	0.737	0.737
BFA	0.647	0.647	0.580	0.577	0.647	0.647	0.405	0.405
BGD	0.672	0.672	0.798	0.795	0.672	0.672	0.821	0.821
BGR	0.619	0.619	0.931	0.926	0.652	0.650	0.954	0.954
BHR	0.736	0.736	0.955	0.954	0.872	0.834	0.983	0.983
BHS	0.755	0.755	0.907	0.906	0.795	0.770	0.921	0.921
BLR	0.560	0.560	0.892	0.886	0.664	0.659	0.997	0.997
BLZ	0.797	0.749	0.966	0.964	0.723	0.723	0.893	0.893
BOL	0.633	0.633	0.816	0.812	0.633	0.633	0.714	0.714
BRA	0.672	0.672	0.888	0.886	0.672	0.672	0.892	0.892
BRB	0.721	0.632	0.987	0.979	0.556	0.556	0.899	0.899
BWA	0.626	0.626	0.535	0.533	0.741	0.695	0.975	0.975
CAF	0.649	0.649	0.571	0.569	0.649	0.649	0.436	0.436
CHL	0.964	0.879	0.990	0.990	0.881	0.787	0.958	0.958
CHN	0.717	0.717	0.917	0.916	0.717	0.717	0.890	0.890
CIV	0.679	0.679	0.600	0.598	0.679	0.679	0.605	0.605
CMR	0.694	0.694	0.661	0.659	0.694	0.694	0.482	0.482
COG	0.648	0.648	0.670	0.667	0.648	0.648	0.317	0.317
COL	0.623	0.623	0.931	0.927	0.623	0.623	0.773	0.773
COM	0.664	0.664	0.792	0.790	0.664	0.664	0.701	0.701
CPV	0.643	0.643	0.898	0.895	0.643	0.643	0.805	0.805
CRI	1.000	1.000	1.000	1.000	0.528	0.528	0.899	0.899
CZE	0.386	0.372	0.964	0.964	0.414	0.402	0.988	0.988
DJI	0.612	0.612	0.610	0.607	0.612	0.612	0.404	0.404
DMA	0.749	0.728	0.997	0.990	0.684	0.682	0.999	0.999
DOM	0.776	0.776	0.895	0.881	0.776	0.776	0.688	0.688
DZA	0.696	0.696	0.920	0.918	0.734	0.700	0.905	0.905
ECU	0.694	0.694	0.909	0.907	0.694	0.694	0.861	0.861
EGY	0.715	0.715	0.884	0.883	0.753	0.747	0.948	0.948
ERI	0.626	0.626	0.666	0.662	0.626	0.626	0.825	0.825
EST	0.515	0.515	0.910	0.910	0.543	0.541	0.952	0.952
ETH	0.644	0.644	0.556	0.554	0.644	0.644	0.482	0.482
FJI	0.702	0.702	0.902	0.900	0.740	0.706	0.905	0.905
GAB	0.804	0.804	0.700	0.691	0.804	0.804	0.452	0.452
GEO	0.689	0.689	0.954	0.951	0.689	0.689	0.824	0.824

Table B.4 (continued)

Country	Life Expectancy at Birth				Immunization DPT			
	<i>Input Efficiency</i>		<i>Output Efficiency</i>		<i>Input Efficiency</i>		<i>Output Efficiency</i>	
	FDH	DEA	FDH	DEA	FDH	DEA	FDH	DEA
GHA	0.657	0.657	0.749	0.746	0.657	0.657	0.765	0.765
GIN	0.671	0.671	0.605	0.604	0.671	0.671	0.470	0.470
GMB	0.636	0.636	0.696	0.693	0.670	0.655	0.932	0.932
GNB	0.632	0.632	0.585	0.583	0.632	0.632	0.495	0.495
GRD	0.647	0.647	0.946	0.943	0.681	0.671	0.939	0.939
GTM	0.714	0.714	0.848	0.847	0.714	0.714	0.788	0.788
GUY	0.600	0.600	0.823	0.818	0.600	0.600	0.877	0.877
HND	0.645	0.645	0.862	0.859	0.764	0.683	0.958	0.958
HRV	0.380	0.380	0.945	0.945	0.400	0.394	0.939	0.939
HTI	0.647	0.647	0.690	0.688	0.647	0.647	0.431	0.431
HUN	0.450	0.450	0.921	0.921	0.533	0.533	1.000	1.000
IDN	0.770	0.770	0.862	0.861	0.770	0.770	0.749	0.749
IND	0.718	0.718	0.821	0.820	0.718	0.718	0.633	0.633
IRN	0.740	0.740	0.898	0.897	0.877	0.857	0.991	0.991
JAM	0.835	0.711	0.984	0.980	0.644	0.644	0.886	0.886
JOR	0.585	0.585	0.934	0.928	0.693	0.634	0.967	0.967
KAZ	0.725	0.725	0.838	0.836	0.858	0.807	0.977	0.977
KEN	0.648	0.648	0.621	0.618	0.648	0.648	0.820	0.820
KGZ	0.654	0.654	0.869	0.866	0.774	0.754	0.990	0.990
KHM	0.678	0.678	0.704	0.702	0.678	0.678	0.518	0.518
KNA	0.708	0.708	0.924	0.923	0.838	0.832	0.997	0.997
KOR	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
KWT	1.000	1.000	1.000	1.000	0.914	0.863	0.978	0.978
LAO	0.666	0.666	0.700	0.698	0.666	0.666	0.544	0.544
LBN	0.712	0.712	0.919	0.918	0.750	0.737	0.937	0.937
LCA	0.694	0.694	0.940	0.938	0.694	0.694	0.874	0.874
LKA	0.715	0.715	0.952	0.951	0.847	0.800	0.978	0.978
LSO	0.600	0.600	0.548	0.545	0.600	0.600	0.843	0.843
LTU	0.546	0.546	0.938	0.930	0.575	0.566	0.939	0.939
LVA	0.617	0.617	0.915	0.911	0.731	0.655	0.960	0.960
MAR	0.739	0.739	0.883	0.882	0.779	0.775	0.951	0.951
MDA	0.621	0.621	0.875	0.871	0.736	0.662	0.961	0.961
MDG	0.646	0.646	0.713	0.710	0.646	0.646	0.540	0.540
MEX	0.758	0.758	0.955	0.954	0.898	0.812	0.962	0.962
MKD	0.501	0.501	0.941	0.941	0.527	0.525	0.952	0.952
MLI	0.644	0.644	0.554	0.552	0.644	0.644	0.496	0.496
MNG	0.615	0.615	0.850	0.846	0.647	0.643	0.949	0.949
MOZ	0.625	0.625	0.562	0.559	0.625	0.625	0.606	0.606
MRT	0.651	0.651	0.663	0.660	0.651	0.651	0.439	0.439
MUS	0.936	0.936	0.973	0.955	0.936	0.936	0.937	0.932
MWI	0.627	0.627	0.510	0.508	0.627	0.627	0.853	0.853
MYS	0.949	0.949	0.989	0.975	1.000	1.000	1.000	1.000
NAM	0.543	0.543	0.628	0.623	0.543	0.543	0.723	0.723

Table B.4 (continued)

Country	Life Expectancy at Birth				Immunization DPT			
	<i>Input Efficiency</i>		<i>Output Efficiency</i>		<i>Input Efficiency</i>		<i>Output Efficiency</i>	
	FDH	DEA	FDH	DEA	FDH	DEA	FDH	DEA
NER	0.646	0.646	0.591	0.589	0.646	0.646	0.264	0.264
NGA	0.659	0.659	0.620	0.617	0.659	0.659	0.290	0.290
NIC	0.628	0.628	0.895	0.891	0.661	0.634	0.909	0.909
NPL	0.658	0.658	0.767	0.764	0.658	0.658	0.733	0.733
OMN	0.931	0.858	0.976	0.970	1.000	1.000	1.000	1.000
PAK	0.693	0.693	0.821	0.819	0.693	0.693	0.582	0.582
PAN	0.579	0.559	0.965	0.965	0.553	0.553	0.955	0.955
PER	0.700	0.700	0.905	0.903	0.737	0.710	0.915	0.915
PHL	0.748	0.748	0.904	0.904	0.748	0.748	0.769	0.769
PNG	0.628	0.628	0.748	0.744	0.628	0.628	0.541	0.541
POL	0.550	0.550	0.954	0.946	0.651	0.634	0.990	0.990
PRY	0.676	0.676	0.918	0.916	0.676	0.676	0.723	0.723
ROM	0.558	0.558	0.908	0.902	0.661	0.644	0.990	0.990
RUS	0.617	0.617	0.864	0.860	0.650	0.635	0.931	0.931
RWA	0.636	0.636	0.523	0.521	0.636	0.636	0.847	0.847
SAU	0.615	0.615	0.946	0.941	0.648	0.645	0.951	0.951
SDN	0.685	0.685	0.749	0.747	0.685	0.685	0.473	0.473
SEN	0.640	0.640	0.684	0.681	0.640	0.640	0.582	0.582
SLB	0.607	0.607	0.894	0.890	0.607	0.607	0.801	0.801
SLE	0.635	0.635	0.488	0.486	0.635	0.635	0.449	0.449
SLV	0.634	0.634	0.912	0.908	0.668	0.664	0.949	0.949
SVK	0.464	0.464	0.944	0.944	0.549	0.549	1.000	1.000
SVN	0.380	0.375	0.971	0.971	0.363	0.357	0.939	0.939
SWZ	0.710	0.710	0.631	0.630	0.710	0.710	0.804	0.804
SYR	0.699	0.699	0.910	0.908	0.736	0.735	0.955	0.955
TCD	0.642	0.642	0.633	0.631	0.642	0.642	0.264	0.264
TGO	0.660	0.660	0.644	0.641	0.660	0.660	0.564	0.564
THA	0.786	0.786	0.913	0.900	0.931	0.859	0.970	0.970
TJK	0.650	0.650	0.884	0.881	0.650	0.650	0.827	0.827
TKM	0.639	0.639	0.851	0.848	0.757	0.726	0.984	0.984
TON	0.655	0.655	0.927	0.924	0.776	0.696	0.960	0.960
TTO	0.883	0.883	0.964	0.962	0.930	0.903	0.965	0.939
TUN	0.547	0.547	0.942	0.934	0.648	0.598	0.970	0.970
TUR	0.627	0.627	0.908	0.904	0.627	0.627	0.811	0.811
TZA	0.634	0.634	0.589	0.587	0.634	0.634	0.821	0.821
UGA	0.647	0.647	0.556	0.554	0.647	0.647	0.586	0.586
UKR	0.650	0.650	0.887	0.884	0.770	0.767	0.999	0.999
URY	0.570	0.540	0.959	0.959	0.544	0.531	0.929	0.929
UZB	0.639	0.639	0.889	0.885	0.757	0.726	0.984	0.984
VCT	0.613	0.613	0.953	0.948	0.725	0.715	0.994	0.994
VEN	0.724	0.661	0.958	0.954	0.657	0.657	0.633	0.633
VNM	0.681	0.681	0.901	0.899	0.717	0.701	0.931	0.931
VUT	0.683	0.683	0.889	0.887	0.683	0.683	0.807	0.807

Table B.4 (continued)

Country	Life Expectancy at Birth				Immunization DPT			
	<i>Input Efficiency</i>		<i>Output Efficiency</i>		<i>Input Efficiency</i>		<i>Output Efficiency</i>	
	FDH	DEA	FDH	DEA	FDH	DEA	FDH	DEA
WSM	0.582	0.582	0.902	0.896	0.689	0.646	0.975	0.975
YEM	0.646	0.646	0.736	0.733	0.646	0.646	0.662	0.662
ZAF	0.620	0.620	0.645	0.642	0.620	0.620	0.784	0.784
ZAR	0.648	0.648	0.599	0.597	0.648	0.648	0.280	0.280
ZMB	0.629	0.629	0.511	0.509	0.629	0.629	0.811	0.811
ZWE	0.595	0.595	0.535	0.532	0.595	0.595	0.791	0.791

Table B.5. List of Countries

Code	Region	Country	Code	Region	Country	Code	Region	Country
AGO	AFR	Angola	GMB	AFR	Gambia, The	OMN	MNA	Oman
ALB	ECA	Albania	GNB	AFR	Guinea-Bissau	PAK	SAS	Pakistan
ARE	MNA	United Arab Emirates	GRD	LAC	Grenada	PAN	LAC	Panama
ARG	LAC	Argentina	GTM	LAC	Guatemala	PER	LAC	Peru
ARM	ECA	Armenia	GUY	LAC	Guyana	PHL	EAP	Philippines
ATG	LAC	Antigua and Barbuda	HND	LAC	Honduras	PNG	EAP	Papua New Guinea
AZE	ECA	Azerbaijan	HRV	ECA	Croatia	POL	ECA	Poland
BDI	AFR	Burundi	HTI	LAC	Haiti	PRY	LAC	Paraguay
BEN	AFR	Benin	HUN	ECA	Hungary	ROM	ECA	Romania
BFA	AFR	Burkina Faso	IDN	EAP	Indonesia	RUS	ECA	Russian Federation
BGD	SAS	Bangladesh	IND	SAS	India	RWA	AFR	Rwanda
BGR	ECA	Bulgaria	IRN	MNA	Iran, Islamic Rep.	SAU	MNA	Saudi Arabia
BHR	MNA	Bahrain	JAM	LAC	Jamaica	SDN	AFR	Sudan
BHS	LAC	Bahamas, The	JOR	MNA	Jordan	SEN	AFR	Senegal
BLR	ECA	Belarus	KAZ	ECA	Kazakhstan	SLB	EAP	Solomon Islands
BLZ	LAC	Belize	KEN	AFR	Kenya	SLE	AFR	Sierra Leone
BOL	LAC	Bolivia	KGZ	ECA	Kyrgyz Republic	SLV	LAC	El Salvador
BRA	LAC	Brazil	KHM	EAP	Cambodia	SVK	ECA	Slovak Republic
BRB	LAC	Barbados	KNA	LAC	St. Kitts and Nevis	SVN	ECA	Slovenia
BWA	AFR	Botswana	KOR	EAP	Korea, Rep.	SWZ	AFR	Swaziland
CAF	AFR	Central African Rep.	KWT	MNA	Kuwait	SYR	MNA	Syrian Arab Republic
CHL	LAC	Chile	LAO	EAP	Lao PDR	TCD	AFR	Chad
CHN	EAP	China	LBN	MNA	Lebanon	TGO	AFR	Togo
CIV	AFR	Cote d'Ivoire	LCA	LAC	St. Lucia	THA	EAP	Thailand
CMR	AFR	Cameroon	LKA	SAS	Sri Lanka	TJK	ECA	Tajikistan
COG	AFR	Congo, Rep.	LSO	AFR	Lesotho	TKM	ECA	Turkmenistan
COL	LAC	Colombia	LTU	ECA	Lithuania	TON	EAP	Tonga
COM	AFR	Comoros	LVA	ECA	Latvia	TTO	LAC	Trinidad and Tobago
CPV	AFR	Cape Verde	MAR	MNA	Morocco	TUN	MNA	Tunisia
CRI	LAC	Costa Rica	MDA	ECA	Moldova	TUR	ECA	Turkey
CZE	ECA	Czech Republic	MDG	AFR	Madagascar	TZA	AFR	Tanzania
DJI	MNA	Djibouti	MEX	LAC	Mexico	UGA	AFR	Uganda
DMA	LAC	Dominica	MKD	ECA	Macedonia, FYR	UKR	ECA	Ukraine
DOM	LAC	Dominican Republic	MLI	AFR	Mali	URY	LAC	Uruguay
DZA	MNA	Algeria	MNG	EAP	Mongolia	UZB	ECA	Uzbekistan
ECU	LAC	Ecuador	MOZ	AFR	Mozambique	VCT	LAC	St. Vincent & Grenadines
EGY	MNA	Egypt, Arab Rep.	MRT	AFR	Mauritania	VEN	LAC	Venezuela, RB
ERI	AFR	Eritrea	MUS	AFR	Mauritius	VNM	EAP	Vietnam
EST	ECA	Estonia	MWI	AFR	Malawi	VUT	EAP	Vanuatu
ETH	AFR	Ethiopia	MYS	EAP	Malaysia	WSM	EAP	Samoa
FJI	EAP	Fiji	NAM	AFR	Namibia	YEM	MNA	Yemen, Rep.
GAB	AFR	Gabon	NER	AFR	Niger	ZAF	AFR	South Africa
GEO	ECA	Georgia	NGA	AFR	Nigeria	ZAR	AFR	Congo, Dem. Rep.
GHA	AFR	Ghana	NIC	LAC	Nicaragua	ZMB	AFR	Zambia
GIN	AFR	Guinea	NPL	SAS	Nepal	ZWE	AFR	Zimbabwe

Table B.5. Continued

Developed countries included in the efficiency estimation for learning scores

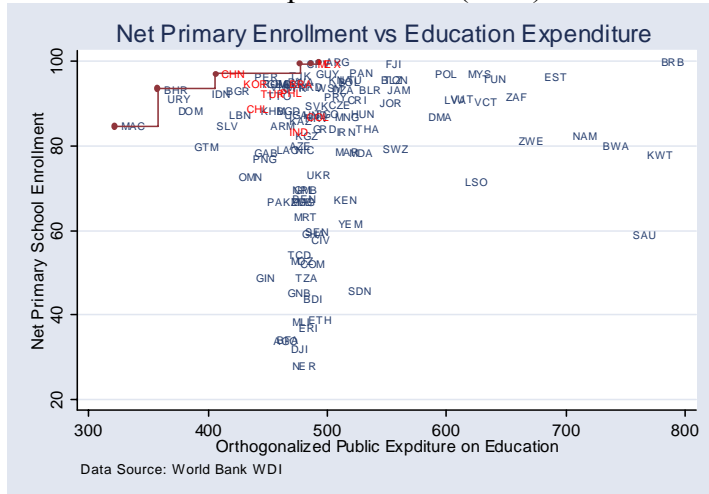
Code	Country	Code	Country	Code	Country
AUS	Australia	ESP	Spain	LUX	Luxembourg
AUT	Austria	FIN	Finland	NLD	Netherlands
CAN	Canada	FRA	France	NOR	Norway
CHE	Switzerland	GBR	United Kingdom	NZL	New Zealand
CYP	Cyprus	GRC	Greece	SWE	Sweden
DEU	Germany	ISL	Iceland	USA	United States
DNK	Denmark	ITA	Italy		

Table B.6. Definition and Source of Variables

Definition of Variable	Source
<i>Output variables for education</i>	
School enrollment, primary (% gross)	World Bank WDI
School enrollment, primary (% net)	World Bank WDI
School enrollment, secondary (% gross)	World Bank WDI
School enrollment, secondary (% net)	World Bank WDI
Literacy rate, youth total (% of people ages 15-24)	World Bank WDI
Average years of school, ages 15+	Barro-Lee Database
First level complete, ages 15+	Barro-Lee Database
second level complete, ages 15+	Barro-Lee Database
Learning scores	Crouch and Fasih (2004)
<i>Input variables for education</i>	
Public education spending per capita in PPP terms, calculated	World Bank WDI
Literacy rate, adult total (% of people ages 15 and above)	World Bank WDI
Teachers per pupil, equal the reciprocal of pupils per teacher	World Bank WDI
<i>Output variables for health</i>	
Life expectancy at birth, total (years)	World Bank WDI
Immunization, DPT (% of children ages 12-23 months)	World Bank WDI
Immunization, measles (% of children ages 12-23 months)	World Bank WDI
Disability Adjusted Life Expectancy	Mathers et al (2000)
<i>Input variables for health</i>	
Literacy rate, adult total (% of people ages 15 and above)	World Bank WDI
public spending on health per capita in PPP terms, calculated	World Bank WDI
public spending on health per capita in PPP terms, calculated	World Bank WDI
<i>Variables used in the calculation</i>	
Pupil-teacher ratio, primary	World Bank WDI
Public spending on education, total (% of GDP)	World Bank WDI
GDP per capita, PPP (constant 1995 international \$)	World Bank WDI
Health expenditure, private (% of GDP)	World Bank WDI
Health expenditure, public (% of GDP)	World Bank WDI
<i>Variables used in the Panel Tobit regression</i>	
Wages and salaries (% of total public expenditure)	World Bank WDI
Total government expenditure (% of GDP)	World Bank WDI
Share of expenditures publicly financed (public/total)	World Bank WDI
GDP per capita in constant 1995 US dollars	World Bank WDI
Urban population (% of total)	World Bank WDI
Dummy variable for HIV/AIDS	WHO mappings of diseases
Gini Coefficient	World Bank WDI
Aid (% of fiscal revenue) calculated as Official development assistance and official aid (current US\$) *official exchange rate * PPP conversion factor / Revenue, excluding grants (current LCU)	World Bank WDI
Institutional Indicators including	a. The State Failure Task Force
a. State Failure data	b. ICRG Online Website
b. ICRG International Country Risk Indicators	c. Kaufmann, <i>et al.</i> 1999a,b and 2002
c. Worldwide Governance Research Indicators	

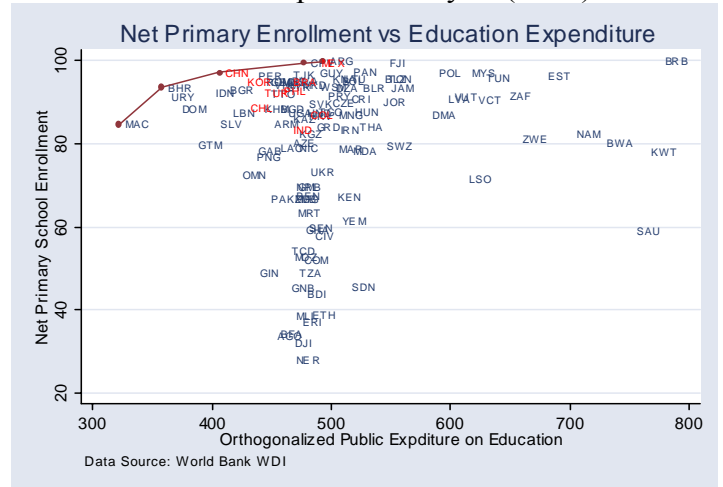
Figure B. 1. Efficiency Frontiers for Education

Free Disposable Hull (FDH)



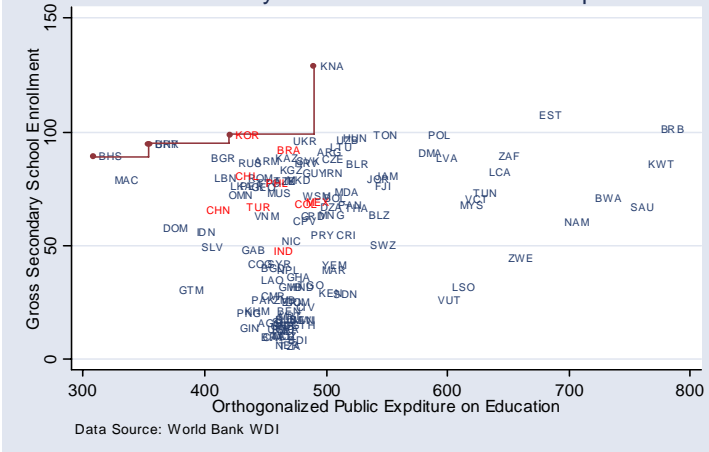
(a.1)

Data Development Analysis (DEA)



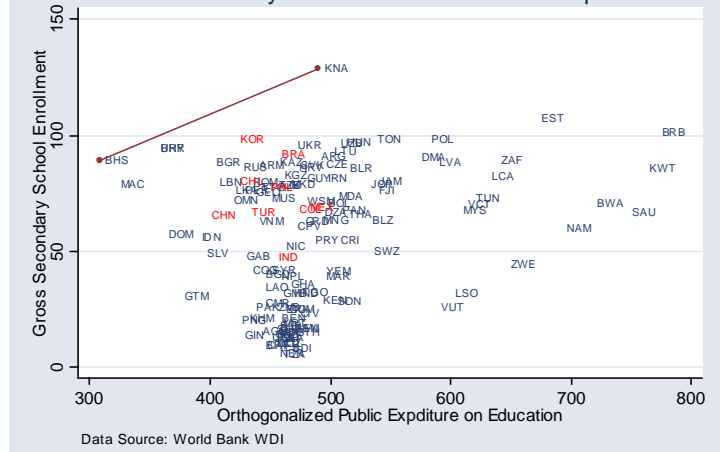
(a.2)

Gross Secondary Enrollment vs Education Expenditure



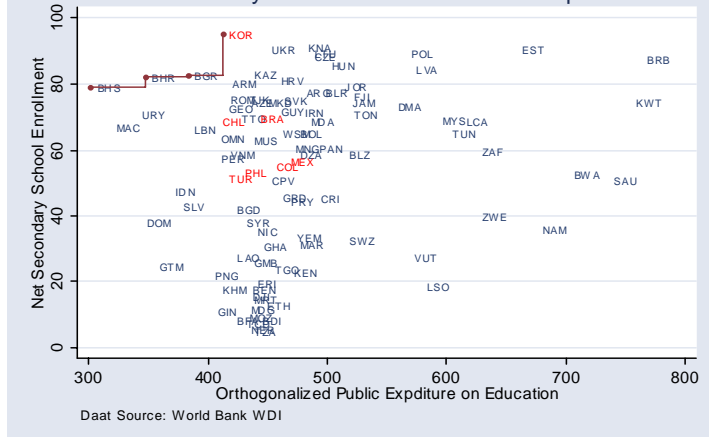
(b.1)

Gross Secondary Enrollment vs Education Expenditure



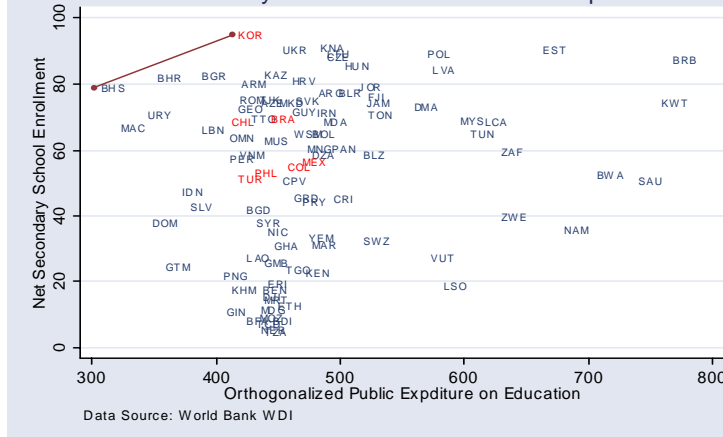
(b.2)

Net Secondary Enrollment vs Education Expenditure

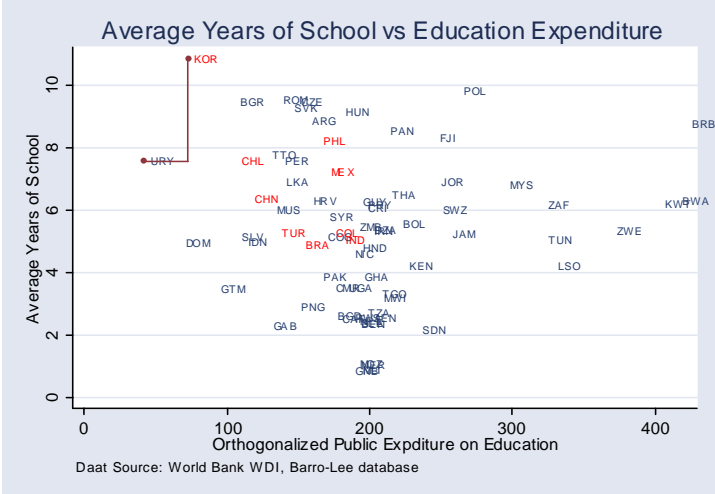


(c.1)

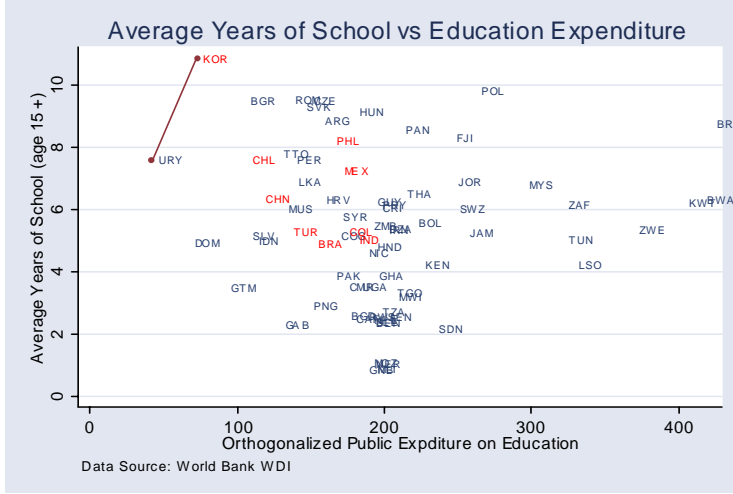
Net Secondary Enrollment vs Education Expenditure



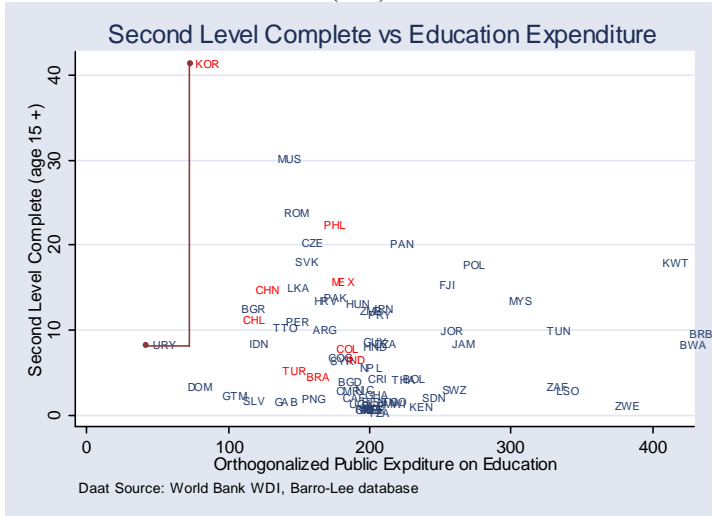
(c.2)



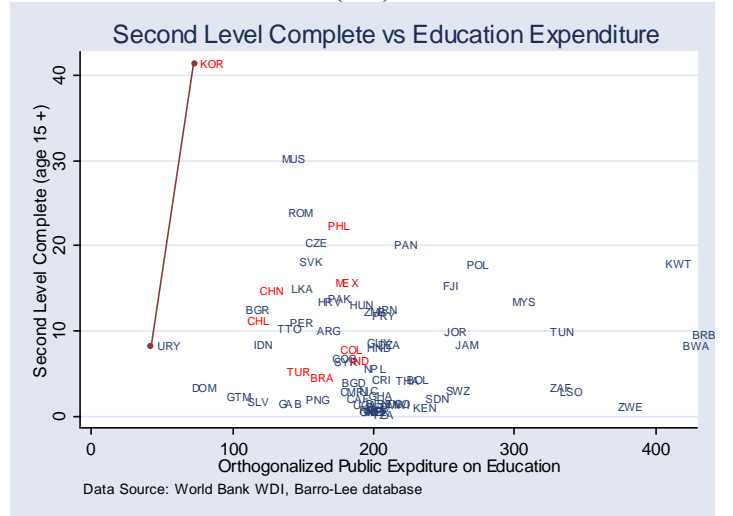
(d.1)



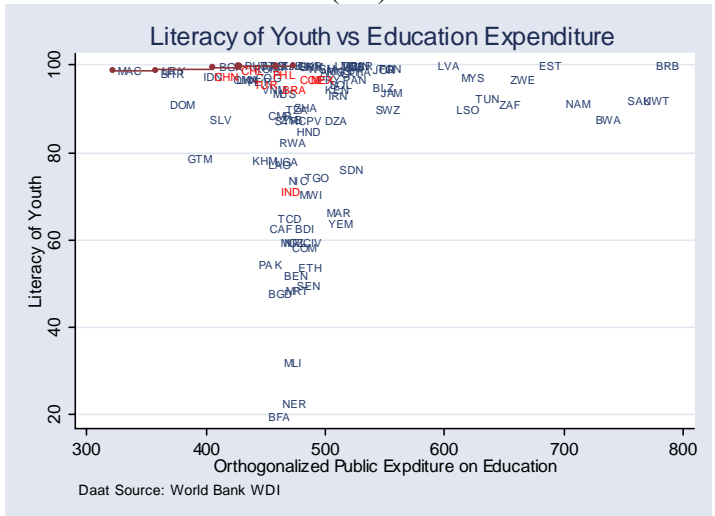
(d.2)



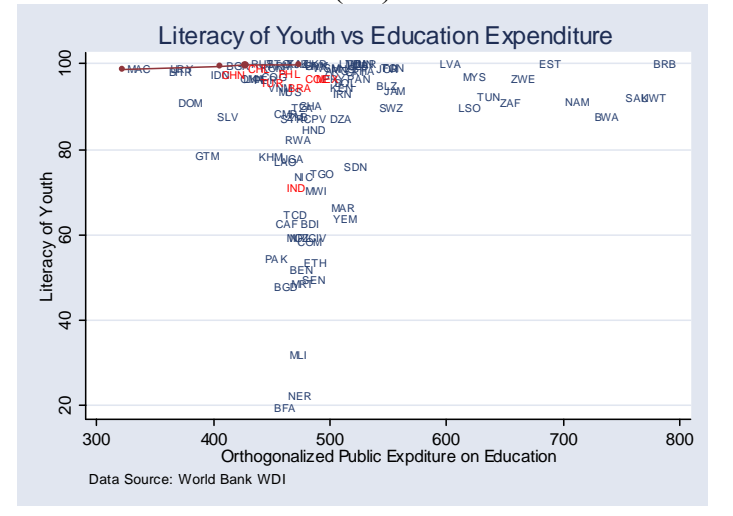
(e.1)



(e.2)



(f.1)



(f.2)

Appendix C. Table C.1. Spearman rank-correlation on input efficiency rankings (FDH)

	Gross Primary Enroll.	Gross Secondary Enroll.	Net Primary Enroll.	Net Secondary Enroll.	Literacy of Youth	Avg. Yrs. of Sch.	First Level Comp.	Second Level Comp.	Life Expecta ncy	Immuniza tion DPT	Immunizat ion Measles	DALE
Gross Primary Enrollment	1.00 (125)	0.63 (125)	0.84 (114)	0.63 (97)	0.55 (98)	0.71 (73)	0.53 (73)	0.60 (73)	0.22 (124)*	0.15 (124)***	0.21 (124)*	0.22 (123)*
Gross Secondary Enrollment		1.00 (125)	0.64 (114)	0.83 (97)	0.76 (98)	0.81 (73)	0.51 (73)	0.63 (73)	0.16 (124)***	0.17 (124)***	0.25 (124)	0.20 (123)**
Net Primary Enrollment			1.00 (114)	0.57 (95)	0.61 (91)	0.80 (67)	0.71 (67)	0.76 (67)	0.17 (113)***	0.11 (113)#	0.17 (113)***	0.23 (113)*
Net Secondary Enrollment				1.00 (97)	0.83 (77)	0.81 (53)	0.55 (53)	0.69 (53)	0.09 (96)#	0.17 (96)***	0.24 (96)*	0.17 (96)***
Literacy or Youth					1.00 (98)	0.88 (65)	0.54 (65)	0.75 (65)	-0.01 (96)#	0.21 (97)**	0.36 (97)	0.07 (96)#
Average Years of School						1.00 (73)	0.67 (73)	0.84 (73)	-0.01 (73)#	0.09 (73)#	0.29 (73)*	0.19 (72)***
First Level Complete							1.00 (73)	0.70 (73)	0.05 (73)#	0.07 (73)#	0.20 (73)***	0.19 (72)***
Second Level Complete								1.00 (73)	0.09 (73)#	0.23 (73)**	0.36 (73)	0.28 (73)*
Life expectancy at Birth									1.00 (135)	0.74 (135)	0.66 (135)	0.87 (134)
Immunization DPT										1.00 (135)	0.87 (135)	0.73 (134)
Immunization Measles											1.00 (135)	0.66 (134)
DALE												1.00 (134)

Note:

1. Figures are correlation coefficients from Spearman test, number of observations are in parentheses.
2. All coefficients are significant at 1% level, unless indicated otherwise, * 2% significance, ** 5% significance, *** 10% significance, # insignificant

Table C.2. Spearman rank-correlation on input efficiency rankings (DEA)

	Gross Primary Enroll.	Gross Secondary Enroll.	Net Primary Enroll.	Net Secondary Enroll.	Literacy Youth	Avg. Yrs. of School	First Level Comp.	Second Level Comp.	Life expectancy	Immunization DPT	Immunization Measles	DALE
Gross Primary Enrollment	1.00 (125)	0.80 (125)	0.88 (114)	0.74 (97)	0.58 (98)	0.70 (73)	0.60 (73)	0.73 (73)	0.30 (124)	0.24 (124)	0.23 (124)	0.30 (123)
Gross Secondary Enrollment		1.00 (125)	0.74 (114)	0.94 (97)	0.81 (98)	0.83 (73)	0.65 (73)	0.83 (73)	0.30 (124)	0.29 (124)	0.28 (124)	0.32 (123)
Net Primary Enrollment			1.00 (114)	0.69 (95)	0.64 (91)	0.78 (67)	0.76 (67)	0.80 (67)	0.22 (113)*	0.19 (113)**	0.17 (113)***	0.23 (113)*
Net Secondary Enrollment				1.00 (97)	0.86 (77)	0.88 (53)	0.75 (53)	0.87 (53)	0.20 (96)**	0.24 (96)*	0.24 (96)**	0.26 (96)*
Literacy or Youth					1.00 (98)	0.91 (65)	0.73 (65)	0.88 (65)	0.02 (96)#	0.18 (97)***	0.28 (97)	0.09 (96)#
Average Years of School						1.00 (73)	0.85 (73)	0.97 (73)	0.03 (73)#	0.09 (73)#	0.24 (73)**	0.09 (72)#
First Level Complete							1.00 (73)	0.83 (73)	0.14 (73)#	0.21 (73)***	0.29 (73)*	0.18 (72)#
Second Level Complete								1.00 (73)	0.13 (73)#	0.21 (73)***	0.36 (73)*	0.19 (73)#
Life expectancy at Birth									1.00 (135)	0.85 (135)	0.77 (135)	0.94 (134)
Immunization DPT										1.00 (135)	0.88 (135)	0.89 (134)
Immunization Measles											1.00 (135)	0.80 (134)
DALE												1.00 (134)

Note:

1. Figures are correlation coefficients from Spearman test, number of observations are in parentheses.
2. All coefficients are significant at 1% level, unless indicated otherwise, * 2% significance, ** 5% significance, *** 10% significance, # insignificant

Table C.3. Spearman Test on Output Efficiency Rankings (FDH)

	Gross Primary Enroll.	Gross Secondary Enroll.	Net Primary Enroll.	Net Secondary Enroll.	Avg. Literacy of Youth	Avg. Yrs of School	First Level Comp.	Second Level Comp.	Life expectancy	Immunization DPT	Immunization Measles	DALE
Gross Primary Enrollment	1.00 (125)	0.50 (125)	0.74 (114)	0.34 (97)	0.32 (98)	0.37 (73)	0.44 (73)	0.31 (73)	0.33 (124)	0.23 (124)	0.26 (124)	0.30 (123)
Gross Secondary Enrollment		1.00 (125)	0.69 (114)	0.91 (97)	0.85 (98)	0.84 (73)	0.53 (73)	0.79 (73)	0.72 (124)	0.70 (124)	0.84 (124)	0.76 (123)
Net Primary Enrollment			1.00 (114)	0.64 (95)	0.60 (91)	0.66 (67)	0.57 (67)	0.60 (67)	0.63 (113)	0.46 (113)	0.45 (113)	0.59 (113)
Net Secondary Enrollment				1.00 (97)	0.87 (77)	0.82 (53)	0.33 (53)*	0.77 (53)	0.69 (96)	0.73 (96)	0.73 (96)	0.72 (96)
Literacy or Youth					1.00 (98)	0.85 (65)	0.56 (65)	0.63 (65)	0.62 (96)	0.67 (97)	0.68 (97)	0.67 (96)
Average Years of School						1.00 (73)	0.62 (73)	0.8 (73)	0.72 (73)	0.73 (73)	0.76 (73)	0.73 (72)
First Level Complete							1.00 (73)	0.48 (73)	0.49 (73)	0.45 (73)	0.48 (73)	0.56 (72)
Second Level Complete								1.00 (73)	0.75 (73)	0.64 (73)	0.67 (73)	0.78 (73)
Life expectancy at Birth									1.00 (135)	0.67 (135)	0.69 (135)	0.94 (134)
Immunization DPT										1.00 (135)	0.95 (135)	0.66 (134)
Immunization Measles											1.00 (135)	0.70 (134)
DALE												1.00 (134)

Note:

1. Figures are correlation coefficients from Spearman test, number of observations are in parentheses.
2. All coefficients are significant at 1% level, unless indicated otherwise, * 2% significance, ** 5% significance, *** 10% significance, # insignificant

Table C.4. Spearman Test on Output Efficiency Rankings (DEA)

	Gross Primary Enroll.	Gross Secondary Enroll.	Net Primary Enroll.	Net Secondary Enroll.	Literacy of Youth	Avg. Years School	First Level Comp.	Second Level Comp.	Life expectancy	Immunization DPT	Immunization Measles	DALE
Gross Primary Enrollment	1.00 (125)	0.48 (125)	0.74 (114)	0.32 (97)	0.30 (98)	0.32 (73)	0.38 (73)	0.25 (73)**	0.34 (124)	0.23 (124)	0.27 (124)	0.30 (123)
Gross Secondary Enrollment		1.00 (125)	0.68 (114)	0.95 (97)	0.86 (98)	0.86 (73)	0.52 (73)	0.78 (73)	0.73 (124)	0.73 (124)	0.86 (124)	0.76 (123)
Net Primary Enrollment			1.00 (114)	0.65 (95)	0.61 (91)	0.69 (67)	0.58 (67)	0.62 (67)	0.64 (113)	0.47 (113)	0.45 (113)	0.61 (113)
Net Secondary Enrollment				1.00 (97)	0.87 (77)	0.83 (53)	0.35 (53)	0.81 (53)	0.69 (96)	0.73 (96)	0.73 (96)	0.72 (96)
Literacy or Youth					1.00 (98)	0.86 (65)	0.56 (65)	0.64 (65)	0.63 (96)	0.66 (97)	0.67 (97)	0.68 (96)
Average Years of School						1.00 (73)	0.62 (73)	0.84 (73)	0.73 (73)	0.74 (73)	0.75 (73)	0.73 (72)
First Level Complete							1.00 (73)	0.46 (73)	0.48 (73)	0.46 (73)	0.48 (73)	0.54 (72)
Second Level Complete								1.00 (73)	0.76 (73)	0.67 (73)	0.66 (73)	0.77 (73)
Life expectancy at Birth									1.00 (135)	0.67 (135)	0.69 (135)	0.95 (134)
Immunization DPT										1.00 (135)	0.94 (135)	0.67 (134)
Immunization Measles											1.00 (135)	0.71 (134)
DALE												1.00 (134)

Note:

1. Figures are correlation coefficients from Spearman test, number of observations are in parentheses.
2. All coefficients are significant at 1% level, unless indicated otherwise, * 2% significance, ** 5% significance, *** 10% significance, # insignificant

Appendix D. Productivity Change Over Time

Malmquist indexes are defined using distance functions. These functions describe multiple input-multiple output production technologies based on input and output quantity data without price information or behavioral assumptions (i.e. cost minimization or profit maximization). The distance functions can be either output based or input based.

The output distance function can be defined for any production technology S^t as the reciprocal of the maximum proportional expansion of the output vector y , given inputs x .

$$D_o^t(x^t, y^t) = \inf \left(\lambda : (x^t, y^t / \lambda) \in S^t \right) = \left[\sup(\lambda : (x^t, \lambda y^t) \in S^t) \right]^{-1} \quad (D.1)$$

If $(x^t, y^t) \in S^t$, then $D_o \leq 1$ and $D_o = 1$ if and only if (x^t, y^t) is on the boundary or frontier of technology. The distance function is the reciprocal of the output efficiency measure defined by Farrell and used in previous sections.

In Figure D.1, the frontier of the transformation set is defined by (B_t, C_t) in period t and by (B_{t+1}, C_{t+1}) in period $t+1$. The distance of country A from the country B in period t , which is a measure of how far the production point A is from the frontier, can be expressed as $D^t(x^t, y^t) = OA_t / OB_t$. Similarly, the distance between the production point A_{t+1} and the frontier in period $t+1$ is defined as $D^{t+1}(x^{t+1}, y^{t+1}) = OA_{t+1} / OB_{t+1}$.

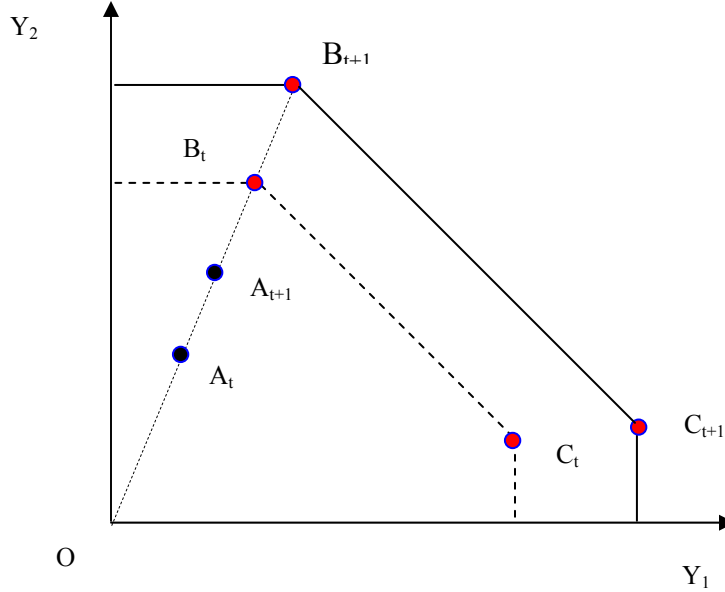


Figure D. 1. Output Possibility Set, periods t and t+1

The Malmquist index requires the definition of a distance function with respect to two different time periods (t and $t+1$). This distance measures the maximum change in outputs required to make (x^{t+1}, y^{t+1}) feasible in relation to technology at t , and is defined as $D^t(x^{t+1}, y^{t+1}) = OA_{t+1} / OB_t$. Alternatively, the distance function could be defined as

the change in output required to make (x^t, y^t) feasible in relation to technology at $t+1$. This would be defined as $D^{t+1}(x^t, y^t) = OA_t / OB_{t+1}$. Hence the Malmquist productivity index is defined as the ratio of two distances, that can be computed in relation with technology at t or at $t+1$. The period t -based and period $(t+1)$ -based Malmquist indices are defined, respectively, as

$$M_0^t = \frac{D^t(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \quad (D.2)$$

$$M_0^{t+1} = \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t+1}(x^t, y^t)} \quad (D.3)$$

One possible case in reality is that the frontier shift is not parallel in all dimensions, as indicated in Figure D.2. Country B in period $t+1$ is producing more y_1 and less y_2 compared to the production point in period t . In another word, the country B is not expanding along the same ray through the origin, but rather biased in some direction, as pointed by Nin, Arndt, and Preckel (2003) among others. In this case, the output-oriented, period t -based Malmquist index will estimate productivity decrease due to technical regress while the period $(t+1)$ -based Malmquist will show the opposite.

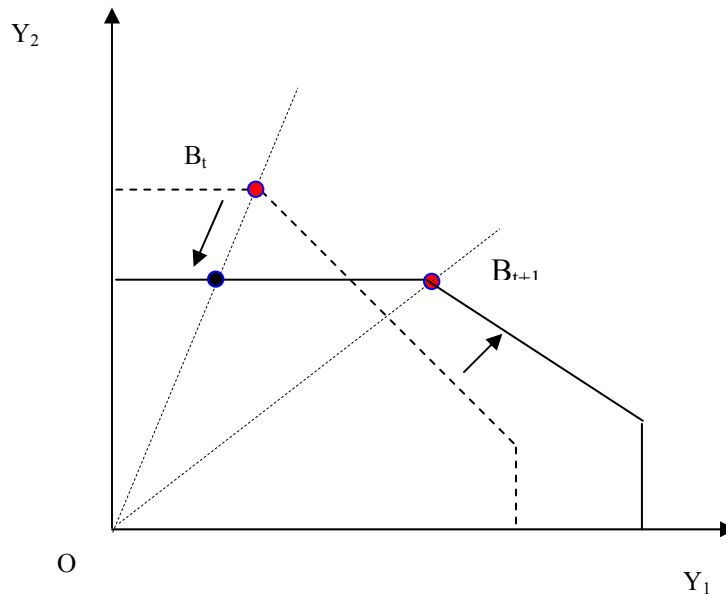


Figure D. 2 Contemporaneous Production Set (Biased Technical Change)

To avoid an arbitrary selection of base period mentioned above, the geometric average of both is suggested (Fare, *et al*, 1994):

$$M_o(x^{t+1}, y^{t+1}, x^t, y^t) = \left[\frac{D^t(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t+1}(x^t, y^t)} \right]^{1/2} \quad (D.4)$$

This expression can be rewritten as:

$$M_o(x^{t+1}, y^{t+1}, x^t, y^t) = \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \left[\frac{D^t(x^{t+1}, y^{t+1})}{D^{t+1}(x^{t+1}, y^{t+1})} \frac{D^t(x^t, y^t)}{D^{t+1}(x^t, y^t)} \right]^{1/2} \quad (D.5)$$

The ratio outside the brackets captures the change in relative efficiency between the two time periods. The term in the brackets captures the technological shift between the two periods. This expression is the basis of our empirical application, following Coelli and Rao (2003).

An alternative approach to dealing with the biased technical change is to define a sequential production set, following Nin, Arndt, and Preckel (2003). Specifically, it is assumed that the input-output mix, or technology, in period t is always available in period $t+1$. The production possibility set, the sequential one, in period $t+1$ is then defined by the frontier (B_t, B_{t+1}) in Figure D.3. This setup will clearly rule out the possibility of technical regress and give lower efficiency change than otherwise.

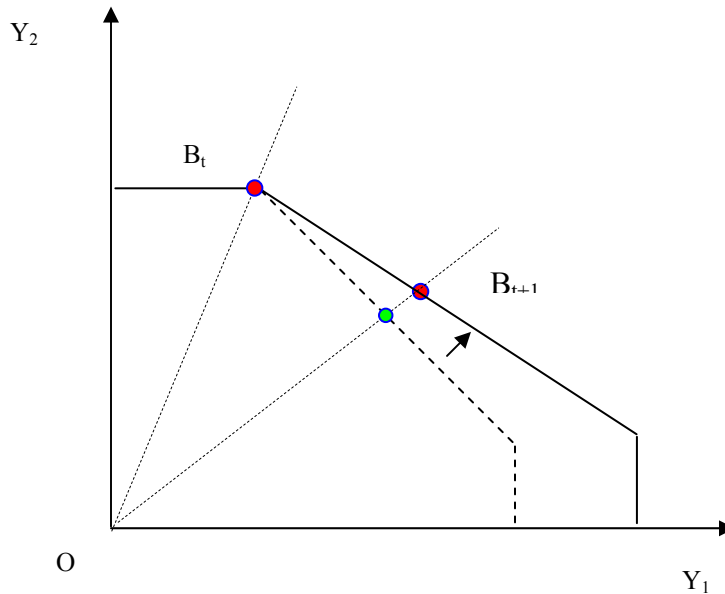


Figure D. 3 Sequential Production Set (Biased Technical Change)

Variable Returns to Scale Efficiency and Sequential Technical Change
Table D.1. Education, single input (public spending per capita on education), single output

	Region	VRSTE Output		VRSTE Input		EFFCH	TECHCH	TFPCH	No. of Countries
		1975-80	1996-02	1975-80	1996-02				
Gross Primary Enrollment	AFR	.563	.650	.843	.851	1.299	1	1.299	23
	EAP	.793	.808	.897	.847	.987	1	.987	8
	ECA	.754	.735	.845	.793	.944	1	.944	4
	LAC	.787	.813	.860	.843	1.054	1	1.054	20
	MNA	.694	.692	.798	.747	1.114	1	1.114	10
	SAS	.554	.769	.882	.911	1.446	1	1.446	5
Net Primary Enrollment	AFR	.537	.651	.841	.819	1.355	1	1.355	12
	EAP	.929	.959	.927	.859	.969	1	.969	4
	ECA	.958	.907	.792	.799	.963	1	.963	2
	LAC	.870	.935	.837	.831	1.045	1	1.045	13
	MNA	.752	.842	.787	.724	1.198	1	1.198	9
	SAS	-	-	-	-	-	-	-	-
Gross Secondary Enrollment	AFR	.184	.293	.819	.830	2.072	1.038	2.150	23
	EAP	.508	.705	.874	.860	1.484	1.038	1.540	8
	ECA	.750	.864	.913	.854	1.235	1.038	1.281	4
	LAC	.564	.723	.859	.874	1.450	1.038	1.505	20
	MNA	.521	.703	.804	.774	2.443	1.038	2.535	10
	SAS	.324	.478	.880	.901	1.806	1.038	1.874	5
Net Secondary Enrollment	AFR	.179	.341	.317	.304	1.519	1.248	1.895	6
	EAP	.576	.695	.525	.623	1.555	1.248	1.941	3
	ECA	.824	.895	.747	.711	1.256	1.248	1.568	1
	LAC	.535	.678	.504	.451	1.420	1.248	1.772	10
	MNA	.385	.629	.453	.410	1.891	1.248	2.360	8
	SAS	-	-	-	-	-	-	-	-
Literacy of Youth	AFR	.554	.741	.814	.831	1.442	1	1.442	20
	EAP	.924	.988	.879	.868	1.009	1	1.009	6
	ECA	.967	.990	.940	.880	.967	1	.967	4
	LAC	.899	.952	.872	.845	1.024	1	1.024	18
	MNA	.729	.906	.778	.749	1.230	1	1.230	10
	SAS	.499	.662	.869	.871	1.430	1	1.430	5
Average Years of School	AFR	.261	.323	.340	.315	1.737	1	1.737	19
	EAP	.653	.708	.406	.495	1.342	1	1.342	7
	ECA	.750	.768	.648	.621	1.387	1	1.387	3
	LAC	.618	.625	.418	.427	1.300	1	1.300	18
	MNA	.456	.549	.389	.326	1.929	1	1.929	6
	SAS	.302	.397	.363	.379	2.137	1	2.137	5
First Level Complete	AFR	.135	.164	.340	.315	1.417	1	1.417	19
	EAP	.367	.382	.363	.342	1.066	1	1.066	7
	ECA	.764	.639	.646	.528	.913	1	.913	3
	LAC	.372	.266	.404	.349	.816	1	.816	18
	MNA	.299	.217	.389	.317	1.266	1	1.266	6
	SAS	.146	.194	.363	.370	2.101	1	2.101	5
Second Level Complete	AFR	.082	.098	.341	.339	1.417	1.77	2.509	19
	EAP	.439	.444	.470	.517	.991	1.77	1.754	7
	ECA	.284	.276	.355	.414	1.045	1.77	1.849	3
	LAC	.337	.228	.418	.381	.839	1.77	1.485	18
	MNA	.357	.266	.389	.357	1.233	1.77	2.182	6
	SAS	.202	.235	.385	.424	1.734	1.77	3.068	5

Table D.2 Health, Single Input (Public Spending per capita on Health), Single Output

	Region	VRSTE Output		VRSTE Input		EFFCH	TECHCH	TFPCH	No. of Countries
		1997-99	2000-02	1997-99	2000-02				
Life Expectancy at Birth	AFR	.642	.618	.680	.681	.972	1	.972	42
	EAP	.870	.872	.738	.735	1.008	1	1.008	16
	ECA	.919	.911	.616	.626	1.019	1	1.019	25
	LAC	.923	.920	.739	.723	.995	1	.995	31
	MNA	.889	.892	.725	.754	1.049	1	1.049	13
	SAS	.821	.834	.713	.718	1.029	1	1.029	5
Immunization DPT	AFR	.601	.629	.686	.682	1.022	1.078	1.101	42
	EAP	.837	.824	.772	.740	.930	1.078	1.003	16
	ECA	.949	.957	.681	.633	.953	1.078	1.027	25
	LAC	.863	.883	.732	.694	.944	1.078	1.017	31
	MNA	.882	.920	.778	.751	1.063	1.078	1.146	13
	SAS	.742	.773	.736	.724	.976	1.078	1.053	5
Immunization Measles	AFR	.632	.638	.682	.681	.975	1.089	1.061	42
	EAP	.837	.827	.778	.740	.924	1.089	1.007	16
	ECA	.944	.951	.712	.634	.943	1.089	1.027	25
	LAC	.904	.912	.770	.694	.924	1.089	1.006	31
	MNA	.878	.909	.798	.755	1.055	1.089	1.148	13
	SAS	.701	.732	.735	.725	.970	1.089	1.056	5
DALE	AFR	.655	-	.563	-	-	-	-	41
	EAP	.717	-	.830	-	-	-	-	16
	ECA	.602	-	.903	-	-	-	-	26
	LAC	.698	-	.904	-	-	-	-	31
	MNA	.707	-	.863	-	-	-	-	15
	SAS	.691	-	.787	-	-	-	-	5

Table D.3. Education, Multiple Inputs, Multiple Outputs

	Region	VRSTE Output		VRSTE Input		EFFCH	TECHCH	TFPCH	No. of Countries
		1975-80	1996-02	1975-80	1996-02				
EDU2-2 Gross Primary and Secondary Enrollment	AFR	.587	.685	.906	.902	1.292	1.003	1.296	21
	EAP	.860	.928	.935	.905	1.039	1.030	1.070	7
	ECA	.913	.939	.913	.842	.937	1.065	.999	3
	LAC	.854	.911	.906	.914	1.102	1.029	1.134	20
	MNA	.729	.820	.841	.793	1.278	1.029	1.314	10
	SAS	.580	.817	.940	.963	1.457	1.101	1.470	5
EDU2-2n Net Primary and Secondary Enrollment	AFR	.723	.703	.787	.750	1.062	1.009	1.076	6
	EAP	.921	.954	.905	.881	1.015	1.074	1.088	3
	ECA	1.00	.973	1.00	.836	.999	1.299	1.298	1
	LAC	.881	.942	.808	.822	1.074	1.066	1.138	9
	MNA	.782	.862	.777	.695	1.168	1.097	1.286	8
	SAS	-	-	-	-	-	-	-	-
EDU3-2 Gross Primary and Secondary Enrollment	AFR	.762	.922	.909	.909	1.043	1.002	1.045	18
	EAP	.840	.929	.896	.896	1.066	1.022	1.089	6
	ECA	.913	.917	.909	.909	1.018	1.037	1.057	3
	LAC	.849	.919	.922	.922	1.116	1.021	1.139	18
	MNA	.787	.870	.892	.892	1.235	1.008	1.245	10
	SAS	.813	.966	.982	.982	1.140	1.010	1.153	5
EDU3-2n Net Primary and Secondary Enrollment	AFR	.909	.894	.924	.897	.953	1.014	.970	6
	EAP	.937	.981	.961	.959	1.030	1.021	1.052	2
	ECA	1.00	.996	1.00	.969	.916	1.300	1.192	1
	LAC	.964	.983	.931	.948	1.045	1.063	1.109	9
	MNA	.930	.950	.934	.947	1.137	1.078	1.225	8
	SAS	-	-	-	-	-	-	-	-
EDU3-3 Gross Primary & Secondary Enrollment, Literacy of Youth	AFR	.939	.946	.950	.944	.974	1.018	.991	18
	EAP	.995	.996	.989	.968	.961	1.026	.986	6
	ECA	.999	1.00	.993	.996	.959	1.029	.987	3
	LAC	.968	.983	.966	.960	.996	1.023	1.019	18
	MNA	.959	.966	.964	.953	.956	1.008	.965	10
	SAS	.919	.930	.970	.983	1.027	1.007	1.036	5
EDU3-3bl Avg. Yrs. of School, First & Secondary Level Complete	AFR	.789	.724	.896	.876	1.025	1.167	1.201	15
	EAP	.902	.872	.942	.901	.989	1.279	1.256	6
	ECA	.957	.987	.962	.978	1.026	1.137	1.168	2
	LAC	.893	.846	.939	.883	.999	1.170	1.168	17
	MNA	.899	.811	.925	.827	.950	1.259	1.193	6
	SAS	.883	.888	.984	.956	1.129	1.375	1.547	5
EDU2-3bl Avg. Yrs. of School, First & Secondary Level Complete	AFR	.416	.451	.725	.733	1.560	1.054	1.641	17
	EAP	.730	.778	.747	.732	1.064	1.106	1.178	7
	ECA	.938	.943	.873	.773	.885	1.047	.922	2
	LAC	.690	.690	.777	.713	1.070	1.072	1.146	18
	MNA	.496	.576	.661	.599	1.393	1.105	1.509	6
	SAS	.328	.510	.673	.808	2.189	1.086	2.378	5

Table D.4. Health, Multiple Inputs and Multiple Outputs

	Region	VRSTE Output		VRSTE Input		EFFCH	TECHCH	TFPCH	No. of Countries
		1997-99	2000-02	1997-99	2000-02				
HEA2-2 Life Expectancy at birth, Immunization DPT	AFR	.818	.802	.861	.842	.952	1.032	.982	31
	EAP	.899	.897	.853	.818	.950	1.055	1.001	9
	ECA	.966	.965	.755	.730	.954	1.063	1.014	18
	LAC	.941	.936	.843	.824	.950	1.051	.998	23
	MNA	.973	.970	.915	.902	.983	1.041	1.023	11
	SAS	.957	.956	.939	.907	.965	1.032	.995	4
HEA3-2 Life Expectancy at birth, Immunization DPT	AFR	.823	.805	.866	.842	.952	1.031	.982	31
	EAP	.904	.903	.853	.818	.950	1.054	1.001	9
	ECA	.970	.969	.763	.736	.957	1.059	1.013	18
	LAC	.948	.943	.862	.838	.950	1.051	.998	23
	MNA	.973	.970	.907	.893	.984	1.060	1.044	10
	SAS	.957	.957	.939	.907	.970	1.031	.999	4
HEA3-2 Life Expectancy at birth, Immunization Measles	AFR	.820	.787	.866	.838	.934	1.029	.961	31
	EAP	.900	.898	.860	.817	.937	1.069	1.001	9
	ECA	.971	.970	.798	.739	.942	1.078	1.015	18
	LAC	.957	.953	.887	.848	.941	1.062	.998	23
	MNA	.972	.971	.908	.894	.986	1.064	1.050	10
	SAS	.952	.957	.937	.906	.962	1.046	1.005	4
HEA3-3 Life Expectancy at birth, Immunization DPT & Measles	AFR	.830	.812	.868	.842	.952	1.031	.981	31
	EAP	.904	.903	.860	.819	.941	1.064	1.001	9
	ECA	.977	.974	.800	.740	.944	1.075	1.013	18
	LAC	.958	.954	.887	.848	.941	1.062	.998	23
	MNA	.974	.971	.909	.895	.986	1.063	1.049	10
	SAS	.958	.957	.941	.907	.965	1.039	1.001	4

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