# Measuring Efficiency of Macro Systems: An Application to Millennium Development Goal Attainment

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At least part of the effort toward attainment of health and education Millennium Development Goals (MDGs) could come from improvements in efficiency of delivery mechanisms. Hence, it is important to know which countries—or which regions within countries—are able to attain higher MDG outcomes even after controlling for resource inputs. This information can be useful for policymakers and can enable a second-stage analysis of *why* is it that some regions or countries are doing better than others. This paper reviews the methodology for measuring efficiency of macro systems using the health and education sectors as examples. A simpler characterization of efficiency that is less dependent on econometric specifications is introduced. As an example, this method of measuring efficiency is applied to assess the efficiency of health system outcomes at the district (*kabupaten*) level in Indonesia.

The UN Millennium Declaration—adopted by 189 countries in September 2000—has focused attention on the attainment of eight Millennium Development Goals (MDGs) by 2015. The goals, which are reflective of a fairly broad conceptualization of development, include targets for poverty reduction, gender equality, environment sustainability, educational attainment, as well as health improvements (UNDP 2003). This focus on MDGs has resulted in renewed attention toward measurement and monitoring issues, as well as on projections of indicators to 2015 to assess which countries are "on track." In addition, there have been attempts to identify resource, institutional, and other constraints to MDG attainment (World Bank 2004).

There is a general consensus in the development community that at least part of the effort toward MDG attainment (and this is especially true for the social sector) could come from improved efficiency of existing delivery mechanisms (Jayasuria and Wodon 2003). Whereas it is true that macroeconomic growth would facilitate improvements in human development, the positive spillover effects from economic growth to the social sector are not as big as they might be for income poverty reduction (World Bank 2004). Furthermore, there is empirical

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evidence that suggests that high levels of economic development are not necessarily a prerequisite for high levels of human development. One reason is that given the labor-intensive nature of service provision, the supply of health and education costs relatively less in poorer countries (Dreze and Sen 1989). Hence, at least in principle, the same levels of health and education outcomes could be achieved at far lower resource outlays in low-income countries. Two oft-cited examples are those of Sri Lanka and the state of Kerala in India. The implications are that resource constraints can, at least in part, be offset by good governance, effective institutions, political will, or other such factors.

In order to identify efficiencies, the first step is to identify which countries as well as which regions within countries have been relatively successful in MDG attainment *after* controlling for resource inputs. A second step would be to then examine *why* is it that some countries are doing better than others in their resource-level group in achieving MDG outcomes. If a given country is found to be relatively efficient but has yet to attain a given MDG then this would imply that additional resource outlays are most likely going to be required for achieving further progress. If, on the other hand, a country is relatively inefficient then this suggests that both increases in efficiency at current resource levels as well as increases in resource outlays are potential pathways to MDG outcome increases. In addition, identification is a first step toward understanding factors that contribute to inefficiencies: some of these may be policy-related, but others may be factors that are beyond the immediate control of governments (e.g., external shocks, civil strife, etc.).

The problem of estimating MDG efficiency is similar to the classic problem of estimating technical efficiency in industrial and agricultural economics, whereby efficiency in converting inputs into outputs is inferred from how far the output of a given production unit is from the maximum output (the "frontier"). This paper summarizes the methodology as applied to MDG attainment for two macro systems, namely the health and education sectors.[1] The paper then outlines a simpler way to characterize efficiency that is more transparent and less dependent on econometric specifications and assumptions. The paper concludes with a discussion of this approach in helping identify policy-dependent factors that can have an effect on improving the efficiency of MDG outcomes. These issues are especially relevant for human development in Asian DMCs as most projections show that, even though progress on income-related MDGs has been encouraging, the prognosis for achieving social-sector and other nonincome MDGs by 2015 is not positive for the region (ADB 2004).

[1]This part of the paper draws upon Tandon et al. (2003).

## I. THEORETICAL BACKGROUND

In the production function literature, technical efficiency is defined as output relative to the maximum output for given input levels (Kumbhakar and Lovell 2000). Usually, one way to assess efficiency is to estimate a frontier production function (the maximum observed output for all available input levels).[2] Once the frontier has been identified, then distance from the frontier is a measure of efficiency [$b/(a+b)$ in Figure 1]. Figure 1 shows one example with two countries having the same output. However, because country A is able to achieve the same output at a lower level of inputs than country B, it is deemed to be more efficient.

The first step in applying this framework to MDG attainment is to conceptualize the pertinent sectors as production units. In this paper, we consider applying the efficiency framework to health and education-related MDG attainment and this implies conceptualizing—at least metaphorically—the health sector and education sector as production-oriented macro systems. The next steps are to specify inputs, outputs, and other factors that can have an influence on the production process.

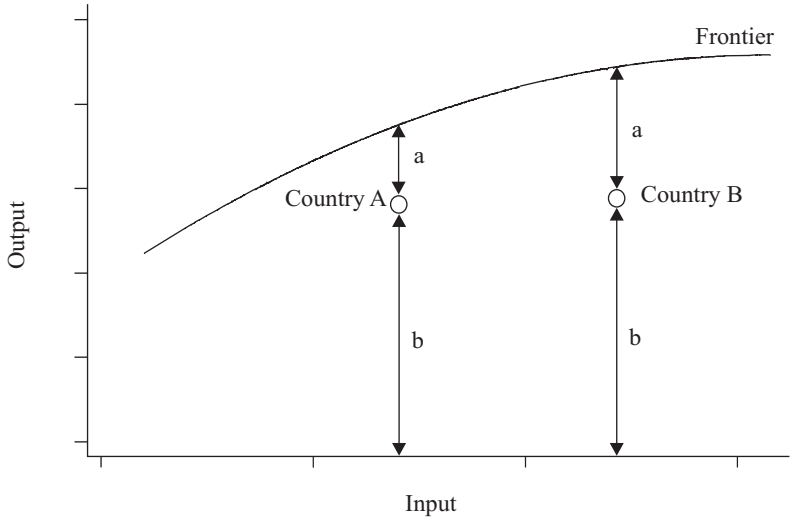
### A. Outputs

As the concern is to assess the efficiency of MDG attainment, the relevant MDG indicators can be assumed to represent outputs of the respective sectors.[3] So, for instance, for the education sector we take net primary enrollment ratio as an indicator for the education MDG target. Similarly, we take under-five morality rate as an indicator for the health MDG target (the actual target being a two-thirds reduction of this indicator between 1990 and 2015).

[2]This approach is the macro approach. A micro approach to measuring efficiency would identify the set of available interventions that yield the maximum possible outcomes.

[3]In several instances, there are multiple indicators of any given MDG target. This multiplicity can be taken into account by constructing an output index. For expository purposes, for now we focus only on one of the indicators each for the health and education MDG targets.

Figure 1. **Frontier Production Function and Technical Efficiency**




## B. Inputs

Inputs typically refer to (controllable) sectoral factors that contribute to attainment of the chosen MDG indicators. The idea here is to take into consideration resources at the disposal of the respective sectors.[4] For this purpose, inputs could be public expenditure allocations, existing capital, buildings, labor employed in the health and education sectors, etc. From a short-term policymaker's point of view, for instance, budgetary allocations are often the only controllable factor that could be considered as inputs.

## C. Exogenous Determinants

These are factors that are not directly related to resources in the sector in question, but may have an effect on the relationship between inputs and outputs. In other terms, this refers to factors that characterize the environment within which production is taking place. So, for instance, educational attainment could be considered an exogenous determinant of health in that, for the same resource input, higher educated populations are likely to have systematically higher health

[4]It is important to note that we are not estimating a full production function, in that we are not taking into account all factors that contribute to the achievement of outcomes: we are only considering resources at the disposal of the respective sectors as inputs. Other factors influencing outcomes—which include socioeconomic, behavioral, institutional, and environmental factors—can be incorporated as exogenous determinants characterizing the environment within which conversion of input resources to outcomes occurs.

outputs. Similarly, controlling for the level of sectoral expenditure, a higher *share* of that sector in total expenditure may serve as a proxy for political commitment to that sector and may have a positive influence on outcome attainment.

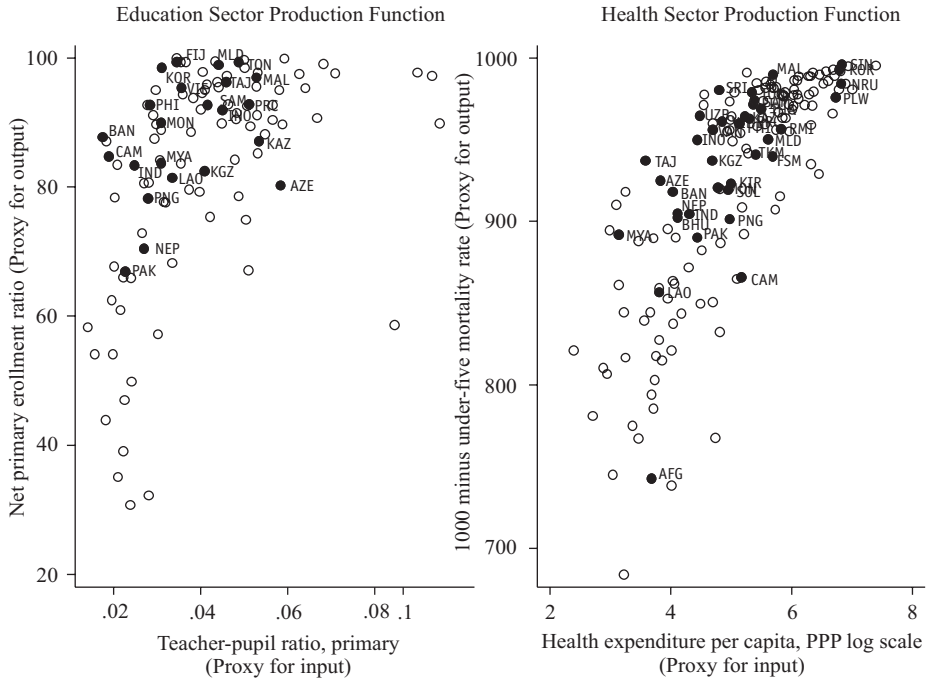
Table 1 summarizes the application of this theoretical framework to the measurement of MDG efficiency in the education and health sectors. Figure 2 plots the education and health sector production functions using data from 2000 (Asian DMCs highlighted).[5] As can be seen, both sectors exhibit properties of standard production functions: increases in inputs appear on average to increase output, albeit at a diminishing rate.

Table 1. **Conceptualizing the Education and Health Sectors as Production Units**

| **Macro System** | **Output Indicator (MDG Indicator)** | **Input Indicators** | **Exogenous Determinants** |
|---|---|---|---|
| Education Sector | Net primary enrollment ratio (percent) | Primary school expenditure per capita<br>Primary pupil-teacher ratio | Governance indicators<br>Social capital indicators<br>Poverty rate<br>Population density<br>Percent of total expenditure to sector |
| Health Sector | Under-five mortality rate per 1,000 (reported inversely as 1,000 minus this rate) | Health expenditure per capita<br>Hospital beds<br>Medical personnel per capita | |

[5]Due to problems related to data completeness, only one input indicator is used as a proxy for this analysis.

**Figure 2. Education and Health Sector Production Functions**




## II. EMPIRICS OF EFFICIENCY MEASUREMENT

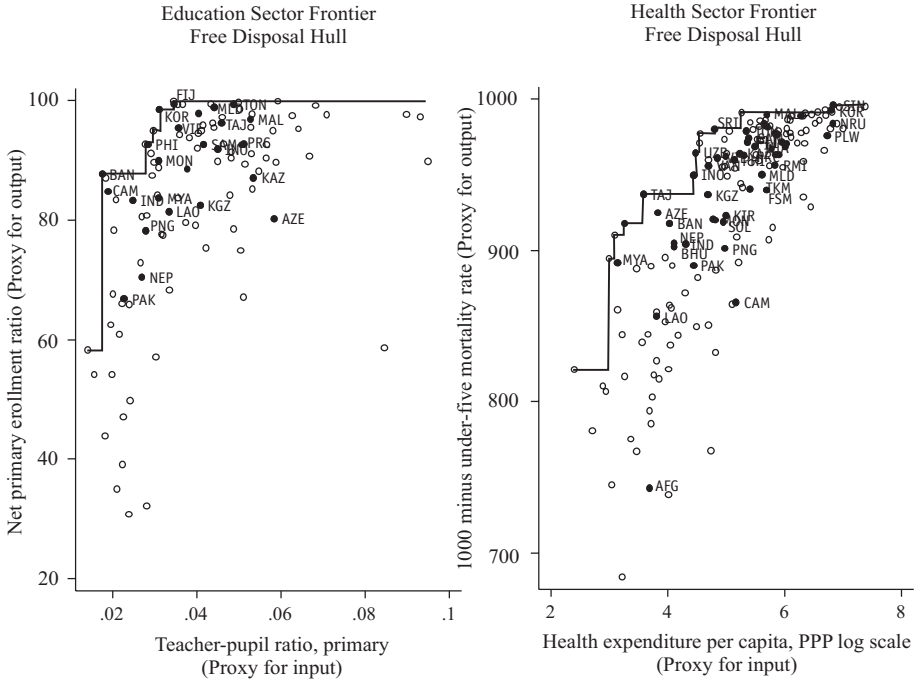
Econometrically, the frontier production function and efficiency can be estimated using two sets of approaches: (i) a *deterministic* approach, or (ii) a *stochastic* approach (Kumbhakar and Lovell 2000). A key difference between the two approaches has to do with how each conceptualizes the data-generating mechanism. In the deterministic approach, the frontier is estimated such that all observed data points lie below it, and all deviations from the frontier are attributed to inefficiency. In the stochastic approach, at least some of the deviations from the frontier are allowed to be attributable to factors other than inefficiency (e.g., to measurement error).

### A. Deterministic Frontiers

Examples of estimating efficiency using a deterministic frontier approach include free disposal hull (FDH), data envelopment analysis (DEA), and corrected ordinary least squares (COLS). The latter (COLS) is a parametric approach in that the frontier is defined using a specified functional form. The former two (FDH and DEA) are nonparametric in that there is no specific

functional form that is imposed on the data. Figure 3 plots estimates of the frontier in the health and education sectors using FDH analysis. As can be seen, FDH derives the frontier using piecewise linear segments. By definition, all points on the frontier have maximum efficiency (i.e., efficiency values of 1). Inefficiencies are calculated by estimating the vertical distance of each point from the FDH frontier.

**Figure 3. Education and Health Sector Frontiers: Free Disposal Hull (FDH) Method**



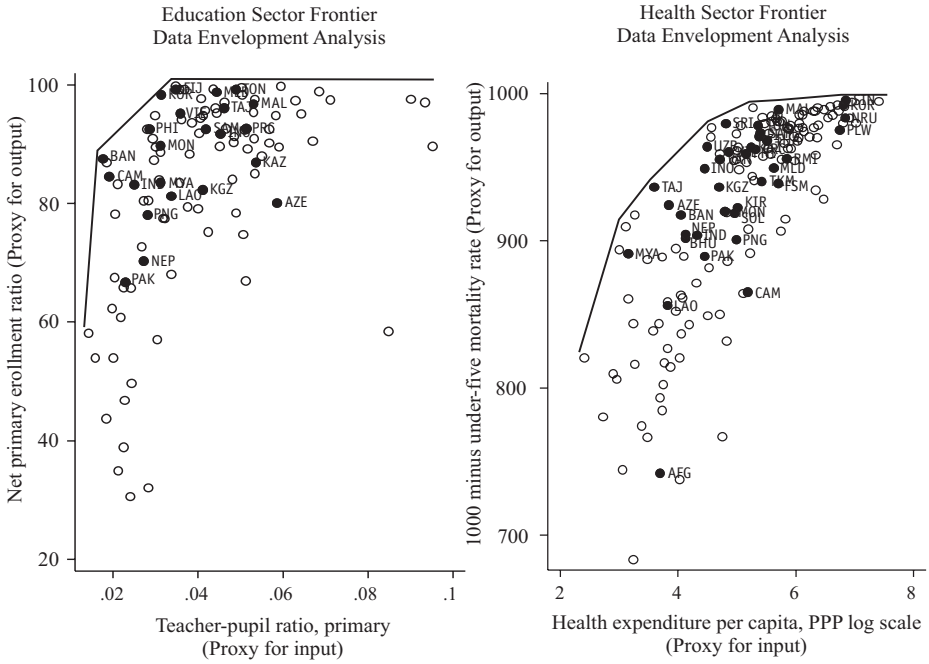

For the education sector, FDH frontier analysis suggests that countries such as Azerbaijan (AZE), Kazakhstan (KAZ), Kyrgyz Republic (KGZ), Lao PDR (LAO), Pakistan (PAK), Papua New Guinea (PNG), and Nepal (NPL) are relatively far from the frontier, i.e., they are relatively inefficient in that their attainment of primary enrollment ratios after controlling for input levels is low. In contrast, countries such as Bangladesh (BAN), Cambodia (CAM), Republic of Korea (KOR), and Philippines (PHI) are practically on the frontier indicating very high efficiency levels in the education sector. For the health sector, FDH analysis suggests that Afghanistan (AFG), Lao PDR (LAO), Pakistan (PAK), Papua New Guinea (PNG), and Tuvalu (TUV) are relatively far from the frontier and, hence, relatively inefficient in attaining lower under-five mortality rates. In

contrast, for their resource levels, Malaysia (MAL), Myanmar (MYA), Sri Lanka (SRI), and Tajikistan (TAJ) have relatively efficient health systems.

The same data can be analyzed using DEA methods (Figure 4). The DEA is also nonparametric and uses the least number of linear segments to "envelop" the data: it constructs an upper convex hull on the data. Because it does not wrap the data as tightly as FDH, DEA methods can yield somewhat different conclusions regarding efficiency estimates: e.g., Philippines as per DEA analysis has a lower estimate of education efficiency vis-à-vis that obtained using FDH analysis.

The COLS analysis (not shown) is another deterministic method but uses a parametric regression to fit the data and then moves the regression line up by the largest positive residual to ensure that all the data lie below it. Deterministic methods, although more transparent, are usually not a good way to estimate technical efficiency given that they leave no room for measurement error. In particular, the methods can be very sensitive to outlying observations.

**Figure 4. Education and Health Sector Frontiers: Data Envelopment Analysis (DEA) Method**



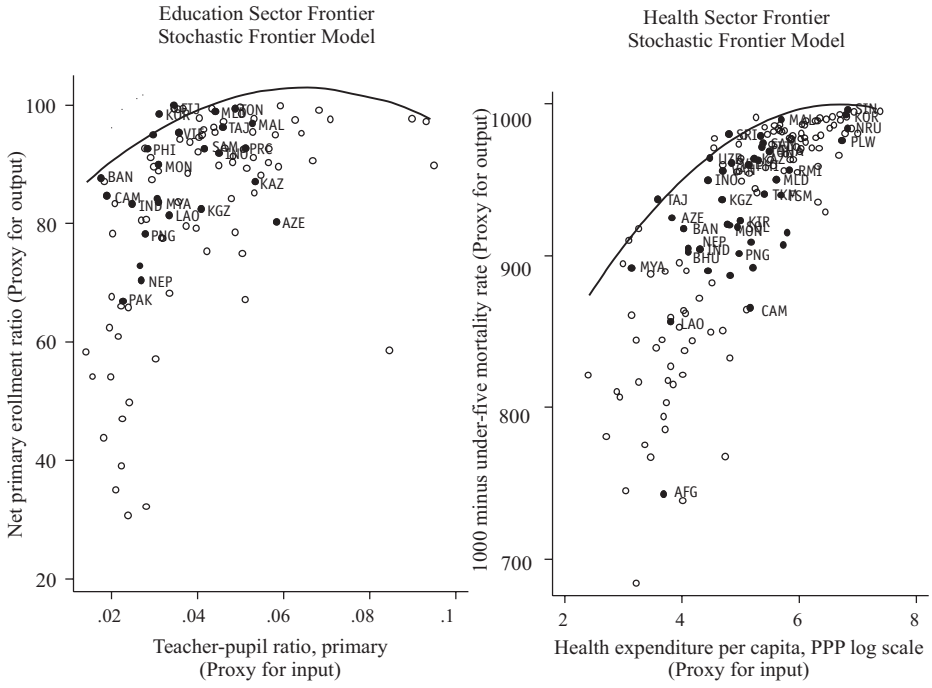

Source: World Development Indicators (2004)

Source: WHO Statistical Information System (2004)

## B. Stochastic Frontiers

Stochastic frontier models allow for random errors in the estimation process. The simplest formulation of a stochastic frontier model is a basic regression model with error decomposition: part of the error term is assumed to represent efficiency and is assumed to follow a one-sided distribution such as the exponential or truncated normal. Figure 5 plots the stochastic frontier using an exponential distribution for efficiency. Some data points in the stochastic method can be higher than the frontier (e.g., Sri Lanka [LKA] and Tajikistan [TJK] for health) if the random noise portion of the error term is large enough.[6]

**Figure 5. Education and Health Sector Frontiers: Stochastic Frontier Method**




Source: World Development Indicators (2004)

Source: World Development Indicators (2004)

If panel data are available, then stochastic error decomposition methods can be applied using a fixed-effect model. The country with the highest fixed effect is assumed to be the most efficient and the difference between this and

[6]In addition, as shown in Figure 5, the estimates of the education sector frontier using the stochastic frontier approach indicate that regularity conditions for a production function are violated: there are negative returns after a certain level of resource inputs.

each of the other country units is an estimate of the inefficiency. Such panel data methods are often the most robust for measurement of efficiency for several reasons: (i) multiple observations per unit over time usually contain more information and hence make it easier to tease out true efficiency effects in the error term from random noise; (ii) they do not require any distributional assumptions on the efficiency component of the error term; and (iii) they do not require the assumption that the efficiency component be uncorrelated with inputs.

## C. Measuring Efficiency: A Simple Framework

As the above discussion has shown, efficiency in MDG outcome attainment can be measured using frontier production function analysis. Empirically, there are several different ways that the frontier can be estimated from the data. These include deterministic methods such as FDH and DEA as well as stochastic methods such as error-decomposition models. As can be seen from Figures 3 to 5, the estimated efficiency can be different depending on the type of method chosen to estimate it, and hence the absolute values are not comparable across the different methods. Stochastic methods appear to be "truer" to the data-generating mechanism but require technically complex assumptions regarding distributions and error mixtures. Furthermore, some argue that the theoretical assumptions underlying efficiency measurement using such methods are unlikely to hold true in the social sector (Ravallion 2003).

In this subsection, we outline a simpler visual approach to assessing efficiency. This approach does not require econometric assumptions regarding functional form or distributions on the error term. It assesses distance from the "best" performers after roughly controlling for input levels. Input levels are broken into quintiles and then the distribution *within* each quintile of input allows us to assess which countries are at the top end of the distribution (and which ones are at the bottom: the worst performers). Figure 6 plots the distributions of outcomes by input quintiles for the education and health sectors. Within each input quintile, Table 2 reports the top three and bottom three countries in terms of efficiency. These represent countries that, for their input resource levels are the top and bottom performers, respectively, in terms of MDG outcome attainment in the social sectors. There are already some interesting patterns that can be observed: African counties are most likely to be poor performers in both the education and health sectors, even after controlling for inputs. Civil strife appears to be a risk factor for low health outcomes (e.g., Afghanistan and Sierra Leone). Countries that are efficient in education attainment need not be efficient in health attainment (e.g., Azerbaijan and Cambodia). These observations prompt the need for further investigation as to the determinants of efficiency. For instance, we find that the probability of being efficient within a resource group increases with the

ability of countries to control corruption, the effect being higher in the health sector vis-à-vis the education sector (Figure 7).

Table 2. **Education and Health Sector Outcomes: High versus Low Efficiency Countries (Asian DMCs highlighted)**

| Input Quintile | Education Sector Outcomes | | Health Sector Outcomes | |
|---|---|---|---|---|
| | **High Efficiency** | **Low Efficiency** | **High Efficiency** | **Low Efficiency** |
| 1 | **Bangladesh (BAN)**<br>Equatorial Guinea (EQG)<br>**Cambodia (CAM)** | Eritrea (ERI)<br>Burkina Faso (BUF)<br>Niger (NGR) | **Tajikistan (TAJ)**<br>**Azerbaijan (AZE)**<br>Comoros (COM) | Niger (NGR)<br>**Afghanistan (AFG)**<br>Sierra Leone (SIE) |
| 2 | **Korea (KOR)**<br>Jamaica (JAM)<br>Dominican Republic (DOR) | Ghana (GHA)<br>Tanzania (TNZ)<br>Djibouti (DJI) | **Sri Lanka (SRI)**<br>Georgia (GEO)<br>Moldova (MOL) | Central African Republic (CAR)<br>Liberia (LIB)<br>Angola (ANG) |
| 3 | Peru (PER)<br>**Fiji (FIJ)**<br>Mexico (MEX) | Namibia (NAM)<br>Swaziland (SWA)<br>Kenya (KEN) | Cuba (CUB)<br>Jamaica (JAM)<br>Libya (LBY) | Zimbabwe (ZIM)<br>**Cambodia (CAM)**<br>Swaziland (SWA) |
| 4 | Argentina (ARG)<br>Ecuador (ECU)<br>**Tonga (TON)** | Oman (OMA)<br>Serbia & Montenegro (YUG)<br>Ukraine (UKR) | **Malaysia (MAL)**<br>Belarus (BLR)<br>Dominica (DOM) | **Maldives (MLD)**<br>Namibia (NAM)<br>Botswana (BOT) |
| 5 | Barbados (BAR)<br>Seychelles (SEY)<br>Malta (MLT) | **Armenia (ARM)**<br>**Azerbaijan (AZE)**<br>Saudi Arabia (SAU) | **Singapore (SIN)**<br>Czech Republic (CZR)<br>Malta (MLT) | **Tuvalu (TUV)**<br>South Africa (SOA)<br>Brazil (BRA) |

**Figure 6. Education and Health Sectors: Outcomes by Input Quintiles**

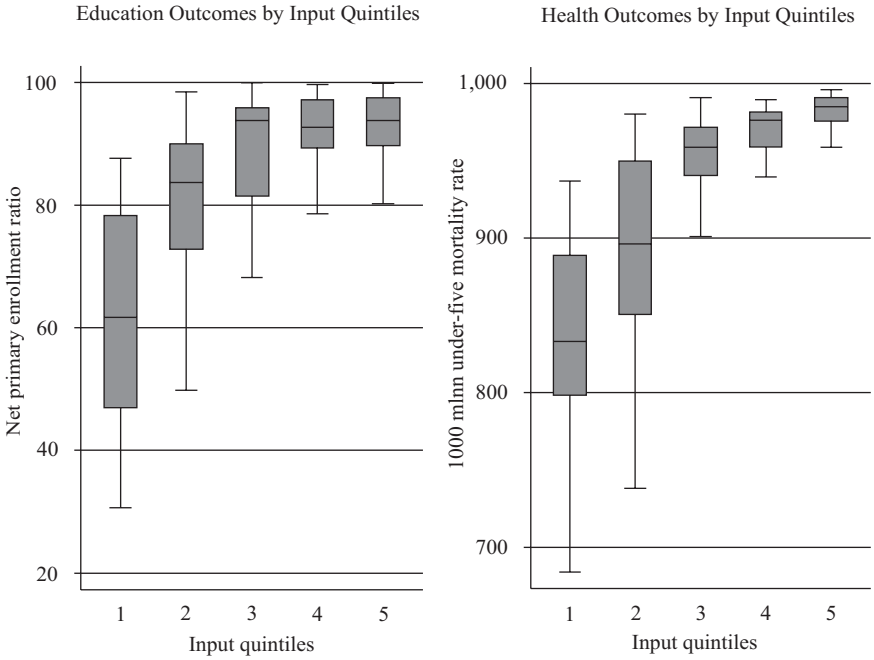
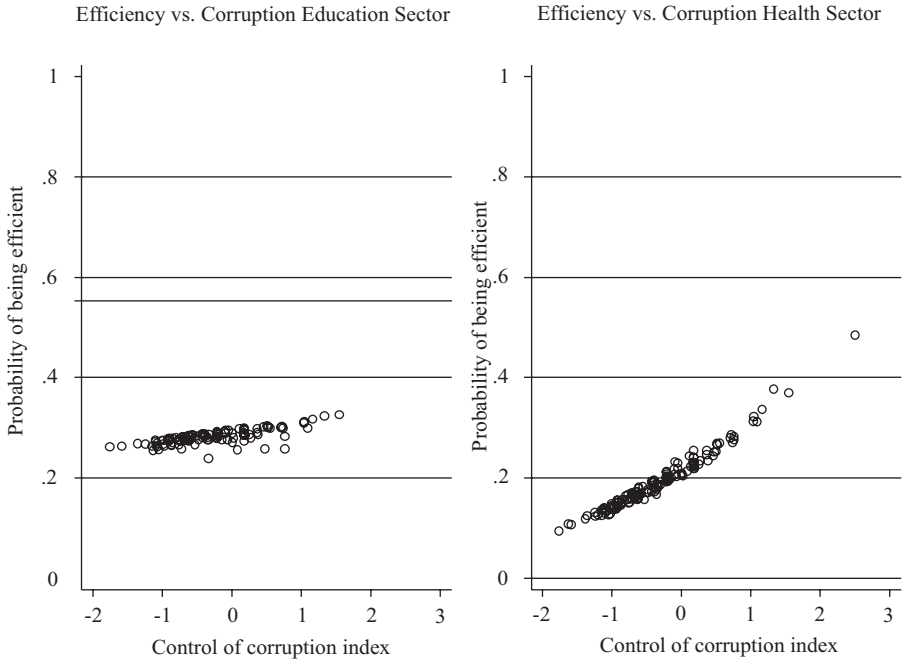


**Figure 7. Education and Health Sectors: Efficiency versus Corruption**




## III. EFFICIENCY OF THE HEALTH SYSTEM IN INDONESIA: A SUBNATIONAL APPLICATION

Arguably, the greatest utility of doing a sectoral efficiency analysis is *within* countries and not *across* countries, the latter often being dismissed by some as being of relevance only for international organizations and donor countries (Haines and Cassels 2004). For policymakers, the most useful information content of a macro system efficiency analysis could come from being able to identify regions or districts within countries that are outperforming others despite resource constraints. Information on efficient subnational regions can be useful for many reasons. First, as a stock-taking exercise, it can help shed light on the extent to which variations in education or health outcomes exist within countries. Second, as mentioned earlier, once such regions or districts are identified, such an analysis can help highlight what factors might be responsible for differences in outcome attainment, and to what extent these are related to resource deficiencies. An oft-cited example is the state of India in Kerala that has stellar education and health outcomes despite having a fairly low income per capita. Good governance, political will, and lower levels of income inequality are often cited as reasons explaining Kerala's efficiency with regard to outcome attainment in the social sector.

This section reports on the results obtained from an exercise done for measuring health system efficiency at the district (*kabupaten*) level in Indonesia (WHO 2005). The potential relevance of such an analysis for policymakers is especially apparent given the recent implementation of decentralization in Indonesia. Instead of using a proxy for resource inputs, the Indonesia subnational application used a more general conceptualization of factors influencing outcomes: these factors were taken to be an index of district-level *constraints* to attainment of district-level health system outcomes.

The approach follows a framework developed by Hanson et al. (2003). In the empirical application of their approach, they categorize constraints in terms of the level at which they operate and the degree to which the effect of the constraint can be overcome by additional resources (Ranson et al. 2003). Hanson et al. consider constraints at three broad levels: (i) community/household; (ii) health service delivery; and (iii) overall environment. Under community/household constraints they look at factors such as female education (which influences demand for health). For health service delivery, they consider indicators such as vaccination coverage (DPT3), number of nurses per 100,000 population, and health infrastructure (proportion of population living within one hour of health facility). For overall environment, they consider a corruption control index, a government effectiveness index, and GDP per capita. They create an overall index: an unweighted average of all three levels of constraint indicators measuring the degree to which it is likely to be difficult for countries to scale up access to health interventions. Although useful, their framework—by mixing both input indicators (such as nurses per capita) with outcome indicators (such as immunization coverage) and with exogenous determinants (such as governance)—potentially dilutes the recovery of critical information content regarding the efficiency of health systems.

In the application to the district level in Indonesia, we follow a modification of the Hanson et al. (2003) approach. We create an outcome index (composed of a weighted average of complete immunization coverage, skilled birth attendance, iodized salt content, catastrophic expenditure, and life expectancy); and an input index (a weighted average of estimated permanent income, female education, nurses per 100,000, out-of-pocket health expenditure, and access to health facilities).[7] The output index consists of health system outcomes including an index measuring the extent to which the population is protected from impoverishment (catastrophic expenditure). The framework adapts the one used by the World Health Organization in its country-level efficiency analysis (WHO 2000). Figure 8 plots the outcome index versus the input index

[7]The weights were derived using confirmatory factor analysis assuming one outcome factor and one input factor. However, the analysis is not sensitive to choice of weights and factors: similar results were obtained using an unweighted index.

for 300+ *kabupatens* in Indonesia for which data were available, along with a DEA frontier (some of the districts on or near the frontier are labeled). Figure 9 plots the same data using the simpler approach elaborated in the previous section. As the figures suggest, there are wide variations in district-level health system performance. Resource and environmental constraints are only part of the explanation: other factors such as district-level governance and epidemiological background may need to be studied for further determinants of efficiency analysis. This analysis is part of ongoing research.

**Figure 8. Indonesian District-level Health System Efficiency Analysis--I**

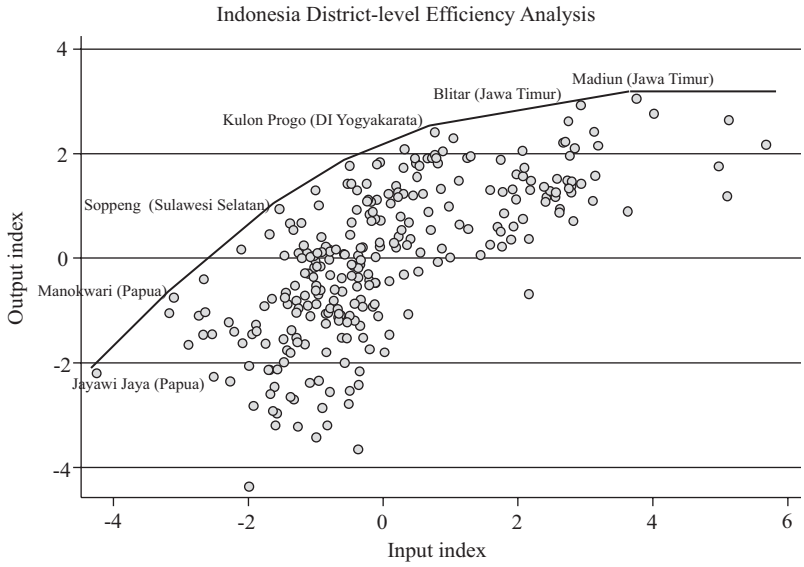
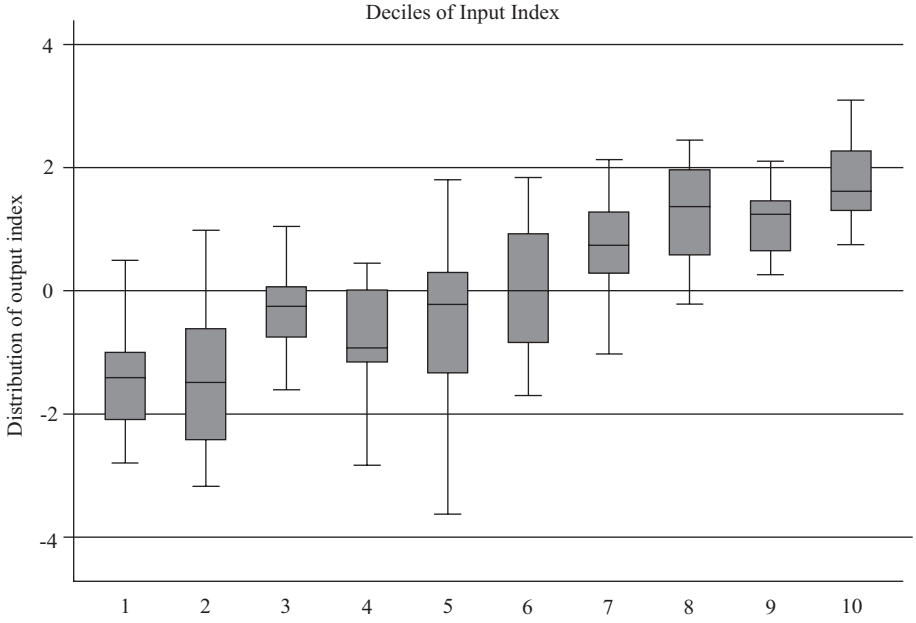


Figure 9. **Indonesian District-level Health System Efficiency Analysis–II**




## IV. CONCLUSIONS

Almost all countries in the world have signed on their commitment to attainment of MDG outcomes. At least part of the effort toward attaining MDGs in the social sector has to come from additional resource outlays to these sectors. However, improvements in efficiency at existing resource levels—or those combined with additional resource outlays—provide one more mechanism by which progress can be made. Frontier production analysis provides one simple framework within which to examine these efficiency-related issues at the macro system level such as at the level of the health sector or the education sector.

This paper gives an overview of the application of frontier methods to attain two MDG indicators: net primary enrollment for education and under-five mortality rates for health. We compare the attainment of these MDG outcomes relative to the resource inputs currently available to these sectors. For illustrative purposes, we consider the teacher–pupil ratio as an indicator of the resource inputs to the education sector, and we take health expenditure per capita as a proxy for resources available to the health sector. Although the proxies may be crude, they are used more for expository purposes.

We show how the health and education sectors can be viewed as production units and apply different ways of estimating the frontier to the data: the key point being that the choice of method can yield very different estimates of efficiency. In addition, the complexity of the econometric methods used may not be transparent and the assumptions required too heroic for the data at hand. A simpler approach is to simply derive efficiencies by looking at the distribution of the outcome within different bins of the input index. This method is transparent and easy to explain to non-specialists (including policymakers) and does not require detailed assumptions regarding the distribution of efficiency. It also easily allows us to assess exogenous (environmental) factors that influence efficiency such as governance and control of corruption, yielding insights into what policy-related or other factors may be constraining MDG attainment in the social sectors.

We demonstrate the application of the simpler method to assess *kabupaten* efficiency in attaining health system outcomes in Indonesia. Further research needs to be done in order to assess why is it that some regions in Indonesia are doing better than others. However, knowing who are the best performers is critical to understanding policy options that may allow for improvements in outcomes without—or in addition to—additional resource outlays.

## REFERENCES

ADB. 2004. *Review of the Asian Development Bank's Poverty Reduction Strategy.* Asian Development Bank, Manila, Philippines.

Dreze, J., and A. Sen. 1989. *Hunger and Public Action.* Oxford: Clarendon Press.

Haines, A., and A. Cassels. 2004. "Can the Millennium Development Goals be Attained?" *British Medical Journal* 329:394-7.

Hanson, K., K. Ranson, V. Oliveira-Cruz, and A. Mills. 2003. "Expanding Access to Priority Health Interventions: A Framework for Understanding the Constraints to Scaling Up." *Journal of International Development* 15:1-14.

Jayasuria, R., and Q. Wodon. 2003. Efficiency in Reaching the Millennium Development Goals. World Bank Working Paper No. 9, World Bank, Washington, DC.

Kumbhakar, S., and C. A. K. Lovell. 2000. *Stochastic Frontier Analysis*. Cambridge: Cambridge University Press.

Ranson, M. K., K. Hanson, V. Oliveira-Cruz, and A. Mills. 2003. "Constraints to Expanding Access to Health Interventions: An Empirical Analysis and Country Typology." *Journal of International Development* 15:15-39.

Ravallion, M. 2003. On Measuring Aggregate Social Efficiency. Policy Research Working Paper No. 3166, World Bank, Washington, DC.

Tandon, A., J. Lauer, D. B. Evans, and C. J. L Murray. 2003. "Concepts of Efficiency." In C. J. L. Murray and D.B. Evans, eds., *Health System Performance Assessment: Debates, Methods and Empiricism*. World Health Organization, Geneva.

UNDP. 2003. *Human Development Report: Millennium Development Goals.* New York: Oxford University Press.

World Bank. 2004. *Global Monitoring Report: Policies and Actions for Achieving the Millennium Development Goals and Related Outcomes.* World Bank, Washington, DC.

WHO. 2000. *Health Systems: Improving Performance.* World Health Organization, Geneva.
———. 2005. "Sub-National Health System Performance Assessment in Indonesia." Draft Report. World Health Organization, Geneva.