Can developing countries achieve better health for their populations without increasing expenditures?

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Abstract

This paper assesses the performance of health systems in developing countries in achieving health for their populations. The methodology adopted is the application of Data Envelopment Analysis (DEA) to generate estimates of the efficiency with which health (measured by a range of indicators) is generated from per capita health expenditures. Using 1990 data for 63 developing countries and a series of DEA models, the findings revealed that average performance was relatively poor, though there was considerable regional variation. Overall, however, given expenditure better health outcomes could have been achieved. The results of the different DEA models appear robust to Spearman correlation coefficient tests of 'internal' consistency. In addition, the results are qualitatively consistent with the findings of related studies. Work is in progress to investigate the factors associated with superior performance, and a preliminary Tobit analysis has revealed that the share of foreign aid in health expenditure is positively linked to efficiency in health achievement.

I Introduction

This paper examines the performance of health systems in developing countries in regard to the efficiency with which resources are utilised in order to generate health for their populations. The central question is whether there exists significant potential for developing countries to achieve better health for their populations without increasing real or monetary resource expenditures. In order to answer this question, we estimate the average resource efficiency of health systems across a sample of 63 developing countries using data for the year 1990.

Earlier studies have pointed to the wide variability in health performance across countries (measured on the one dimension of life expectancy) noting that "(some countries) obtain better health for less money", (see World Bank 1993, page 53). This conclusion was reached on the observation that, given the level of GDP and the level of education, certain countries were spending less than average on health (as a percentage of GDP), and yet were obtaining above average health status; other countries, meanwhile, were characterised by higher than expected spending on health but lower than expected health status. It can be deduced that the health system within some countries is more efficient, but raises the question of how much more efficient. For those countries which obtained better than average health but from higher than average health expenditure, an obvious related question is how much lower could expenditure have been in securing the observed health status of the population. The chief contribution of this paper is to offer a more comprehensive model for an aggregate health system efficiency assessment based on an application of the technique known as Data Envelopment Analysis (DEA). This model allows the researcher in health policy to quantify the efficiency with which resources are utilised in the production of health (measured on a number of dimensions) within a country's health system. We then implement a series of DEA models in order to estimate the average efficiency for a group of developing countries, and examine the results generated by these models for evidence of internal and external consistency. Furthermore, we suggest that in the short-term, the production of health may be constrained by factors external to the sector such as the level of economic development and the level of female education. We demonstrate that DEA can incorporate such considerations and re-estimate average efficiency over the short-term defined as the period of time over which these variables cannot be expected to improve.

DEA has recently been used extensively in analysis within health, most often to assess the efficiency of the hospital sector. Studies include that by Hollingsworth and Parkin (1995), Ferrier and Valdmanis (1996), and McKillop, Glass, Kerr and McCallion (1999). Among other applications, DEA models have been used to assess primary health care services (see, Salinas-Jimenez and Smith, 1994) and to compare provision of perinatal services across the UK (see, Thanassoulis, Boussofiane and Dyson, 1998), and to assess the efficiency of Health Maintenance Organizations in the US (see Roseman, Siddharthan and Ahern, 1997).

Advantages of the DEA approach

There are several advantages of the DEA approach adopted by this study to assess the performance of health systems across developing countries. Firstly, it permits one to quantify efficiency (or alternatively inefficiency) in the use of multiple resources to produce multiple health outcomes. As such, the technique allows consideration of the health generated for a number of groups within the country concerned. Among the outcome measures of this study we include indicators of the health of men, women, children and the newly born. The mortality statistics that we employ may be viewed as indicators of the extent to which basic health needs are met. In addition, the use of these measures for four different groups incorporate considerations of the distribution of the services which meet these basic health needs (see Streeten *et al*, 1984). This is an important aspect of any study where there may be inequalities in the provision of or access to health care services across groups. In this respect DEA provides an advance over cross-sectional studies of provision of health measured on one outcome such as that of World Bank (1993). Moreover, on the input side, by permitting the specification of multiple resources, a DEA study allows one to estimate the efficiency with which a variety of human and capital resources are jointly utilised in the production of health.

Furthermore, unlike parametric techniques, estimation does not require precise knowledge of the functional form of the underlying production relationship. This means that the researcher does not confuse inefficiency measurement and misspecification errors. Indeed, DEA analysis affords flexibility in the underlying technologies and values each country's efficiency performance in the most favourable light. The estimate obtained for a country's health sector is in effect a benchmark of its performance against that of the most efficient countries of the sample. Thus we obtain a quantitative estimate of efficiency in the delivery of health given the current performance within developing countries. Arguably, this is more meaningful than estimates of the potential for efficiency improvement made on the basis of an examination of a single country's health sector data. However, as suggested below, detailed research of sectors can yield richer qualitative information on the sources of inefficiency and in that respect can complement a DEA study.

It is desirable that a country be compared with other countries that are not vastly dissimilar, particularly when estimating the potential for efficiency improvements over the short-term. To this end we include only developing countries in our sample, but we have pooled both low- and middle-income countries in order to ensure a sample that is large enough relative to the number of inputs and outputs to yield meaningful analysis (see Nunamaker, 1985 and Lovell, 1993). However, one may wish, for example, to restrict efficient peers to those countries that are at similar levels of economic development and which have made similar progress on social aspects such as education. DEA permits two approaches in this regard. Firstly, one may simply use the output from a run to check which countries are selected as efficient peers, which we do in this paper for the six key models. However, a second, more direct intervention is possible in that one may incorporate 'environmental' variables within the DEA model. For example, for a selection of the models of this study we have restricted the peer countries to be those at a similar level of development and / or whose population are characterised by a similar minimum level of education. This ensures that a country is compared with other countries that face constraints external to the health sector, but which, nonetheless, are at least as binding on health production, at least in the short-term.

Lastly, a DEA study generates quantitative efficiency scores that can then be utilised in a follow-on examination of the factors associated with better performance across health systems of developing countries. One possibility, which we have tried in this paper, is to perform an econometric analysis. However, as detailed below the findings of our preliminary Tobit analyses have been rather disappointing.

II The Methodology

This study employs the non-parametric approach of Färe, Grosskopf and Lovell (1994) which uses the observed input and output data to construct efficiency frontiers, without estimation of parameters. These efficiency frontiers then provide the benchmark against which the performance of an individual unit may be assessed.

The construction of efficiency frontiers

Each country can be considered as a unit producing m=1,….,M (health) outcomes from n = 1….,N inputs. The set of production possibilities, S^t, for each period t = 1,...,T, models the transformation of resource vectors $x^t \in R^N_+$ into outcome vectors $y^t \in R^M_+$ is then given by $S^t = \{(x^t,y^t) : x^t \text{ can produce } y^t\}$. The boundary of this set (the production frontier) represents the transformation of health resources into health outcomes and it is against this (best-practice) efficiency frontier that performance is assessed.

The next step is to construct an empirical production frontier at time t from an observed set of resources and corresponding health outcomes. One can regard the production of 'health' for a country's population from expenditures or resources as the observed activities. The empirical production frontier is formed from best-observed practice among the countries of the sample. In other words, DEA constructs an empirical best practice frontier as a (piecewise linear) envelopment of the observed data.

Efficiency in the production of health is measured relative to this empirical frontier - countries which are operating on (and determine) this frontier are termed efficient and those not operating on the frontier are termed inefficient. The performance of the latter group is inefficient in the sense that the health outcomes observed could have been attained from fewer real or monetary resources. Equivalently, given the level of resource expenditure, better performance on health would have been possible.

In an attempt to clarify what is involved in the above steps, note that the technology S^t can also be modelled by the resource requirement set

$$L^t(y^t) = \{x^t : (x^t, y^t) \varepsilon S^t\} \quad t = 1,...,T \qquad (1)$$

where the resource requirement set $L^t(y^t)$ denotes the collection of all resource vectors x^t that yield at least outcome vector y^t during period t. Technically, the empirical best practice frontier can be estimated as the lower bound of the resource requirement set, $L^t(y^t)$. The resource requirement set, $L^t(y^t)$, encompasses all resource vectors, x^t , which yield at least outcome vector, y^t , during period t.

To estimate $L^t(y^t)$ empirically it is assumed that the sample set constitutes observations on j = 1,...,J countries' health systems, each using n = 1,...,N resources, x^t_{jn}, in each period t = 1,...,T to generate m = 1,...,M outcomes, y^t_{jm}, in each period t = 1,...,T. $L^t(y^t)$ is then estimated from the observed set of resources and outcomes such that the empirical construction of the piecewise linear envelopment of the input requirement set is given by:

$$\begin{aligned} L^t(y^t) = \{x^t : y^t_m \leq \Sigma^J_{j=1} z_j y^t_{jm}, \quad & m = 1,2,\ldots M, \\ \Sigma^J_{j=1} z_j x^t_{jn} \leq x^t_n, \quad & n = 1,2,\ldots N, \\ z_j \geq 0, \quad & j = 1,2,\ldots J\}, \qquad (2) \end{aligned}$$

where z_j is an intensity variable from activity analysis denoting the intensity levels at which each of the J health system activities or countries are (or might conceivably be) operated.

__Measuring resource efficiency relative to the constructed frontier__

For each individual country health system, the resource-based technical efficiency measure for period t can be obtained as:

$$F_i^t(y^t,x^t) = \min\{\lambda : \lambda x^t \varepsilon L^t(y^t)\} \qquad (3)$$

where $0 < F_i^t(y^t,x^t) \leq 1$.

Given the resource measure of technical efficiency (3), a country's resource vector x^t (used in generating y^t) will be located on the efficient frontier when (3) has a value of one. If (3) has a value less than one, the country is classified as inefficient in the production of health relative to best-observed practice. This measure is empirically calculated as the solution to the linear programming problem:

$$F_i^t(y^t,x^t) = \min_{\lambda, z} \lambda$$

$$\text{st} \quad \Sigma^J_{j=1} z_j y^t_{jm} \geq y^t_{jm,} \quad m = 1,\ldots,M,$$

$$\Sigma^J_{j=1} z_j x^t_{jn} \leq \lambda x^t_{jn,} \quad n = 1,\ldots,N,$$

$$z_j \geq 0, \quad j = 1,\ldots,J \qquad (4)$$

where the restrictions on the z variables imply that constant returns to scale is imposed on the reference technology.

__Model Specifications__

This study measures resource efficiency within the health sector for a group of developing countries using a series of DEA models. We believe there to be a number of advantages in using a series of models. Not only are we are able to quantify efficiency within the health sector for the group, but we are also able to comment on the stability of the findings on average efficiency, and on the consistency of the rankings of individual regions and countries as generated by the different models.

As regards the question of which inputs and outputs to include in the empirical models, we have taken care to consider variation in both the input and output vectors. For example, the models (a), (b), (c) and (d) allow variation in both the number and specification of outputs while retaining stability on inputs. Models (e) and (f) both include the same four output measures but allow for differences on inputs. The six key models of the study are detailed below in Box 1.

Box 1

Description of the Models

Model (a) – 7 outputs (child mortality, perinatal mortality, adult male mortality, adult female mortality, TB, % of children immunised (3rd dose DPT) and % immunised against measles) 1 input (health expenditure per capita).
Model (b) – 4 outputs (child mortality, perinatal mortality, adult male mortality, adult female mortality), 1 input (health expenditure per capita).
Model (c) – 5 outputs (child mortality, perinatal mortality, adult male mortality, adult female mortality, TB), 1 input (health expenditure per capita).
Model (d) – 4 outputs (child mortality, adult male mortality, TB, % of children immunised (3rd dose DPT)), 1 input (health expenditure per capita).
Model (e) – 4 outputs (child mortality, perinatal mortality, adult male mortality, adult female mortality, 3 inputs (the number of doctors per 1000 of population, number of hospital beds per 1000 of population, and the number of nurses per 1000 of population).
Model (f) – 4 outputs (child mortality, perinatal mortality, adult male mortality, adult female mortality), 2 inputs (health expenditure per capita and number of hospital beds per 1000 of population).

III Data

This paper analyses data referring to the year 1990 from a sample of 63 developing countries. Classified by income group, the sample includes 31 low-income economies, 26 lower-middle-income economies, and 6 upper-middle-income economies (see World Bank, 1993).

The DEA models employ up to seven 'outputs' or indicators of the health enjoyed by the respective population. These outputs include four measures of population mortality. More specifically, the adult male and adult female mortality rate (defined as the probability of dying between ages 15 and 60), the child mortality rate (defined as the probability of dying by age 5), and the rate of perinatal mortality (defined as the number of deaths after the 28th week of the pregnancy and within 7 days of life per 1000 births). We also include statistics on the annual incidence of tuberculosis (per 100 000 population). Given that we are interested in maximising good health outcomes, we take the reciprocals of the mortality rates and tuberculosis rate as our outputs. Lastly, as regards outputs, we include statistics of the coverage of public immunization programmes that can be regarded as indicators of access to health services and protection against poor health. These are the percentage of children (age less than one year) which have received the measles vaccination, and the percentage which have received the third dose of the diphtheria, whooping cough and tetanus vaccination. These data are all found in the World Development Report of 1993.

On the input side the DEA models include measures of the real and monetary resources expended by the health sector. Information on health expenditures per capita at official exchange rates were obtained from the World Bank (1993). However, it is true to say that that these dollar-converted values fail to reflect the relative purchasing power of currencies. Therefore, it has been necessary to adjust expenditures to take account of price differences across countries by using data on purchasing power parity incomes derived originally from the United Nations Income Comparison Project. In two of the models, (e) and (f), we have made use of information on real resources of the health sector, including human resources (the number of doctors and the number of nurses per 1000 population) and the infrastructure of the health sector (the number of hospital beds per 1000 population). Again, this information was originally collated by the World Health Organisation but is available from World Bank (1993).

IV The Results

The average efficiency of health systems in developing countries

Table 1 presents the mean efficiency score generated by the country data for each of the six models described in Box 1 above. Information is also given on the extent of variation of score across countries (standard deviation) and the number of countries that were found to be efficient by each model. From the results it is clear that the average efficiency is relatively low – varying from 51.2%, model (b), to 61.7% in model (e). Obviously, this suggests that there is potential for considerable improvement in the efficiency of a number of countries' health systems. Namely, given performance on health outcome measures there is potential for at least a 38.3% improvement in efficiency of input usage on average (see results for model e).

The relatively high values for the standard deviation measures in Table 1 however indicate that there is considerable variability in efficiency by country for all model specifications. Taking this into consideration, policymakers and researchers may be more interested in investigating the (benchmark) efficiency score for an individual country. This will provide an estimate of the potential for efficiency improvement in the health sector for that country, and indicate, for example, whether country A is performing better than country B. If data is available for a number of years then it is possible to discern whether a country's performance is improving or worsening relative to best practice in each year.

Table 1

Model	**(a)**	**(b)**	**(c)**	**(d)**	**(e)**	**(f)**
Geometric mean	0.578	0.512	0.574	0.555	0.617	0.587
Standard Deviation	0.222	0.216	0.219	0.227	0.258	0.258
No. efficient	6	3	5	6	12	12
Sample size	63	63	63	63	58	58

Stability of the findings on average efficiency of the group

As regards the estimates of average efficiency shown in Table 1, it is clear that changing either the number or specification of outputs results in little variation in the findings. For example, considering the models, (a), (b), (c) and (d), the maximum difference in estimated efficiency score of the group between these is 0.066. The average results are, however, less robust to variations in the specification of inputs. For example, the DEA models (b), (e) and (f) retain the four mortality statistics as health status outcomes but allow variation in the number and specification of inputs. The findings reveal that the efficiency score of the group varied by up to 0.105 between these models. Model (e) includes measures of real resource use in the health sector (doctors, nurses and hospital beds) and finds efficiency to be 61.7%, on average. The model specification (f) attempts to take account of both current expenditure and infrastructure of the health sector. In the absence of a reliable measure of health infrastructure, 'hospital beds' are included as an input and suitable proxy for the capital stock of the sector. This finds a precedent in Grosskopf and Valdmanis, (1987).

Regional estimates

Table 2 below illustrates the findings on mean efficiency score by region. On the whole the models exhibit the same ranking of regions. Those regions found superior in their efficiency performance include China and 'Other Asia'. However, model (e) that considers the usage of real resources finds a greater comparative lead in the performance of these two regions. Particularly poor average performance is found in the Latin American region, India and the East Europe countries. It is to be expected that different factors may account for the inefficiency within each region. For example, greater inequity in user access to resources may explain some part of the inefficiency found within the Latin America region, but this would be unlikely to be the case for the East European economies. It is known, however, that the latter have experienced a fall in life expectancy after the reforms of 1989 (see UNDP, 1998, page 22) so that the data may be less representative in that it is biased by the problems of transition years in these countries.

Table 2

Model	(a)	(b)	(c)	(d)	(e)	(f)
Sub-Saharan Africa	0.673	0.622	0.665	0.655	0.672	0.627
India	0.408	0.398	0.398	0.397	0.502	0.434
China	0.919	0.897	0.918	0.913	1	0.897
Other Asia	0.693	0.664	0.690	0.648	0.882	0.777
Latin America & Caribbean	0.480	0.406	0.479	0.462	0.649	0.445
Middle Eastern Crescent	0.511	0.416	0.510	0.488	0.514	0.443
Eastern Europe	0.432	0.353	0.431	0.408	0.247	0.353

Internal consistency of the DEA models

Before placing reliance on the efficiency score generated for an individual country (and hence its ranking *vis-à-vis* other countries) one might consider whether the different models rank the countries similarly. Following Parkin and Hollingsworth (1997) this can be regarded as a test of the 'internal consistency' of the findings of the various models.

Firstly, it is recognised that it is a characteristic of the DEA technique that as the number of inputs and outputs is increased relative to the number of observations, a greater number of units may be described as efficient (see, for example, Numamaker, 1995). In this regard we find the models of this study to be relatively stable as regards changes in the number of outputs, when one compares the results for (a), (b), (c) and (d), but increasing the number of inputs results in a greater number of countries found to be operating on the frontier, (when one compares (b), (e) and (f)).

Secondly, in order to test whether the six models produce relative efficiency rankings of the countries that are (statistically) significantly different from one another, we have calculated pairwise Spearman Rank correlation coefficients. The results are shown in Table 3.

Table 3

Model	**(a)**	**(b)**	**(c)**	**(d)**	**(e)**
(b)	0.9018				
(c)	0.9986	0.8942			
(d)	0.9913	0.8850	0.9896		
(e)	0.3481	0.3550	0.3448	0.3234	
(f)	0.8484	0.9594	0.8411	0.8285	0.4331

It was found that the coefficients for the different pairs of models were statistically significantly different from zero and thus the findings can be described as 'internally consistent'. As indicated by the high value for the coefficients in the first three rows of Table 3, models (a), (b), (c) and (d) that allow for variability on outputs would all appear to produce not only similar average results but also very similar rankings or relative efficiency results for the individual countries. Therefore, as regards the specification of a suitable health sector model, one can conclude that the DEA results are unlikely to be unduly sensitive to the configuration of outputs or 'health of the nation' outcome indicators. More importantly from the practical perspective of data collection it appears that little information would be lost by only including the four measures of mortality as outputs as in model (b).

It is interesting to consider the correlation between model (f) and the other specifications. The pairwise correlation coefficients are relatively high (except between (f) and (e)) which would suggest that the relative efficiency ranking of a particular country's current health expenditures is not strongly influenced by the existing stock of health infrastructure.

Specification (e) omits health expenditures and instead includes measures of the number of doctors, nurses and hospital beds among the inputs. Such a model may be useful if one is primarily interested in the efficiency with which real resources are used in the health sector. Moreover, given that statistics on the numbers of doctors, for example, are regularly collected by the World Health Organization, such a model may be viable where health expenditure data is incomplete[1]. However, given the relatively low values of the Spearman coefficients for pairs including (e), it is true to say that the relative rankings of the individual countries may be sensitive to the substitution of measures of physical and human resources for overall health expenditures.

The external consistency of the findings

It is important to consider whether the findings of these DEA models concur with the findings of comparative research on health sectors using different methodologies. While DEA studies can provide information additional to that of studies employing a different methodology, there should be similar patterns and common findings across all studies. Of course, one cannot discount the possibility (though unlikely) that all methodologies may be seriously erroneous but produce similar findings.

It is interesting firstly to investigate which countries are found to be efficient in terms of superior performance on health indicators given per capita health expenditure. Almost without exception, China and Sri Lanka are found to be efficient by the various models. It is interesting to compare these findings with that of the World Development Report (1993)[2]. Using a sample of both developing and industrial countries it was found that China and Sri Lanka obtained better health (measured as life expectancy) for less expenditure. In this respect the findings of the WDR one-dimensional study concur with the findings of this DEA study. It is important to note that the DEA may find some countries to be efficient because health expenditure is exceptionally low. For example, Tanzania, a country that spent only $4 per capita on health in 1990 is found to be on the DEA efficient frontier. Whilst this can be interpreted as meaning that Tanzania is doing as best as possible on health, given its low expenditure, it cannot be regarded as a general model of 'best-practice' in health to be emulated by other countries were health spending is much higher. It is important therefore to check that the DEA models are not classifying Tanzania as an efficient peer for countries where GDP and health spending are much higher. On the whole, this does not appear to be the case.

V External constraints on efficiency in the short-run

It is important to state that the analysis above does not suggest that mere re-organisation of the health sector alone may result in large efficiency gains in the short-term. Rather, it must be considered whether complementary (long-term) investments in other sectors (in particular, education) may also be necessary to enhance production of health in the economy. For example, it is well documented that better–educated mothers are more competent to access and utilise health services for the benefit of their families.

To some extent the efficiency with which a country may generate good health outcomes from real or monetary resources of the health sector may inevitably be influenced, most likely constrained, by factors external to that sector. Where this is true, the failure to make allowance for such 'environmental' factors may give misleading assessments of the performance of the health sector. For example, in the context of a DEA study of primary care in England, Salinas-Jimenez and Smith (1994) found evidence that the exclusion of environmental variables that took account of rates of morbidity and unemployment, strongly influenced the efficiency scores of certain Family Health Service Authorities.

Therefore, in this study we have considered that factors external to the health sector may impact significantly upon its capability to generate good health outcomes. In this regard the most important influences are arguably the level of development of the country and the level of female education. We have run a set of models incorporating indicators of these 'uncontrollable' environmental variables, namely per capita GDP (at purchasing power parity) as an indicator of the level of development, and the rate of female literacy as a variable representing the level of female education. These new models measure the efficiency with which health resources produce health outputs subject to the constraint that peer countries are characterised by equal or worse levels of development and / or education. Thus, given a sample, the efficiency score of each individual country will be at least as high as that generated by a similar model which excludes the environmental variable(s). As a starting point we take a basic model with the array of outputs and inputs as shown for (a) in Box 1 above. The specifications (g), (h) and (i), which are variants on (a), measure technical efficiency in the use of resources, allowing that the country under assessment has a level of female education, model (g), or a level of development, model (h), or both, model (i), which is at least as poor as efficient peers. The results, shown below in Table 4, can be viewed as a measure of the short-term (externally constrained) performance of the health sectors of developing countries.

Table 4

Model	(g)	(h)	(i)
Geometric mean	0.656	0.587	0.661
Standard Deviation	0.240	0.229	0.239
No. efficient	18	8	18
Sample size	63	63	63

By comparison with the results for model (a), Table 4 illustrates the importance of taking account of female education and the capacity to effectively utilise available services for family health. The mean efficiency score generated by model (g) is 0.656 from Table 4, as compared with a value of 0.578 generated by model (a) from Table 1. Once female education is taken into account the findings indicate that a greater number of countries are classed by the DEA analysis as efficient, or exhibiting best-practice given the constraints of the relatively low level of female education. By failing to allow for the influence of this environmental factor one may overestimate the degree of inefficiency and scope for improvement in the health sector alone, at least in the short-run. By contrast, the level of development within the country as measured by per capita income does not appear to exert a significant influence on the production of health from expenditures. Model (h) gives an estimated average efficiency score of 0.587 in Table 4, as compared with 0.578 for model (a) in Table 1.

VI Investigating the factors associated with better efficiency performance

The primary focus of this DEA study was to quantify the average efficiency within the health sectors of developing countries, and to provide an illustration of a technique that one might employ to estimate the extent to which individual countries could improve their resource expenditures given the health produced. However, we have attempted to go a step further and use the information from these scores in order to obtain insight into the factors associated with better efficiency. This involves performing an econometric analysis, more specifically a Tobit analysis. A Tobit analysis is suitable because, by design, DEA assigns a numerical value of one to all units deemed efficient. Following Ferrier and Valdmanis (1996) we proceed by specifying the dependent variable as the reciprocal of the efficiency score (**1/EFF**). The independent variables considered include: the share of total health expenditure in GDP (**SHARE**); the proportion of total health expenditure accounted for by foreign aid (**AID**); the ratio of private to public expenditure on health (**PRIVATE**); the number of hospital beds per 1000 population (**HOSPITAL**); the number of doctors per 1000 population (**DOCTOR**); and, the rate of female literacy (**EDUCATION**). With the inclusion of a constant the general equation to be estimated is thus given by (5) below:

1/EFF = f (CONSTANT, SHARE, AID, PRIVATE, HOSPITAL, DOCTOR, EDUCATION) (5)

We have undertaken three separate Tobit analyses using the efficiency scores obtained from models, (a), (f), and (i) above. The estimates for the coefficients on the independent variables of each of the equations are shown in Table 5 below, with the standard errors given in parentheses. Given that the dependent variable in each case is the reciprocal of the efficiency score, a positive (negative) value for a coefficient indicates that the variable is negatively (positively) correlated with better efficiency.

Table 5

	Model (a)	Model (e)	Model (i)
CONSTANT	2.994 (4.993)***	2.127 (3.589)***	0.748 (1.073)
SHARE	-0.054 (-0.517)	0.017 (0.168)	0.121 (0.983)
AID	-0.025 (-2.167)***	-0.025 (-2.115)***	-0.018 (-1.332)*
PRIVATE	-0.053 (-0.279)	0.017 (0.092)	-0.015 (-0.069)
HOSPITAL	-0.276 (-1.656)*	-0.323 (-1.915)**	0.119 (0.627)
DOCTOR	-0.929 (-0.376)	-0.025 (-0.100)	-0.040 (-0.142)
EDUCATION	0.001 (0.128)	0.004 (0.781)	0.009 (1.409)*

*** indicates that the estimate is statistically significant at the 5% level of significance, ** indicates significance at the 10% level, and * indicates significance at the 20% level.

The results of this preliminary analysis were poor in the sense that few factors could be identified as (statistically) significantly correlated with better efficiency. In particular, the unexpected sign on the variable representing the level of female education is puzzling for equations based on (a) and (e), though this not significant in either case. The analysis found that the share of health expenditure accounted for by foreign aid is positively associated with efficiency in the production of health. This is more likely due to supply-side factors. For example, foreign assistance for the health sector may be likely to result in the direct provision of primary care services, where the marginal impact of additional spending is often greatest. Foreign aid may also be embodied in human resources, which may lead to the transfer and augmentation of professional skills. Arguably, the presence of foreign donors may promote accountability within the sector.

On general assessment, given the argument above that very different factors may account for the inefficiency across regions, this may contribute to the problems of identifying those factors. Econometric equations which included regional dummies were found to have greater explanatory power, but cannot answer the underlying question of which factors are associated with better performance. It may be that a case study comparison of efficient countries may be a more fruitful approach.

VII Conclusion

As demonstrated the DEA technique allows a much richer assessment of the efficiency of a country's health system. In particular, DEA models can include multiple resources and indicators of health status. As such, the technique allows an assessment of efficiency both in the use of monetary resources and, in the joint use of several real resources. In addition given the possibility of specifying a number of outputs, DEA models allow one to consider efficiency in the use of resources to meet the basic health needs of various groups of the population, thereby incorporating considerations of the distribution of health services. We have considered a series of DEA models and find the average efficiency of the sample of 63 developing countries to be relatively low.

It has been argued that the efficiency of a health system may be influenced by external factors. By the inclusion of the pertinent 'environmental' variables, one can obtain an assessment of the short-term efficiency of a health system over the period of time when such constraints can be expected to be binding. The results of our analysis indicate that the level of female education is a significant external constraint on health system performance.

Finally, work is in progress to investigate the factors associated with higher efficiency but our preliminary econometric analysis has found this to be positively associated with the share of foreign aid in health care expenditure.

[1] However, the problem with such models is that input set should include all the inputs of the health system which account for the greater part of expenditure, i.e., doctors, nurses and hospital beds at least.

[2] WDR, 1993, pages 53-54. Using other measures of health status, including child mortality, the researchers found similar results.

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