VALUE EFFICIENCY ANALYSIS OF HEALTH SYSTEMS

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Abstract

Measuring the performance of health systems is necessary to orient policy decisions. Lacking a theoretical health production function, benchmarking is the best feasible strategy to establish a relationship between health resources and outcomes. This paper uses Value Efficiency Analysis (VEA) to measure the efficiency of the health systems of 166 countries using data on healthy life expectancy and infant mortality as health outcomes. Expenditure in health and education are used as inputs. The results show that the public share in health expenditure and the weight of health expenditure on public budgets are two factors positively associated with health systems' performance.

Key Words: Data envelopment analysis, Value efficiency analysis, Health system performance, Health outcomes

JEL codes: H51, I12, D24

1. **Introduction**

The increasing efforts of rich and developing countries to improve the quality and quantity of health services call for an objective and accurate assessment of the performance of their health systems. Both policy makers and citizens demand the best possible outcomes from the health system, given the considerable amount of resources devoted to it. However, the measurement of productive efficiency in health care is far from being an easy task. Traditionally, the main difficulty has concerned how to correctly measure the outcome of the health services (Kooreman, 1994). The usual approach is to use measurable intermediate indicators of the services provided (outputs), which are assumed to have a fundamental impact on the health status of the population (outcome).

Health system outcomes may be defined as those changes on the health status of the population that can be attributed to spending on health care (Häkkinen and Joumard, 2007: 5). The World Health Organization database reports information on many variables that conform to this definition (life expectancy, infant mortality, inequality in access, prevalence of certain diseases, etc) for a wide sample of countries in the world. Although there may be some controversy on the appropriateness of some of these variables as relevant outcomes of the health system (Häkkinen and Joumard, 2007: 14), most analyses at the system level have relied on the use of life expectancy and infant mortality to approach the outcomes of the health system (Or, 2000; WHO, 2001; Retzlaff-Roberts et al. 2004; Afonso and St. Aubyn, 2005).

The measurement of health efficiency at the system level of analysis is also subject to a second problem. The health status of a country's population is not only affected by expenditure in health services. Many other factors that relate to the social, economic and natural environment also play an important role (Naylor et al. 2002). Therefore, these influences external to the health system must be accounted for in order to provide accurate estimations of performance. Among all external factors, education has been recognized widely as a main driver of health (Ross and Wu, 1995; Grossman and Kaestner, 2004; Grossman, 2005; Cutler and Lleras-Muney, 2006). Educated people can better interpret and evaluate information and, therefore, can make better choices to improve and preserve health.

In recent years a variety of research studies have been published that attempt to measure the efficiency of health systems across the world. Most of them restrict the sample to the OECD member countries and apply non parametric frontier measurement techniques such as DEA-Data Envelopment Analysis or FDH-Free Disposal Hull (Retzlaff-Roberts et al. 2004; Räty and Luoma, 2005; Afonso and St. Aubyn, 2005). But the most influential study was carried out by the World Health Organization in the World Health Report 2000 (WHO, 2001). In this case the analysis included 191 member countries and a synthetic index was constructed weighting five dimensions representing the goals of the health systems. In this paper, we apply frontier analytical techniques, like DEA, to measure the performance of the countries in the WHO sample, using information on health and non-health inputs and health outcomes.

The extreme flexibility of DEA and its ability to handle multiple outputs and inputs in the specification of the production process explains its extensive use in the measurement of health efficiency (Hollingsworth et al. 1999; Puig, 2000; Worthington, 2004). However, DEA also has some drawbacks that limit its application. One of the most important limitations of DEA is its low discriminating power, especially when many dimensions are taken into account and the sample size is limited (Ali, 1994). In those cases, DEA results show a considerable number of efficient DMUs (Decision Making Units), even though some of them would be considered as low performers with a more delicate inspection of the data. These DMUs obtain a score of 100% simply because they are not comparable to the rest of the sample in one on other dimension[1]. In fact, the DEA score is a weighted index of inputs and outputs and each country has an extreme degree of flexibility to choose those weights. In the WHO World Health Report 2000 the five health goal dimensions received fixed weights for all the countries in the sample[2]. DEA does just the opposite. Each country is free to select its own weights and is compared with the achievement that other countries would attain with those particular weights. In fact both approaches may seem as extreme cases. Some flexibility to express differences in specific country goals or values can be desirable but not to the extent of allowing total disparity.

[1] Using the lowest quantity of an input, for instance. This problem is also present in variants of DEA such as FDH.

[2] The use of fixed weights and other aspects of the WHO report have been strongly criticised by Richardson et al. (2003). Lauer et al. (2004) revised the WHO 2000 data to allow for flexible weights in a DEA like setting.

Some recent advances in the DEA methodology, namely VEA-Value Efficiency Analysis, are useful to account for this problem, at the cost of an increased level of analytical complexity. The objective of this paper is to obtain performance scores for all the countries in the WHO database using VEA. We will compare activity data that includes both indicators of results (health outcomes) and resources employed (health and non-health inputs). To avoid the limitations of DEA extreme flexibility of weights we will rely on VEA-Value Efficiency Analysis. This technique is based on DEA but adds a constraint on how input and output weights can be chosen by the different countries within the sample. As a result, VEA significantly improves both the discriminating power of DEA and the consistency of the weights in which the evaluation is based upon. The empirical application also examines if there is some relationship between the direct implication of governments in the financing of health services and the performance of the health system.

The paper is structured as follows. Section 2 briefly reviews the VEA model as an extension of conventional DEA. Section 3 presents the data and Section 4 discusses the empirical results. Concluding remarks are provided in a final section.

2. Methods

To compute the VEA efficiency scores we must first obtain the DEA frontier for the countries in the sample. The DEA frontier identifies the countries that would be considered completely efficient under certain (conservative) assumptions. Even though there are many variants of DEA programs, in this paper we follow the traditional specifications of Charnes et al. (1978) for the constant returns to scale frontier (CRS) and Banker et al. (1984) for the variable returns to scale frontier (VRS). About the orientation of the efficiency model we choose an output orientation because we believe that the main concern of governments and citizens regarding health during the last decades has been to improve the quality and quantity of health services and not cost containment. The CRS DEA model with an output orientation requires solving the next mathematical program for each DMU *i* in the sample[3]:

[3] We describe the dual DEA programs instead of the more usual primal specifications because we will use the weights of inputs and outputs in these dual programs to perform the VEA analysis. Anyway, the primal specification would, of course, reach exactly the same solutions and provide the same performance indicators.

$$\min \frac{\sum_{m=1}^{M} v_m x_{im}}{\sum_{s=1}^{S} u_s y_{is}}$$
$$s.a:$$
$$\frac{\sum_{m=1}^{M} v_m x_{jm}}{\sum_{s=1}^{S} u_s y_{js}} \geq 1 \quad , \quad \forall j \tag{1}$$
$$u_s, v_m \geq 0 \quad , \quad \forall s, m$$

where x_{im} represents the consumption of input m by DMU i, y_{is} represents the production of output s by DMU i, v_m is the shadow price of input m, and u_s is the shadow price of output s. The program finds the set of shadow prices that minimizes the production cost of unit i with respect to the value of its product, conditioned to obtain ratios larger or equal to 1 for all the other DMUs in the sample. If DMU i is efficient optimal shadow prices will give the minimum possible value of the ratio, i.e. 1. Inefficiency would be reflected by a value greater that 1 for the objective function. Fractional program (1) involves some computational complexities. Thus, it may be preferable to solve the following equivalent linear program:

$$\min \sum_{m=1}^{M} v_m x_{im}$$
$$s.a:$$
$$\sum_{s=1}^{S} u_s y_{is} = 1 \tag{2}$$
$$\sum_{s=1}^{S} u_s y_{js} - \sum_{m=1}^{M} v_m x_{jm} \leq 0 \quad , \quad \forall j$$
$$u_s, v_m \geq 0 \quad , \quad \forall s, m$$

This program finds the shadow prices that minimize the cost of DMU i, but normalizing the output value to 1. If DMU i is efficient it will obtain a cost equal to 1, while if it is inefficient it will obtain a value greater than 1. If DMU i is inefficient then the solution to the linear program must identify another DMU in the sample that obtains the minimum cost of 1 with the shadow prices that are most favourable to DMU i. Program (2) is solved for every DMU in the sample, and each of them will obtain its most favourable set of shadow prices for inputs and outputs and the corresponding scores of relative efficiency. For an easier interpretation, it is common to use the inverse of the objective function in (2) as the efficiency score. Therefore, the score is bounded within the (0,1] interval and values lower than 1 reflect the degree of productive inefficiency.

Banker et al. (1984) relax the CRS assumption modifying linear program (2) to allow for VRS:

$$\begin{aligned} &\min \sum_{m=1}^{M} v_m x_{im} + e_i \\ &s.a: \\ &\sum_{s=1}^{S} u_s y_{is} = 1 \\ &\sum_{s=1}^{S} u_s y_{js} - \sum_{m=1}^{M} v_m x_{jm} - e_i \leq 0 \quad , \quad \forall j \\ &u_s, v_m \geq 0 \quad , \quad \forall s, m \end{aligned} \tag{3}$$

where the intercept e_i is added to relax the CRS condition that forced the objective function to pass through the origin in (2). In program (3) that condition will only be satisfied if e^*_i=0. For values greater or smaller than 0 the reference in the frontier for the DMU will be located in a local zone with decreasing or increasing returns to scale, respectively. Most productive activities are subject to variable returns to scale and health is just one of them. It is relatively easy to obtain great improvements in the health level of the population of poor countries with a very limited expenditure in vaccination campaigns, information about common diseases, etc. Increasing returns are observed within these countries. The opposite occurs in rich countries. Obtaining additional increases in the health status of the population in rich countries is much more expensive because of decreasing returns. Thus, we consider that the VRS frontier is the most appropriate to evaluate health efficiency.

A distinctive feature of DEA is the absolute flexibility in the way the linear program can assign weights (shadow prices) for each particular DMU in the sample. Recall that the program is solved independently for each DMU and, then, shadow prices for inputs and outputs may be completely different from one DMU to another. The main argument to defend extreme weight flexibility in DEA is the convenience to obtain an evaluation of the inefficiency of each DMU under its most favourable scenario. However, extreme flexibility may also be object of criticism because it often produces an extreme inconsistency in the values of the shadow prices across DMUs. To avoid this inconsistency the DEA literature has suggested some solutions to restrict the range of acceptable values for those weights (Thompson et al. 1986; Dyson and Thanassoulis, 1988; Allen et al. 1997; Roll et al. 1991; Wong and Besley, 1990; Pedraja et al. 1997; Sarrico and Dyson, 2004).

In turn, the problem of weights restriction methods is that they require making value judgements about the range of shadow prices that is considered appropriate. In order to facilitate the implementation of weight restrictions in practice Halme et al. (1999) proposed an alternative methodology under the name Value Efficiency Analysis (VEA). The objective of VEA is to restrict weights using a simple piece of additional information that must be supplied by an outside expert. The most notable difference between VEA and conventional methods of weights restriction is that instead of establishing appropriate ranges for shadow prices, the expert is simply asked to select one of the DEA-efficient DMUs as his Most Preferred Solution (MPS). Once the MPS is selected, the standard DEA program is supplemented with an additional constraint that forces the weights of the DMU under evaluation (*i*) to make the MPS (*o*) efficient. In other words, the new linear program requires that the optimal shadow prices selected by DMU *i* must also be good for the MPS. As this requirement is made for all the DMUs in the sample, the optimal sets of shadow prices of all the linear programs must be good for the MPS. Thus, the MPS forces a high degree of consistency in the sets of shadow prices across DMUs. An immediate effect of the VEA constraint is that DMUs that obtained a DEA score of 1 just because they had an extreme value in one input or output will only obtain a VEA score equal to 1 if they can resist the additional comparison with the MPS.

The VRS VEA program with an output orientation can be expressed as follows:

$$
\begin{aligned}
&\min \sum_{m=1}^{M} v_m x_{im} + e_i \\
&s.a: \\
&\sum_{s=1}^{S} u_s y_{is} = 1 \\
&\sum_{s=1}^{S} u_s y_{js} - \sum_{m=1}^{M} v_m x_{jm} - e_i \leq 0 \quad , \quad \forall j \\
&\sum_{m=1}^{M} v_m x_{om} + e_i - \sum_{s=1}^{S} u_s y_{os} = 0 \\
&u_s , v_m \geq 0 \quad , \quad \forall s, m
\end{aligned}
\tag{4}
$$

Program (4) is identical to program (3) but the MPS constraint has been added. Thus, the MPS (*o*) must obtain a value of 1 with the shadow prices of DMU (*i*). Indirectly, this requirement restricts the range of shadow prices allowed to the range that makes the MPS (*o*) efficient[4].

A controversial issue in VEA is how to select the MPS (Korhonen et al. 1998). Our empirical setting is designed to evaluate efficiency of countries regarding their health achievements. In this context, it would be difficult to find an expert that would provide the MPS. We propose a new alternative method that avoids supplying any external information. We will perform various VEA analyses considering each of the countries that are DEA efficient as the MPS. Then, we will compute the average reduction in the variation of the shadow prices of the variables included in the VEA model. The country that achieves the greatest reduction in the variation of shadow prices would be our selected MPS. This approach has two advantages. First, it is objective and does not require the implication of an outside expert. Second, it obtains the greatest possible congruence in the shadow prices of the set of linear programs that are computed to calculate the value efficiency scores. Thus, it seems very in accordance with the objective we were pursuing with the implementation of VEA instead of DEA.

[4] We used the software LINGO to solve the DEA and VEA programs of this research. While many packages are pre-programmed to solve DEA, we are not aware of anyone that can solve VEA. However, any mathematical programming software can be used.

3. Data

We are interested in measuring value efficiency scores for all the countries in the WHO database for the year 2002. However, at the moment the required data were not available for some of the countries and, therefore, they were excluded from the analysis. The final sample includes a total of 166 countries which is sufficiently large and representative. We followed existing literature to choose the variables that could reasonably approach the relevant dimensions of health production at the system level of analysis (Table 1).

To approach the output of the health system we follow the specification that has been common in previous empirical research (Retzlaff-Roberts et al. 2004; Afonso and St. Aubyn, 2005; Räty and Luoma, 2005). Life expectancy is a variable that is widely available and can be considered as a long run global result of the health system of a country. Countries with bad access to health services, poor quality of health care centres and physicians and low expenditure in medicines would, in general, have a low average life expectancy. In contrast, it is reasonable to assume that many (although not all) health care services should translate into a higher life expectancy for the population. However, adding years to life is not per se a desirable goal for a health system[5]. Life expectancy is a quantitative indicator that should be complemented with some reference to the quality of those years of life. The WHO database provides a variable that approaches the Healthy Life Expectancy of the population, which indicates for each country the years of life that a person that is born today can expect to live in good health conditions[6].

The second output variable that has been widely used in previous literature is infant mortality. Although there are also many factors that influence infant mortality, access to health resources (medicines, medical advise, vaccinations, etc.) should produce lower indices of infant mortality. Unfortunately the WHO does not provide data on infant mortality for the year 2002. Thus we had to use the data for 2004, while the rest of the data refer to 2002[7].

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[5] It is a common trade off to consider, even at the individual level of analysis, whether to add more years to life or more life to the years.
[6] Using Healthy Expectancy of Life we depart from most studies that use Expectancy of Life.
[7] Alternatively we could have chosen 2004 as the year to analyse. However, Healthy Life Expectancy data were only available for 2002. This is the reason why we choose this year for the empirical analysis.

The input variables should capture the magnitude of the resources committed to health production services and other environmental or social factors that influence the health status of the population. The resources devoted to the health system are approached by Per Capita Total Expenditure in Health in Parity of Purchasing Power $US (PPP)[8]. Using PPP expenditure facilitates cross-country comparisons (Gupta and Verhoeven, 2001). But health resources are not the only input in the health production process. It has been argued that the social environment greatly influences the health status of the population (Naylor et al. 2002). An appropriate and available proxy for the beneficial influences of the social environment is the level of education. The basic argument is that a person that is better educated would make healthier choices (Cowell, 2006). Additionally, education is an excellent proxy of other social dimensions that may influence health (nutrition, hygiene, use of health services, working conditions, etc.). We use as an indicator of the level of education the School Life Expectancy (Years)[9].

Table 2 succinctly describes the variables used as inputs and outputs in our empirical analysis[10]. There are great inequalities across countries in every dimension of the health production model. Perhaps the most striking differences concern infant mortality rates. This index represents the number of children that die during the first year of life per 1000 live births. The minimum of 2 corresponds to Iceland and reflects the situation of most developed countries. In contrast Sierra Leone and Afghanistan with 165 are the most extreme cases of underdeveloped countries that also suffer from war and violence. If we look at an input dimension we obtain a similar picture. The Democratic Republic of the Congo, with 7.35$ PPP is the country that spends less in health per capita and is representative of underdeveloped countries mostly in Africa and Asia. On the opposite hand, the USA spends 5342$ PPP followed by Norway with 4127, representing the developed and rich part of the world. However, these figures do not guarantee that this money is being spent efficiently. The relationship between resources and outcomes will give us the indicator of performance.

4. Results

The DEA model was run to obtain an initial efficiency frontier. This is a necessary step to know which countries are located on the frontier and, thus, can be

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[8] To compute this variable we multiply the Total Expenditure on Health as percentage of GDP by the GDP per capita in PPP $US. This last variable was extracted from the International Monetary Fund database.

[9] This variable was taken from the UNESCO online database.

considered as candidates to be the MPS for the VEA analysis. Table 3 summarizes the DEA results for the 166 countries grouped by broad geographic areas. European countries are the most efficient on average followed by American and Oceanic countries. As expected, African countries are the least efficient followed by Asian countries. It is noticeable though that Africa is the continent with the largest number of DEA efficient countries. On the opposite hand, we were not able to find any efficient country within the North American area or Oceania.

Overall, the minimum efficiency score is obtained by Lesotho in Southern Africa. With 31.5 years of healthy life expectancy and 55 deaths for each 1000 live births, this country obtains an index of just 0.53, which means that an improvement of 88% in health results could be achieved with a better use of resources. In this particular case this improvement would add 27.8 more years of healthy life and avoid 33.6 deaths out of each 1000 new births. It can also be noticed that the standard deviation is very high in Africa while it is moderate in Europe and America.

A total of 19 countries in the sample obtain a DEA score equal to 1, which means they cannot make any (relative) improvement, given the data observed and the structure of the DEA program. Some of them are rich countries with very good health outcomes (Iceland, Japan) and a balanced commitment of resources to the health sector. However, many other DEA efficient countries are poor countries with very poor health outcomes (Niger, Zimbabwe, Djibouti, Dem. Rep. of the Congo, Sudan). There are two views of this finding. First, poor countries need referents that, in general, cannot be rich countries [5]. Thus, for the standard conditions of many countries in the sample (most of them in Africa and Asia), some of these DEA-efficient countries can be a good reference, even though their health outcomes may seem unreasonable from the viewpoint of developed countries. The second view of these results is that DEA is very flexible in evaluating extreme countries. These countries may assign unreasonable weights to inputs and/or outputs in the DEA program to reach complete DEA-efficiency[11].

[10] The complete data of inputs and outputs for the 166 countries is reported in Table 5.

[11] Both views are partially right. While some countries with poor health results that spend little in health may serve as a referent to countries with still worse results and higher expenditure, many others may be just extreme cases that achieve the DEA efficient frontier just because they are not comparable in some dimension. For example, Niger is the country with the lowest school life expectancy in the sample and this circumstance makes it DEA efficient no matter its life expectancy or infant mortality figures.

In our view, the results of the DEA analysis evidence the strong limitations of this technique. Many countries with poor results are considered efficient simply because there is no other country that does better in some dimension of the production setting. In other words, the flexibility of the weights allows some countries to put a very low value in those dimensions in which they perform poorly and a high value in those dimensions in which they perform better. Niger for instance achieves full DEA efficiency giving school life expectancy a very high value (cost), since it is the country with the lowest school life expectancy in the sample. It would no matter if this country reduced its life expectancy to a half. It would still be DEA-efficient.

To increase the discriminating power of DEA and achieve a higher degree of congruence in the shadow prices assigned by the different countries in the DEA linear programs, we solved 19 VEA analyses using as MPS each of the 19 countries that form the DEA efficiency frontier. For each VEA analysis we compute the coefficient of variation of the weights of each input and output and the average coefficient of variation. The lowest average is achieved when Chile is taken as VEA reference as shown in Table 4. Therefore, we select Chile as the MPS for the VEA analysis. Table 4 also shows the countries that are DEA efficient but are no VEA efficient when Chile is taken as the MPS.

Chile is an efficient country, as indicated by the DEA frontier, and also has nice health results in the indicators of healthy life expectancy (67.5 years) and infant mortality (8 deaths in 1000 births). There are, of course, countries in the sample that would seem a better reference for developed countries (i.e., Japan). However, the MPS has to be an appropriate reference also for underdeveloped countries. Although the health outcomes of Chile are close to those obtained in the developed part of the world, its level of per capita expenditure in health (631$) is closer to the figures of developing countries and not far from many underdeveloped countries. Thus, it seems a reasonable MPS for our VEA. The results of the VEA (Table 5) show a dramatic reduction in the number of countries that are considered efficient and also in the value of the efficiency scores. Remember that now the efficiency program search the weights that maximize the efficiency of the country but those weights must make Chile efficient (i.e. must be reasonable according to our reasonable MPS, Chile).

The number of efficient countries reduces from 19 (DEA) to 8 (VEA). This means that only 8 countries in the sample are efficient when using weights that are reasonable for Chile. These countries are Viet Nam, China, Estonia, Georgia, Costa Rica, Czech Republic, Japan and, of course, Chile. To see how unreasonable some DEA results can be, the VEA score for Niger is just 0.58, while it was completely efficient under the DEA program. The Democratic Republic of the Congo, Zimbabwe and Djibouti also fall from complete DEA-efficient to VEA scores under 0.7. In fact, from the 7 DEA efficient African countries no one survives the VEA restriction. Viet Nam and China are the countries that serve now as referents to underdeveloped countries. VEA also adds coherence in the case of rich countries. For example, the efficiency of the United States drops from 0.92 to 0.75. This happens because, under the VEA constraints, the United States can no longer give a weight of 0 to per capita expenditure. Something similar happens to Iceland that drops from 1 to 0.96 when it is not allowed to give education a weight 0.

The least VEA efficient country is Sierra Leone with a score of 0.46, followed by Lesotho (0.50) and Swaziland (0.52). Europe continues to be the most VEA efficient geographic area, followed by Latin America & Caribbean and Oceania. On average, Asian countries are also a little bit more efficient than North American countries and Africa remains the most inefficient area by far. The standard deviation is high in Africa, Asia and North America while it remains moderate in the rest of the world. Complete results for the 166 countries are provided in Table 6.

Now that we have the value efficiency scores estimated for the entire sample, we are interested in testing whether there is some relationship between the implication of the public sector in the provision and financing of health services and the global performance of the health system. For this purpose, we have compiled data on two variables from the WHO database, namely the "general government expenditure on health as percentage of total expenditure on health" (GIMP) and the "general government expenditure on health as percentage of total government expenditure" (HREL)[12]. Regression analysis is not an appropriate statistical tool to contrast the relationship between DEA or VEA scores and possible explanatory variables. The reason is that these scores are not normally distributed because they are bounded by one.

[12] We refer to these variables as government implication on health financing (GIMP) and health relevance in public budgets (HREL).

More important, the scores are not iid. Therefore non parametric rank based tests are preferable[13].

We ranked countries based on their VEA score and then assign them to 4 efficiency groups of equal size. Then, we used the Kruskal-Wallis non parametric test to contrast the existence of significant differences across the 4 efficiency groups with respect to the variables that reflect the government role in the health system. Table 6 shows the average values for the VEA score and the variables of government implication (GIMP) and health relevance in public budgets (HREL). It is clear from the table that the most efficient groups of countries also have a higher government implication in financing health services. In the most efficient countries (group 4) 62.9% of health expenditure is public expenditure on average, which means that almost two thirds of the system has a public base. In the opposite hand, low efficiency countries have an average of public expenditure on health below 50%. The differences across groups are statistically significant at the 0,01 level. The relevance of health expenditure within the government budget is also positively associated with the performance of the health system. The most efficient countries dedicate an average of 11.4% of the government budget to the health system, while this figure drops to 9.2% in countries with a low efficiency score. The differences are significant at the 0,05 level. Thus, our results support that an active involvement of governments in the health system is positive to achieve the highest efficiency in the use of resources.

5. Concluding remarks

This paper provides additional evidence about the deficit in the discriminating power of DEA when DMUs are free to select the weights of inputs and outputs in the linear programs. There are three ways to improve the discriminating power of DEA. First, the simplest procedure is to reduce the number of input-output dimensions to be considered in the model specification. The cost of this approach is that information that may be relevant to discriminate is overlooked. Second, the sample size may be increased. Theoretically, this would be the best solution although, unfortunately, it may be not feasible (in practice) when the researcher is working with complete populations, as it is often the case. A third approach is to improve the discriminating power of the

[13] For further discussion about the application of non-parametric rank-based statistics to efficiency scores see Brockett and Golany (1996) and Sueyoshi and Aoki (2001).

model by supplying some additional information on how the discrimination must be done. Value Efficiency Analysis (VEA) was developed to easily incorporate a piece of qualitative information within the DEA specification. This information corresponds to the identification of a Most Preferred Solution (MPS) that acts as an ideal reference on the eyes of an expert. Our results show that VEA significantly increases the discriminating power of DEA and achieves congruence in the weights of inputs and outputs.

The paper applied both DEA and VEA methodologies to health data on a sample of 166 countries during the year 2002. The sample includes all the countries for which we were able to compile the required data on inputs and outputs. Our sample nearly comprises the whole population of countries in the world (around 86%). Thus, it is not possible to significantly improve the discriminating power of DEA by increasing the sample size. The DEA scores show moderately high levels of efficiency in health provision, with an average of 0.90. However, VEA analysis only shows an average of 0.85 when consistency in shadow prices is forced. Just incorporating information on an efficient country that is considered as an appropriate general referent (MPS), VEA notably increases the discriminating power.

From 19 DEA efficient countries we obtain just 8 VEA efficient ones. In reality what is happening is that VEA allows a simple identification of the countries which DEA score is based on unrealistic values for the shadow prices of inputs and outputs. These countries (Niger or Zimbabwe, for instance) benefit from the extreme flexibility of DEA but do not resist any further analysis on their activity data. For example, one DMU may obtain a DEA score of 1 simply because it is the unit that produces the largest quantity of an output and, thus, assigns a very large weight to that variable. VEA does not allow this extreme flexibility. The behaviour must be globally acceptable. The MPS indicates what is considered as a globally acceptable behaviour. We followed an innovative approach to objectively select the MPS. We estimated VEA results using as MPS each of the 19 DEA-efficient countries. Then we computed the reduction in the average dispersion of the weights of inputs and outputs and selected as MPS the country that got the highest reduction in dispersion. Chile was the MPS in our sample. This country achieves a 72% reduction in the average coefficient of variation of the weights in the linear programs of the 166 countries that compose the sample, with respect to the

DEA formulation. Thus, the improvement in the discriminating power of VEA is obtained with a better rationality in the selection of shadow prices in the mathematical programs.

The role of governments in financing the health system is a controversial issue. It is commonly stated that private health insurance tends to incur higher management and administrative costs than statutory health insurance (Thomson and Mossialos, 2004). The need to generate a profit is another opportunity cost that public systems do not incur. Our results strongly support public financing of health services. The most efficient countries in our sample have 62.9% of the health system publicly financed, while the least efficient countries hardly reach 50%. The weight of health in the government budget is also positively associated to efficiency. Thus, not only the countries which governments show a deeper commitment with the development and financing of the health system have better services and, therefore, better outcomes. They also use their resources more efficiently.

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Table 1. Variables selected to approach the health production process

Inputs	Outputs
Per Capita Total Expenditure in Health PPP	Healthy Life Expectancy
Expected Years of Education (2004)	Infant Mortality

Table 2. Descriptive statistics of inputs and outputs

	Average	Min	Max	SD
P. cap. total exp. in health PPP ($)	705.6	7.35	5342	984.2
School Life Expectancy	11.6	3.11	20.6	3.5
Healthy life expectancy	57.2	28.5	75.0	11.3
Infant mortality	42.1	2	165	40.7

Table 3. Summary of DEA results by geographic areas

	n	Average	Min	Max	SD	Efficient
Africa	51	0.82	0.53	1.00	0.14	7
Asia	40	0.92	0.78	1.00	0.06	6
Europe	36	0.96	0.93	1.00	0.02	4
Latin America & Caribbean	28	0.93	0.84	1.00	0.04	2
Oceania	8	0.93	0.81	0.97	0.05	0
North America	3	0.95	0.92	0.97	0.03	0
Total	166	0.90	0.53	1	0.10	19

Table 4. Average coefficient of variation of weights for different DEA Efficient countries

Country	CV	Country	CV	Country	CV
Bangladesh*	2.54	Dem. Rep. Congo*	1.02	Japan	1.15
Belarus*	1.47	Djibouti*	1.82	Niger*	0.93
Chile	**0.88**	Eritrea*	1.32	Pakistan*	1.16
China	1.08	Estonia	3.36	Sudan*	2.80
Comoros*	2.41	Georgia	1.38	Viet Nam	2.23
Costa Rica	1.04	Iceland*	0.96	Zimbabwe*	1.20
Czech Republic	1.44				

* These countries are not VEA efficient when Chile is selected as the MPS

Table 5. Summary of VEA results by geographic areas

	n	Average	Min	Max	SD	Efficient
Africa	51	0.70	0.46	0.96	0.14	0
Asia	40	0.89	0.57	1.00	0.09	4
Europe	36	0.94	0.84	1.00	0.04	2
Latin America & Caribbean	28	0.93	0.84	1.00	0.04	2
Oceania	8	0.92	0.81	0.96	0.05	0
North America	3	0.88	0.75	0.97	0.11	0
Total	166	0.85	0.46	1.00	0.14	8

Table 6. Complete VEA results and data on inputs and outputs

Country	VEA RESULTS		INPUTS		OUTPUTS	
	VEA score	VEA rank	Per capita total expenditure in health PPP	Expected years of education	Healthy life expectancy	Infant mortality
Afghanistan	0.570	157	17.6	6.8	35.5	165
Albania	0.946	47	271.5	10.6	61.0	16
Algeria	0.946	48	171.1	12.0	61.0	35
Angola	0.542	161	82.1	3.7	33.5	154
Argentina	0.959	30	687.6	16.4	65.0	16
Armenia	0.953	38	136.3	10.5	61.0	29
Australia	0.931	63	2637.0	20.7	72.5	5
Austria	0.892	92	3077.7	14.8	71.5	5
Azerbaijan	0.897	88	115.4	10.5	57.5	75
Bahamas	0.892	91	1340.2	11.8	63.5	10
Bahrain	0.926	66	945.8	14.4	64.0	9
Bangladesh	0.863	105	27.8	8.6	54.0	56
Barbados	0.941	51	1036.9	13.4	65.5	10
Belarus	0.974	17	381.3	14.2	61.0	8
Belgium	0.909	77	2686.8	18.9	71.0	4
Belize	0.917	71	288.5	12.2	60.0	32
Benin	0.699	137	58.1	7.8	44.0	90
Bhutan	0.825	117	142.1	8.1	53.0	67
Bolivia	0.840	115	209.3	14.2	54.5	54
Botswana	0.532	163	494.1	11.9	35.5	75
Brazil	0.882	97	627.6	14.6	59.5	32
Brunei Darussalam	0.903	83	1602.2	13.5	65.5	8
Bulgaria	0.970	22	534.0	12.8	65.0	12
Burkina Faso	0.583	155	49.7	3.6	35.5	97
Burundi	0.572	156	10.2	5.3	35.0	114
Cambodia	0.746	131	74.7	9.1	47.5	97
Cameroon	0.651	148	89.0	8.8	41.5	87
Canada	0.905	81	2963.9	16.2	72.0	5
Cape Verde	0.960	29	115.3	11.2	61.0	27
Chad	0.658	144	58.4	5.8	41.0	117
Chile	1.000	1	631.9	13.2	67.5	8
China	1.000	1	138.3	10.4	64.0	26
Colombia	0.941	54	371.7	11.2	62.0	18
Comoros	0.876	100	29.6	7.9	54.5	52
Congo	0.723	132	73.9	9.3	46.0	79
Costa Rica	1.000	1	536.7	10.7	67.0	11
Côte d'Ivoire	0.633	149	60.0	6.1	39.5	118
Croatia	0.982	15	838.3	12.6	66.5	6
Cyprus	0.888	95	2281.5	13.0	67.5	4
Czech Republic	1.000	1	1148.4	14.7	68.5	4
Dem. Rep. of Congo	0.608	151	7.4	4.3	37.0	129
Denmark	0.900	85	2608.8	16.4	70.0	4
Djibouti	0.692	139	121.3	3.5	43.0	100
Dominica	0.968	24	429.4	13.4	64.0	12
Dominican Republic	0.907	79	317.2	12.7	59.5	27
Egypt	0.906	80	259.9	11.9	59.0	26
El Salvador	0.900	86	380.9	11.3	59.5	24

Table 6 (continued)

	VEA RESULTS		INPUTS		OUTPUTS	
Country	**VEA score**	**VEA rank**	**Per capita total expenditure in health PPP**	**Expected years of education**	**Healthy life expectancy**	**Infant mortality**
Equatorial Guinea	0.694	138	276.7	9.6	45.5	123
Eritrea	0.820	118	38.7	4.9	50.0	52
Estonia	1.000	1	590.3	15.6	64.0	6
Ethiopia	0.675	141	29.0	5.0	41.5	110
Fiji	0.941	53	167.6	12.9	59.0	16
Finland	0.985	13	1855.9	18.1	71.5	3
France	0.918	70	2742.0	15.5	72.0	4
Gabon	0.763	128	635.7	13.1	51.5	59
Gambia	0.786	123	62.7	7.4	49.5	89
Georgia	1.000	1	166.2	11.9	64.5	41
Germany	0.907	78	2927.3	16.0	72.0	4
Ghana	0.789	122	66.9	7.3	49.5	68
Greece	0.973	19	1693.3	15.4	71.0	4
Grenada	0.878	99	581.4	13.0	59.0	18
Guatemala	0.888	94	214.5	9.3	57.5	33
Guinea	0.719	133	55.7	6.7	45.0	101
Guinea-Bissau	0.657	145	22.3	5.4	40.5	126
Guyana	0.853	111	165.2	12.5	55.0	47
Honduras	0.903	82	213.0	11.3	58.5	31
Hungary	0.934	60	1041.4	15.0	65.0	7
Iceland	0.963	27	2776.8	17.7	73.0	2
India	0.843	113	79.2	8.5	53.5	62
Indonesia	0.921	68	74.9	11.0	58.0	30
Iran (Islamic Republic)	0.863	103	458.8	11.5	57.5	32
Ireland	0.916	73	2354.3	17.0	70.0	5
Israel	0.968	25	1766.2	15.7	71.0	5
Italy	0.969	23	2148.1	15.4	73.0	4
Jamaica	0.989	11	350.5	11.7	65.0	17
Japan	1.000	1	2080.2	14.7	75.0	3
Jordan	0.927	65	344.9	13.0	61.0	23
Kazakhstan	0.862	107	218.6	13.3	56.0	63
Kenya	0.705	136	59.8	8.3	44.5	78
Kiribati	0.811	120	458.4	11.8	54.0	49
Kuwait	0.956	34	1126.4	12.4	67.0	10
Kyrgyzstan	0.863	104	82.2	12.2	55.0	58
Lao People's Dem. R.	0.748	130	47.0	8.5	47.0	65
Latvia	0.941	52	577.6	15.0	63.0	9
Lebanon	0.871	102	1018.3	12.6	60.5	27
Lesotho	0.502	165	67.4	10.0	31.5	55
Liberia	0.562	158	11.5	9.7	35.5	157
Libyan Arab Jam.	0.952	41	481.7	16.5	63.5	18
Lithuania	0.945	49	643.6	15.4	63.5	8
Luxembourg	0.839	116	4058.9	13.7	71.5	5
Madagascar	0.770	126	27.5	9.0	48.5	76
Malawi	0.551	160	57.3	9.4	35.0	109
Malaysia	0.994	10	354.5	12.1	63.5	10
Maldives	0.896	89	205.0	12.5	58.0	35
Mali	0.603	152	51.0	5.9	37.5	121
Malta	0.858	109	3691.2	14.0	71.5	5
Mauritania	0.713	135	49.5	7.1	44.5	78

Table 6 (continued)

Country	VEA RESULTS		INPUTS		OUTPUTS	
	VEA score	VEA rank	Per capita total expenditure in health PPP	Expected years of education	Healthy life expectancy	Infant mortality
Mauritius	0.964	26	350.9	12.7	62.5	12
Mexico	0.971	21	620.4	12.5	65.5	23
Mongolia	0.862	106	162.7	10.3	55.5	41
Morocco	0.934	59	150.4	9.3	60.0	38
Mozambique	0.593	153	27.3	7.6	37.0	102
Namibia	0.670	142	232.7	11.1	43.5	42
Nepal	0.816	119	56.2	8.8	51.5	59
Netherlands	0.910	76	2766.8	16.3	71.5	4
New Zealand	0.962	28	1744.4	18.5	70.5	5
Nicaragua	0.955	36	171.5	10.5	61.5	31
Niger	0.585	154	21.1	3.1	35.5	152
Nigeria	0.653	147	72.9	8.3	41.5	103
Norway	0.841	114	4127.1	17.1	72.0	3
Oman	0.957	33	559.3	11.6	64.0	10
Pakistan	0.856	110	42.9	5.8	53.0	80
Panama	0.984	14	546.1	13.2	66.0	19
Paraguay	0.950	43	282.4	12.6	62.0	21
Peru	0.939	57	247.3	13.9	61.0	24
Philippines	0.949	45	74.4	11.9	59.5	26
Poland	0.974	18	696.8	15.5	65.5	7
Portugal	0.953	37	1677.4	16.0	69.5	4
Qatar	0.887	96	1850.5	12.1	65.5	10
Republic of Korea	0.999	9	941.3	15.8	68.0	5
Republic of Moldova	0.944	50	112.8	11.6	59.5	23
Romania	0.952	39	403.4	12.6	63.0	17
Russian Federation	0.871	101	566.2	13.1	58.5	13
Rwanda	0.609	150	27.1	7.3	38.0	118
Saint Kitts and Nevis	0.913	75	604.8	14.1	61.5	18
Saint Lucia	0.955	35	386.6	13.4	62.5	12
S. Vincent & Grenad.	0.924	67	386.7	11.2	61.0	19
Samoa	0.916	72	241.9	12.2	59.5	25
Sao Tome and Principe	0.852	112	100.2	9.8	54.5	75
Saudi Arabia	0.901	84	774.0	12.8	61.5	22
Senegal	0.770	127	70.3	6.0	48.0	78
Seychelles	0.894	90	775.1	13.7	61.0	12
Sierra Leone	0.459	166	16.7	6.9	28.5	165
Slovakia	0.958	31	897.4	13.8	66.0	7
Slovenia	0.950	44	1720.5	16.0	69.5	4
Solomon Islands	0.899	87	70.7	8.1	56.0	34
South Africa	0.654	146	589.9	13.0	44.0	54
Spain	0.989	12	1759.2	15.8	72.5	4
Sudan	0.792	121	51.4	4.6	48.5	62
Suriname	0.889	93	421.1	12.2	59.0	30
Swaziland	0.524	164	214.2	9.3	34.0	102
Sweden	0.948	46	2567.4	18.8	73.5	3
Switzerland	0.880	98	3621.8	14.7	73.0	4
Tajikistan	0.858	108	46.5	10.2	54.5	91
Thailand	0.940	55	201.9	12.6	60.0	18
The FYR of Macedonia	0.952	42	492.2	12.1	63.5	13

Table 6 (continued)

	VEA RESULTS		INPUTS		OUTPUTS	
Country	**VEA score**	**VEA rank**	**Per capita total expenditure in health PPP**	**Expected years of education**	**Healthy life expectancy**	**Infant mortality**
Timor-Leste	0.774	125	176.6	11.1	50.0	64
Togo	0.715	134	32.6	8.7	45.0	79
Tonga	0.952	40	269.6	13.3	62.0	21
Trinidad and Tobago	0.932	62	450.0	10.9	62.0	18
Tunisia	0.957	32	290.6	13.3	62.5	21
Turkey	0.920	69	608.8	11.2	62.0	28
Uganda	0.677	140	56.2	11.2	43.0	81
Ukraine	0.935	58	254.4	13.7	59.5	14
United Arab Emirates	0.930	64	930.4	11.2	64.0	7
United Kingdom	0.939	56	2099.4	16.1	70.5	5
Un. Rep. of Tanzania	0.660	143	34.3	5.3	40.5	78
Un. States of America	0.751	129	5342.0	15.6	69.0	6
Uruguay	0.972	20	715.0	15.1	66.0	12
Uzbekistan	0.932	61	88.1	11.0	59.5	57
Vanuatu	0.915	74	127.4	10.1	58.5	32
Venezuela (Bol. Rep.)	0.975	16	405.9	11.7	64.5	16
Viet Nam	1.000	1	84.1	10.3	61.5	17
Yemen	0.774	124	106.3	8.7	49.5	82
Zambia	0.559	159	63.3	7.0	35.0	104
Zimbabwe	0.535	162	14.9	9.5	33.5	78

Table 7. Government role in the health system and performance

	Group 1	Group 2	Group 3	Group 4	H-KW
n	41	41	42	42	
VEA Score	0.64	0.85	0.92	0.97	
GIMP	46.9	55.1	61.7	62.9	14.9***
HREL	9.2	9.9	11.1	11.4	7.8**

*** Significance level 0.01 ** Significance level 0.05

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