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HEALTH CARE EFFICIENCY ACROSS COUNTRIES: A STOCHASTIC FRONTIER ANALYSIS

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Abstract

This study addresses the increasingly important issue of efficiency of national health care systems. It uses the stochastic frontier technique to estimate a health production function where the inefficiency term is modeled as a linear function of relevant explanatory variables. The results show that inefficiency of national health care systems is inversely related with per capita income and directly related with income inequality. An important policy related finding is that health care systems are more efficient when greater shares of total health care expenditure come from public sources and out of pocket, rather than from private insurance coverage.

Keywords: Health Care, Efficiency, Stochastic Frontier

JEL: C10, I12

1. Introduction

The issue of health care efficiency is becoming increasingly relevant throughout the world. Within the current decade, per capita expenditure on health care has increased significantly in most countries, but improvements in health outcomes have not necessarily followed. In addition, countries with highest health care expenditure per capita are not necessarily those with healthiest populations. For example, in 2007, per capita health expenditure in the United States was 2.7 times that in Japan, but health adjusted life expectancy in Japan was 6 years longer than that in the United States (WHO, 2010).

In 2000, the World Health Organization (WHO) made an attempt to develop econometric methodology and estimate efficiency of national health care systems. *The World Health Report 2000* (WHO, 2000) presented rankings of countries' health care systems by their estimated efficiency, generating much debate, both political and academic. The Scientific Peer Review Group subsequently established by the WHO suggested continuing research in the field of health care efficiency as an ongoing program.

Most studies of health care efficiency use the production-function framework, where health care outcomes are modeled as the output of a health production function, while health care resources—such as spending on health care and population characteristics that influence health—are treated as its inputs. Then, efficiency is measured by estimating the parameters of this production function and calculating the distance between a country's actual level of health output and the maximum level of output that can be obtained from given inputs, which is called the production frontier. Two methods are commonly used to measure production efficiency: deterministic frontier and stochastic frontier. With the deterministic method, all observed data points are constrained to lie below the frontier, and all deviations from the frontier are attributed to inefficiency. With the stochastic frontier method, some of the deviation from the frontier is attributed to random factors.

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Tandon et al. (2003) provide more detailed descriptions of the two methods and their variants.

In the present study, we construct a stochastic frontier health production function with the inefficiency term modeled as a linear function of a set of explanatory variables. Then, we use the latest available data from the WHO and the World Bank to estimate our stochastic frontier equation, which enables us not only to assess productive efficiency of national health care systems, but also to see what factors might be responsible for their inefficiency.

2. The Stochastic Frontier Model

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2. The Stochastic Frontier Model

This study uses the form of the stochastic production frontier model similar to that suggested by Battese and Coelli (1995). The model can be written as follows:

$$\boxed{y_{it} = \mathbf{x}'_{it}\boldsymbol{\beta} + v_{it} - u_{it}}$$

where y_{it} is the logarithm of the variable that measures health outcome (output) in country i at observation t, $\mathbf{x}_{it}$ is the vector of inputs (health care resources) associated with country i and observation t, $\boldsymbol{\beta}$ is the vector of parameters to be estimated, v_{it} is the random component, assumed to be independently identically distributed with a mean of zero and variance σ_v^2, and u_{it} is a non-negative random component associated with production inefficiency, assumed to be independently distributed such that u_{it} is obtained by truncation (at zero) of the normal distribution with the mean $\mathbf{z}'_{it}\boldsymbol{\delta}$ and variance σ_u^2. Thus, the inefficiency component is a function of a set of explanatory variables, $\mathbf{z}_{it}$, and a vector of parameters, $\boldsymbol{\delta}$, to be estimated. The parameters of the production function ($\boldsymbol{\beta}$) and those in the inefficiency component ($\boldsymbol{\delta}$) can be simultaneously estimated by maximum likelihood.

The production inefficiency for country i and observation t, can be expressed as

$$u_{it} = \mathbf{z}'_{it}\boldsymbol{\delta} + w_{it}$$

where the random variable w_{it} is defined by the truncation of the normal distribution with a zero mean and variance σ_u^2, such that the point of truncation is $-\mathbf{z}'_{it}\boldsymbol{\delta}$. Thus, parameters $\boldsymbol{\delta}$ show how variables $\mathbf{z}$ influence the inefficiency term. If a coefficient is positive, then the corresponding variable is contributing to inefficiency, and if is negative, then the variable and the inefficiency term are inversely related.

The health outcome variable (y) used in this study is health-adjusted life expectancy (HALE), which measures the equivalent number of years of life expected to be lived in full health. The WHO calculates this indicator by weighing the years of ill-health according to severity and subtracting them from overall life expectancy. The methodology of calculating HALE is described in detail in Mathers et al. (2003). Although this measure of health outcome is not perfect, it is probably the best available to reflect the health status of the population in a country.

The following variables are included in the model as the inputs of the production function (**x**):

hlthexp total expenditure on health care per capita in international purchasing power parity (PPP) dollars
eduyrs average years of schooling of population over 25 years old
smoke percentage of smokers among adults (over 15 years old)
alcon alcohol consumption per adult person (over 15 years old), liters of pure alcohol per year

These variables are viewed as inputs of the production function because they are believed to directly enter the process of producing health (as opposed to the variables that influence the efficiency of health production, rather than its level). In this regard, since per capita health care expenditure is a monetary measure of a country's resources used in health care, the justification for the inclusion of this variable as an input in the health production function is obvious.

There is also a wide consensus in the literature on educational attainment as an input in the health production function. Empirical evidence on both developed and developing countries shows that education is significantly positively correlated with health outcomes and is likely to be a causal factor in the production of health (see for instance Aka and Dumont (2008), Becker (2007), Cutler and Lleras-Muney (2006), and Guisan and Exposito (2007)). These and other studies suggest that better educated people generally have healthier behaviors. For example, they are more likely to eat a healthier diet, exercise, seek preventive care, and better understand and comply with medical treatments. These behavioral effects on health are found to be rather large (Cutler and Lleras-Muney (2006)).

Although educational attainment is likely to be (negatively) correlated with health risk factors such as smoking and alcohol consumption, those factors themselves are likely to influence health outcomes directly. According to the WHO (2002), tobacco use is the second largest cause of death in the world and is directly responsible for about one in ten adult deaths worldwide. Similarly, excessive alcohol consumption has numerous harmful health effects. In particular, it increases the risk for heart stroke and vascular diseases, as well as liver cirrhosis and certain cancers (Joumard (2008)). Therefore, these factors are included as inputs in the health production function and are expected to be negatively related with the output. Lastly, the year-specific dummy variables are included to account for possible shifts of the production frontier due to technological changes.

The variables included in the inefficiency component (**z**) are:

gnipc gross national income per capita in international PPP dollars
gini the GINI coefficient
pubshr public health care expenditure as a percentage of total health care expenditure
pktshr out-of-pocket healthcare expenditure as a percentage of total healthcare expenditure

Although, as shown in the literature, income is correlated with health outcomes, it can hardly be viewed as an input to the health production process. Higher income by itself does not make people healthier. It does, however, affect health by facilitating access to the goods and services that contribute to improving health and longevity, such as better nutrition and housing. It also enables society to develop better health technologies (Health Systems Performance Assessment (2003), p. 686). In addition, the level of income per capita may also reflect general working conditions in the country, as wealthier economies tend to have a higher share of service industries and occupations, which are considered to be less health-damaging than manufacturing or construction.

The distribution of income is also likely to influence health care efficiency. If a country's per capita income is relatively high only because of a small group of very wealthy citizens, while the majority of population is poor, then only a small fraction of the population has access to health contributing goods and services mentioned above, and the general working conditions are not likely be better than those in lower income countries. It is also important to note that social differences in access to health care are likely to cause misallocation of health care resources by channeling them to those who can afford (often excessive) health care rather than to those who need it most. Therefore, a variable that measures income distribution, the GINI coefficient, is included in the inefficiency component, and a positive sign of this variable's coefficient is expected.

Public share of health care expenditure is a major characteristic of a country's health care policy and therefore is a key variable with regard to the purpose of this study. There is wide variation in the percentage of public healthcare expenditure across countries, reflecting profound differences in health care systems around the world. The question of whether and how public financing of health care affects health outcomes has recently become a subject of hot political debates but received surprisingly little attention in economic literature. The theory is not clear on whether the benefits of public financing of health care, such as improved access to health care resources and reduced health care inequality, tend to outweigh the possible inefficiencies associated with the loss of market incentives. And empirical studies of this issue are scarce, with the results not easily comparable and often contradicting. Berger and Messer (2002), for example, have found that in the OECD countries, a greater share of publicly financed health expenditures is associated with increased mortality rates. But Greene (2004) has found no statistically significant influence of the share of public spending on health care production efficiency across world countries. In the present study, we maintain that public share of health care expenditure influences the efficiency of health care, rather than being an input in the health production function. Therefore, it is included as an explanatory variable in the inefficiency component. Given the absence of both theoretical clarity and conclusive empirical evidence, we have no prior expectation about the sign of this variable's coefficient.

The share of out-of-pocket spending in total health expenditures is another variable that characterizes health care systems, as the relative weight of direct health care payments by individuals is likely to affect their incentives and hence the magnitude and structure of their demand for health services. For example, as shown in the literature, health insurance tends to shift the demand for health care from preventive to acute care and from primary care toward specialty care (Weisbrod (1991)). This means the share of out-of-pocket spending is likely to influence the efficiency of health production, so it is included as a variable in the inefficiency component. But, as with the share of public expenditure, we have no prior expectation about the direction in which out-of-pocket spending influences health care efficiency, since neither a clear theoretical conclusion nor sound empirical evidence could be found in the literature with this regard.

3. Data and Descriptive Statistics

The data are drawn primarily from the WHO statistical databases and the World Bank databanks. The data for most variables in our model are not available on a consistent basis, but come from surveys conducted in different years for different countries. Therefore, compiling a satisfactory longitudinal dataset for the purposes of this study is hardly feasible. Thus, to obtain a sufficient number of reasonably independent observations for our analysis, we pooled the data from randomly selected three years of the current decade (2000, 2003, and 2007). If an observation for a certain year was missing (because the survey for the country was not conducted in that year), the closest year available was used instead. That is, our dataset does not really have a time dimension but rather contains three random observations for each country from the current decade. Since for most variables included in the model cross-country variation is likely to be much more important than time variation, the use of such pooled dataset appears appropriate for the purposes of this study.

From the sample of all countries for which the WHO and World Bank data were available for all variables in our model, we excluded low-income economies (as classified by the World Bank). These countries hardly have health care systems that are characteristic of the modern world and often rely on external help. Therefore, they should be studied separately. Countries that were undergoing a major national distress (such as a war or natural disaster) were also excluded for obvious reasons. Lastly, we have excluded extremely small countries, with population less than one million, as atypical. The resulting sample consists of 78 world countries and is representative of established national healthcare systems of the current decade.

All variables included in the stochastic frontier model are described in Table 1. Health-adjusted life expectancy varies widely across countries, from 37.0 years in Swaziland to 74.7 years in Japan. The cross-country variations in the variables that characterize health care systems are also quite dramatic. Table 2 shows specific numbers for selected economies. Perhaps the most striking observation one can get from these numbers is that the per capita expenditure on health care in the United States is 2.7 times that in Japan and 2.4 times that in the United Kingdom, while health adjusted life expectancy in the United States is shorter than in both those countries. It is also interesting to note that in both the United Kingdom and Japan the share of public expenditure on health care is much larger than that in the United States, while the shares of out-of-pocket spending do not differ much across the three countries. Given these facts, one may speculate that the apparent ineffectiveness of health care spending in the United States is likely due to the country’s heavy reliance on private health insurance, instead of public health care financing in combination with some out-of-pocket spending. This hypothesis, generalized for all countries, can be tested using our stochastic frontier model.

Table 1. Descriptive Statistics for the Variables (Country Averages)

Variable	Mean	Standard deviation	Minimum	Maximum
hale	63.4	7.8	37.0	74.7
hlthexp	1,173	1,194	54	5947
eduyrs	8.9	2.3	3.8	13.0
smoke	26.0	9.5	4.0	50.9
alcon	6.8	4.1	0.0	14.7
gnipc	14,765	11,649	1,581	42,730
gini	38.8	9.9	23.7	70.7
pubshr	59.0	17.5	24.5	88.4
pktshr	31.8	17.6	4.7	70.7

Table 2. Health Adjusted Life Expectancy and Healthcare Expenditures in Selected Countries, 2007

Country	Health adjusted life expectancy (years)	Health care expenditure per capita (PPP dollars)	Share of public expenditure (%)	Share of out-of-pocket expenditure (%)
Australia	74	3,357	67.5	18.0
Brazil	64	837	41.6	34.3
Canada	73	3,900	70.0	14.9
China	66	233	44.7	50.8
France	73	3,709	79.0	6.8
Germany	73	3,588	76.9	13.1
India	56	109	26.2	66.4
Italy	74	2,687	76.5	20.2
Japan	76	2,696	81.3	15.1
Mexico	67	819	45.4	50.8
Nigeria	42	131	25.3	71.6
Russia	60	797	64.2	29.7
South Africa	48	819	41.4	17.4
Spain	74	2,671	71.8	21.1
United Kingdom	72	2,992	81.7	11.4
United States	70	7,285	45.5	12.3

4. Stochastic Frontier Results

The stochastic frontier health production function was estimated with all continuous variables in logarithmic form, with the exception of the variables that are expressed as percentages (*smoke*, *gini*, *pubshr*, and *pktshr*). This enables us to interpret the marginal effects of the health production inputs on HALE and the marginal effects of the explanatory variables in the inefficiency component as elasticities. The estimation results are shown in Table 3.

Table 3. Stochastic Frontier Health Production Function Estimates

Variable	Coefficient	Standard error
Production function		
ln(*hlthexp*)	0.0615*	0.0032
ln(*eduyrs*)	0.2209*	0.1134
$\ln^2$(*eduyrs*)	−0.0532*	0.0267
smoke	−0.0003	0.0003
ln(*alcon*)	−0.0007	0.0034
year 2003	0.0112*	0.0056
year 2007	0.0169*	0.0056
constant	3.5749*	0.1223
Inefficiency component		
ln(*gnipc*)	−0.7280*	0.3274
gini	0.0233*	0.0115
pubshr	−0.0205*	0.0097
pktshr	−0.0204*	0.0093
constant	6.2858*	2.7760
Distributions of *u* and *v*		
σ_u^2	0.0528*	0.0264
σ_v^2	0.0004*	0.0001
γ	0.9917*	0.0044
Number of observations	234	
Wald χ^2	722.9*	
*Indicates statistical significance at 0.05 level (one-tail test in the expected direction or two-tail test if there is no prior expectation).		

The signs of all estimated coefficients, both in the production function and in the inefficiency component, are consistent with theory. The positive effect of per capita health care expenditure on the HALE frontier is statistically significant. The estimated elasticity of HALE with respect to health care spending (0.06) is low, but given very wide variation in the level of per capita health care expenditure across countries (see Table 1), it can be viewed is an important determinant of a country's health production outcome. Both coefficients in the quadratic term reflecting the effect of education are also statistically significant, showing that the elasticity of HALE with respect to years of education diminishes as the level of education rises. For example, the estimated elasticity number is 0.07 at 3 years of education and 0.05 at 5 years, after which it is no longer significantly positive. The expected negative effects on HALE of the risk factors, smoking prevalence and alcohol consumption, are very small and statistically insignificant. This, however, may be partly due to the fact that the WHO data on these factors are often imprecise. The significantly positive but very small coefficients of the year indicators imply that improvements in health care technology played only a minor role in increasing HALE.

As expected, the inefficiency component of the frontier function (*u*) is inversely related with per capita GNI and directly related with income inequality measured by the

GINI coefficient. But perhaps the most interesting finding of this study is that a greater share of public financing in total health spending significantly decreases health care inefficiency. The same is true about the share of out-of-pocket spending. These results support the hypothesis that health care systems that rely heavily on private health insurance are the least efficient ones.

The stochastic frontier model also allows us to obtain efficiency estimates for each national health care system. Health production efficiency for each country was calculated as $E_i = \exp(-u_i)$ and expressed as a percentage. The efficiency scores vary considerably across countries, from 99.4% for Japan to 59.5% for Swaziland. The scores for the countries ranking at the top, however, do not differ much. For example, the difference between Japan (rank 1), and the United Kingdom (rank 22) is only 1.2 percentage points. The results for selected countries are shown in Table 4.

Table 4. Efficiency of Health Care in Selected Countries

Country	Efficiency (%)	Rank
Australia	98.8	7
Brazil	90.4	69
Canada	98.4	17
China	99.4	2
France	98.3	21
Germany	98.5	16
India	91.9	66
Italy	99.0	5
Japan	99.4	1
Mexico	97.8	33
Nigeria	71.2	75
Russia	89.7	70
South Africa	67.3	77
Spain	99.1	3
United Kingdom	98.2	22
United States	91.5	67

5. Conclusions

This study has continued the analysis of efficiency of national health care system initiated by the WHO. To quantify production efficiency of health care, we have constructed a stochastic frontier production function with health adjusted life expectancy (HALE) as the output and per capita expenditure on health care, education, and health risk factors as the inputs. Modeling the inefficiency term as a linear function of a set of explanatory variables has enabled us to identify factors responsible for inefficiency. We have used the latest data from the WHO and the World Bank to obtain stochastic-frontier estimates of both the elasticity of HALE with respect to the production function inputs and the effects of various factors, including the sources of health care financing, on health care efficiency.

The estimated elasticity of HALE with respect to per capita health care spending is as low as 0.06, but given large differences in the level health care expenditure across countries, it can be viewed is an important determinant of a country's HALE. The elasticity of HALE with respect to years of education is also low and diminishes with more education, so the education input can only be regarded as relevant for countries with low levels of education. The negative effects on HALE of the risk factors, smoking and alcohol consumption, are very small and statistically insignificant.

Quantifying the efficiency of national health care systems and identifying factors that cause inefficiency helps to see the potential for improvements and design policies aimed at raising health care efficiency. Our results show that inefficiency of national health care systems is inversely related with per capita income and directly related with income inequality. The result of this study that is most relevant to health policies is that health care is more efficient in countries with greater shares of public financing and out-of-pocket spending in total health care expenditure, which means health care systems that rely more on private health insurance are less efficient. However, since this result has not been confirmed by other studies, further research is needed to substantiate it both theoretically and empirically.

The same is true with regard to our country efficiency ranking. Better data and econometric methods are needed to construct stochastic frontier models that ensure clearer separation of health production inefficiency from cross-country heterogeneity. It should also be noted that our rankings pertain to the efficiency of health care systems, not to absolute levels of their performance. That is, we do not measure or rank countries' levels of health attainment.

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