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Efficiency of Health Care Systems: Stochastic Frontier Analysis Including Innovation Component

Summary: The efficiency of health care system can be evaluated at three levels: the one related to the healing process itself, the organizational one (associated with the functioning of entities providing health care, such as hospitals) and the systemic one (the overall efficiency of health care system). The goal of this paper is to focus on the latter efficiency concept investigating health care systems' performance at the macroeconomic level. In order to analyze this question we apply a parametric stochastic frontier model (SFA) enriched by the innovation component. This specification allows us to construct the health system efficiency ranking among OECD countries, including Poland. Our results limit the impact of raising health expenses and claim the importance of better resource allocation. We also find the positive effect of pharmaceutical innovation on health condition while the innovation related to medical procedures needs to be less time consuming to be efficient.
Keywords: health care system; efficiency; public spending; health policies; stochastic frontier analysis.

Introduction

In the world of ever increasing health care expenditure mixed with the aging population issue, there has been a substantial raise of interest in the efficiency side of health care systems. At the same time, there are different approaches towards efficiency concept itself. More precisely, the efficiency question can be evaluated from both micro- and macroeconomic perspective. The micro level analysis embraces the behavior and functioning of health care providers while the macroeconomic one focuses on the overall performance of the health care system. In this paper we aim at analyzing the macroeconomic context. The macro efficiency measures have recently raised debates in terms of health policy de-

sign, at both national and supra-national levels. Moreover, recent literature frequently addresses the question of efficiency of the health care system, but the existing studies' scope, methodology and timing does differ. For instance, the World Health Organization focuses on assessing a performance of health care systems of its members but it is unclear whether the observed inefficiencies are due to inadequate use of resources or are simply the consequence of the heterogeneity of the large sample of the study (see [8]). The OECD study, in turn, privileges the cost-effectiveness of health systems and aims at identifying the best practices of containing health expenses (see [4]). Another OECD analysis investigates, among others, the influence of lifestyle-related factors (such as: smoking, alcohol consumption), on the health care system performance (see [5]). The econometric panel frontier model has also been applied by Evans D. B. *et al*. in order to evaluate the linkage between the health care system and health status, finding that increasing the resources for health systems is of crucial importance to improve health in poor countries (see [2]).

In our study we have privileged the methodology that reconciles the ease of frontier modeling with the internal cohesion of the sample. That is why we apply a static stochastic frontier analysis to a sample of OECD countries (for an example of dynamic panel frontier analysis see Ogloblin C., 2011, (see [4]). Moreover, for the first time in the literature, our study also controls for medical and pharmaceutical innovation. Finally, our study brings important and interesting insights on efficiency of health system components and allows for an international benchmark. We believe this study to be helpful for health policy makers, as well as for health managers.

The paper is organized as follows: section 1 presents the modeling procedure, section 2 comments our results, while the last section concludes.

1. Methodology and modeling procedure

In this paper we propose the health care efficiency measure based on parametric stochastic frontier model (SFA).

Stochastic production frontiers were first developed by Aigner, Lovell and Schmidt (1977) (see [1]) and Meeusen and van den Broeck (1977) (see [6]). This specification allows for a non-negative random component in the error term to generate a measure of technical inefficiency, or the ratio of actual to expected maximum output, given inputs and existing technology. The essential formulation of this model is:

$$y_i = \alpha + X_i\beta + v_i + u_i, \tag{1}$$

$$v_i, \sim N[0, {\sigma_v}^2] \tag{2}$$

$$u_i \sim N[0, {\sigma_u}^2] \tag{3}$$

where i is indexing firms, y_i stands for the output, x_i describes the set of inputs, v_i is a random component representing stochastic elements (beyond the control of the firm) as well as any firm specific heterogeneity and u_i is the inefficiency in the system, assumed to be firm-specific. Under the assumption that v_i has stochastic properties of a regression model and is uncorrelated with other components of the model, the parameters of the model can be estimated. The firm specific constants embody the technical inefficiency. Following Green (2003) (see [3]) the inefficiencies are estimated by shifting the function upward so that each constant term is measured as a deviation from the benchmark level. Technical efficiency is measured by:

$$TE_i = \frac{E[y_i|x_i,u_i]}{E[y_i|x_i,u_i=0]} \tag{4}$$

The specification described above can easily be applied to sector efficiency studies. In this paper we are concerned with an overall healthcare system performance. Based on the existing literature (see [2], [4], [5] and [7]) we aim at estimating the effectiveness of health care systems within a group of the OECD countries. An accurate assessment of health policies is needed in a way that desired outcomes can be measured in relation to resources used. If the SFA studies related to health care systems efficiency have been blooming recently, they differ, however, in the choice of outcome variable. The novelty of our approach is built upon the use of technology-specific variables that are expected to control for the impact of innovation in medical sector.

The health system outcome variable (y) used in this paper is *HALE* which measures the equivalent number of years of life expected to be lived in full health. *HALE* indicator is provided by the WHO and is defined as an average number of years that a person can expect to live in "full health" by taking into account years lived in less than full health due to disease and/or injury. The variables used as "inputs" (X) in our production function embrace the following:

— *lnthe_pc* – total expenditure on health care per capita in international purchasing power parity (PPP) dollars
— *lneduc* – average years of schooling of population over 25 years old
— *I_DRUGS* – number of pharmaceutical patents
— *I_MED* – number of medical technologies patents
— *lnalc* – alcohol consumption per adult person (over 15 years old), liters of pure alcohol per year

These variables are treated as inputs in our health production function as they are directly responsible for production of health. Moreover, the model requires also to specify the variables that influence the efficiency of the production of health. In our case the "inefficiency component'' is composed of the following variables:

— *lngdp_pc* – gross national income per capita (PPP)

— *GINI* – the Gini income inequality index
— *PHE_PERC* – public health care expenditure as a percentage of total health care expenditure
— *OOP* – out-of-pocket healthcare expenditure as a percentage of total healthcare expenditure

Our data set was compiled from two sources: The World Health Organization and the OECD. In order to guarantee a consistency of our data set, we have eliminated countries for which any relevant information was missing. We have also cared for our data set to be time-consistent. It means that we have preferred a static model over a dynamic panel data model. Therefore, we have chosen year 2007 for which all data was available. Clearly, we wanted all of inputs and inefficiency component variables to match precisely in time the outcome indicator. Moreover, consistent data on pharmaceutical and medical innovation was available only for 2007.

2. Results

The descriptive statistics are summarized in the table 1 below.

Table 1. Descriptive statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
HALE	34	71.52491	2.721801	66	76
Total health expenditure per capita (the_pc)	34	2790.002	1335.435	766.2114	7152.705
Education (educ)	33	10.70606	1.494352	6.2	12.8
Alcohol consumption (alc)	33	9.927273	3.162008	1.3	16.2
GDP per capita	34	33148.31	13348.68	13895.1	84369.28
GINI	34	0.3139466	0.0593774	0.2358975	0.49402
Public health expenditure as percentage of total health care expenditure (PHE_PERC)	33	68.30232	11.1815	40.2297	82.5137
Out-of-pocket healthcare expenditure as a percentage of total healthcare expenditure (OOP)	29	18.17951	7.521053	6	37.48276
Number of pharmaceutical patents (I_DRUGS)	34	336.0294	847.9827	1	4886
Number of medical technologies patents (I_MED)	34	352.8235	1018.132	1	5885

Source: own research.

The *HALE* frontier maximum likelihood estimation results are presented in the table 2.

Table 2. Stochastic frontier estimates

	b/se
HALE	
lnthe_pc	−0.188*** (0.04)
lneduc	0.289 (0.35)
lnI_DRUGS	1.929*** (0.11)
lnI_MED	−0.951*** (0.10)
Lnalc	−1.108*** (0.06)
_cons	72.351*** (0.69)
lnsig2v _cons	−31.479 (382.96)
lnsig2u lngdp_pc	−6.607*** (1.67)
GINI	−55.023** (17.05)
PHE_PERC	−0.297** (0.10)
OOP	−0.130 (0.07)
_cons	109.858*** (28.52)

* $p<0.05$, ** $p<0.01$, *** $p<0.001$

Source: own research.

The estimation procedure came out with some extremely interesting findings. First, the effect of *per capita* health care expenditure on *HALE* is negative and significant. This results stands in opposition to the theory and existing literature. It means that an increase in health expenses is expected to lower the overall health outcome measured by *HALE* (a 1 percent increase in health care expenses reduce the expected life in full health by almost 0,19 percent, which is pretty much). In our opinion this is very important finding as we can expect health care

spending as a source of inefficiency of the health care system. Therefore, this finding provides us with an idea that it is less important *how much* country can spend on health care; what does matter is *how* the money is spend. Another important result is associated with the spread of innovation in the health care sector. We found that the use of innovative drugs is expected to have a positive effect on *HALE*. However, the effect of the innovative medical techniques on health condition is negative; this situation can be explained by the fact that the implementation of new healing/medical procedures requires substantial financial investments mainly in terms of equipment and is also time consuming. Furthermore, the educational attainment has a positive but statistically insignificant impact on health condition measured by *HALE*. Finally, the population's exposure to the risk factors such as alcohol consumption is predicted to reduce the expected life time in good health.

The analysis of the "inefficiency component" tells us that countries having more equally distributed income structure (GINI comes out with a negative sign) are expected to provide its residents with a better health condition. Another interesting finding is that the share of publicly financed spending in total health care spending is predicted to reduce the inefficiency of the system. The same is true for the out-of-pocket spending – but its impact remains statistically insignificant.

Frontier analysis allows us to construct a benchmark of countries, ranked by their efficiency scores. This is represented in the table 3 below.

Table 3. SFA: benchmarking

Italy	0,8329
Korea	0,8013
New Zealand	0,7736
Iceland	0,7355
Israel	0,7167
Switzerland	0,6982
Greece	0,6856
Turkey	0,6467
Australia	0,5775
Japan	0,5760
Czech Republic	0,5629
Sweden	0,5490
Portugal	0,5442
Poland	0,4949
Netherlands	0,4680
Finland	0,3803

Table 3. SFA: benchmarking (cont.)

Ireland	0,2307
Belgium	0,2035
Luxembourg	0,1742
France	0,1595
Canada	0,1459
Estonia	0,1295
Denmark	0,0855
Norway	0,0707
Austria	0,0699
Hungary	0,0301
Germany	0,0066
Chile	n/a
Mexico	n/a
Slovak Republic	n/a
Slovenia	n/a
Spain	n/a
United Kingdom	n/a
United States	n/a

Source: own research.

The efficiency scores for countries in our study range from 0,0066 to 0,8329. If a country has an efficiency score of 0,39 (which is a mean value in our sample) it means that it could produce the same level of output using only 39% of its inputs – the given *HALE* status could be reached by using less resources.

Inefficiency scores for some countries are indeed surprising and require a closer look. For instance, the efficiency leader in our sample is Italy, while the last position is occupied by Germany. If we compare the wealth of these countries, it does not differ much, with $ 35.539,72 for Germany and $ 32.039,27 for Italy (*per capita*, in PPP). Moreover, Germany spends around 10% of its income on health (again, *per capita*) while Italy spends only 8%. Furthermore, Germany holds 75% more of pharmaceutical patents, compared to Italy. Finally, the share of out-of-pocket spending in Italy is nearly two times higher than the same out-of-pocket share in Germany. At the end, the German *HALE* is 73 whereas *HALE* in Italy is 74. In the light of our modeling procedure, the example of Germany-Italy couple provides us with an essential finding that supports efficiency theory: it is possible to use less resources and get better results. We think therefore that this prediction of the model should not be forgotten by policymakers aiming at designing the most economically and socially efficient health care systems.

Conclusion

The efficiency of health care system is an extremely complex issue and its redesigning is not an easy task. The main difficulty of assessing the health system's performance lies within the choice of the right outcome measures. The most often these measures are the health status variables, such as different indicators of life expectancy. In this study we have also applied this measure – the healthy life expectancy. However, we do believe that there are more adequate measures of health care system performance. Nevertheless, the problem is that there is no consensus for applying the unique measure across OECD countries. In our opinion, 'avoidable deaths' could be this unique measure variable.

The results of our study implies that the innovation does play an important role in raising health care status, however, a distinction needs to be made between medical and pharmaceutical innovation. Finally, our study confirms that the efficiently performing health care system cannot only be achieved by increasing health care spending. Many other factors, related to the social, economic and natural environment should also be taken into consideration.

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Efektywność opieki zdrowotnej w Polsce na tle wybranych krajów OECD z uwzględnieniem czynnika innowacyjności

Synopsis: Problem efektywności opieki zdrowotnej jest zagadnieniem niezwykle złożonym. Występują tu bowiem współzależności procesowe, organizacyjne i systemowe. Efektywność może być zatem oceniana na trzech poziomach: efektywność procesowa (procesu leczenia), efektywność organizacyjna (efektywność działalności podmiotów opieki zdrowotnej, np. szpitale, jednostki ambulatoryjnej opieki zdrowotnej) oraz efektywność systemowa (efektywność systemu jako całości).

W artykule przedstawione zostaną wady i zalety stosowania różnych miar efektywności. Przeanalizowane zostaną również wskaźniki efektywności opieki zdrowotnej w Polsce na tle wybranych krajów OECD z uwzględnieniem czynnika innowacyjności. Autorzy podejmą ponadto próbę oceny przyczyn niskiej efektywności opieki zdrowotnej w Polsce oraz próbę odpowiedzi na pytanie: czy istnieje zależność między innowacyjnością kraju a efektywnością opieki zdrowotnej.

Słowa kluczowe: system opieki zdrowotnej, wydajność, wydatki publiczne, polityka zdrowotna.