

Comparing the performance of health systems in providing life expectancy

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Abstract

The health systems of lower and higher level of life expectancy countries should not be compared with each other. Data envelopment analysis, a tool seldom used in demography or public health provides an objective framework for such a comparison. Data on OECD member nations suggest that irrespectively of which life expectancy group a country belongs to, higher expenditure, higher level of education, less tobacco consumption and higher level of preventive and curative care lead to increases in life expectancy. Moreover, benchmarking the performance of a country's health system can help policymakers in setting achievable goals.

Introduction

Mortality in the last decades has been declining rapidly. With few exceptions, life expectancy has risen all around the world (Oeppen and Vaupel 2002). As pointed out by Cutler and Meara (2001:1), “the constancy of mortality reductions masks significant heterogeneity by age, cause and source”. Although factors like increase in income, improved nutrition, hygiene, housing conditions contributed to the steady increase, modern health care systems and medical technology undoubtedly played a key role in this shift.

The impact medical technology and knowledge had and continue to have in the improvement of health outcomes and increase in life expectancy is well documented (Bunker et al. 1994; Preston 1996; Cutler and McClellan 2001; Jamison et al. 2001; Kremer 2002; Macinko, Starfield and Shi, 2003; Soares 2005; Papageorgiou et al. 2007). However, the extent to which health care affects health is determined by access to care. The organisation and funding of a health system determine the ease of access to health care: from universal to based on one's ability to pay. This reflects the wider values of a country – from social to more de-regulated and market driven – which vary dramatically across the world (Esping-Andersen 1990). Moreover, countries differ in the level of expenditure devoted to the health system. This, in turn, may be determined by the value placed on health, the resources available and the way these resources are used. The latter refers to efficiency of a health system, which in a broad sense can be defined as maximising ‘health’ within resources available (Maynard and Bloor, 2011).

Health systems play an important role in helping us understand life expectancy trends, and in this paper we aim to investigate the relationship between efficiency of health systems and life expectancy. As Hoffmann (2011:1986) noted, “ a recent branch of research tries to look more

systematically at categories of welfare states and their performance in terms of relative and absolute health disparities” (Dahl et al. 2006; Eikemo et al. 2008). In our research, we would like to adopt a similar approach but focusing on the relation between health system efficiency and life expectancy. However, not only the health systems contribute to life expectancy. By Preston (1975, 1985), for example, level of education is an important non-health system related aspect of health.

Preston (1975) showed that life expectancy and national income are positively correlated with decreasing returns of life expectancy to income. However, this relationship masks the impact of health policies and health behavior of individuals in different countries.

Our aim is to unravel the magnitude of life expectancy that can be achieved by current health policies and identify factors responsible for providing it.

Data

Here we use health care spending as a proxy for health policies and measure the efficiency of their implementation relatively to other countries. In order to avoid problems of quantifying social determinants of health (McKeown 1976), we focus on cross-sectional comparison of OECD member nations as they are likely to share similar nutrition, housing and living conditions.

Information on the characteristics of the health systems is available in OECD Statistics (OECD 2014). This database contains a range of information on the characteristics of national health systems, such as total health expenditures in percentage of the GDP, the proportion of this expenditures funded publicly and privately, type of health insurance and the percentage of its coverage, number of beds per 1000 population, number of physicians, total health expenditure per capita and other indicators.

Reliable information on life expectancy at birth or remaining life expectancy at certain ages can be found in the Human Mortality Database (HMD 2012).

It is difficult to quantify the impact health care expenditure or number of hospital beds has on the number of years lived. However, it can be observed how effectively individual countries manage their health expenditures. Our research question then can be formulated as “what is the relative efficiency of individual countries in providing life expectancy given their inputs of the health system”.

Methodology

We model the relationship between life expectancy and health care spending non-parametrically by using data envelopment analysis (Banker et al. 1984), a technique that identifies their best practice frontier. Data envelopment analysis is a linear programming technique used in operations research. It is seldom used in the field of public health (Evans et al. 2001; Greene 2004; Despotis 2004; Somarriba and Pena 2009). This nonparametric approach that identifies an efficient frontier based on the attainable production set of the countries. Our approach follows two steps:

1. Use data envelopment analysis to calculate the efficiency of each OECD member nation in providing life expectancy based on their per capita health expenditures.
2. As life expectancy is not solely based on health expenditures, other covariates influence the performance of health care systems as well. To quantify their influence, we regress efficiency on covariates of health care related covariates.

Data envelopment analysis

The optimization program can be summarized as follows (e.g., Cooper et al.2007). Let θ denote efficiency and λ weights,

$$\begin{aligned} \max_{\theta, \lambda} \quad & \theta \\ \text{s. t.} \quad & x_o \geq X\lambda \\ & \theta y_o \leq Y\lambda \\ & e\lambda = 1 \\ & \lambda \geq 0, \end{aligned}$$

where x_o and y_o stand for optimal solution of inputs (X) and outputs(Y), respectively.

The efficiency of a country is defined as the ratio of the weighted sum of its outputs (life expectancy) and the weighted sum of its inputs (health expenditures and indices). The efficient frontier is established by those countries that achieve the maximal life expectancy from a given number of inputs. These countries serve as benchmarks for the less efficient countries whose (in)efficiency is given by their distance from the efficient frontier.

The advantage of using data envelopment analysis versus the traditional parametric approaches (i.e., specifying a functional form of the production function) is that (i) no a priori distribution or functional form is assumed; (ii) the efficiency indices of the countries can be directly compared with each other as each efficiency index envelopes the effect of all inputs; (iii) the optimal weights of the inputs are computed, and not arbitrarily set.

It also allows us to measure the years of life that can be gained by adopting health policies of other nations. In a second step, following Evans et al . (2001) we regress best practice life expectancy on education, health care and policy indicators to shed light on its major contributors.

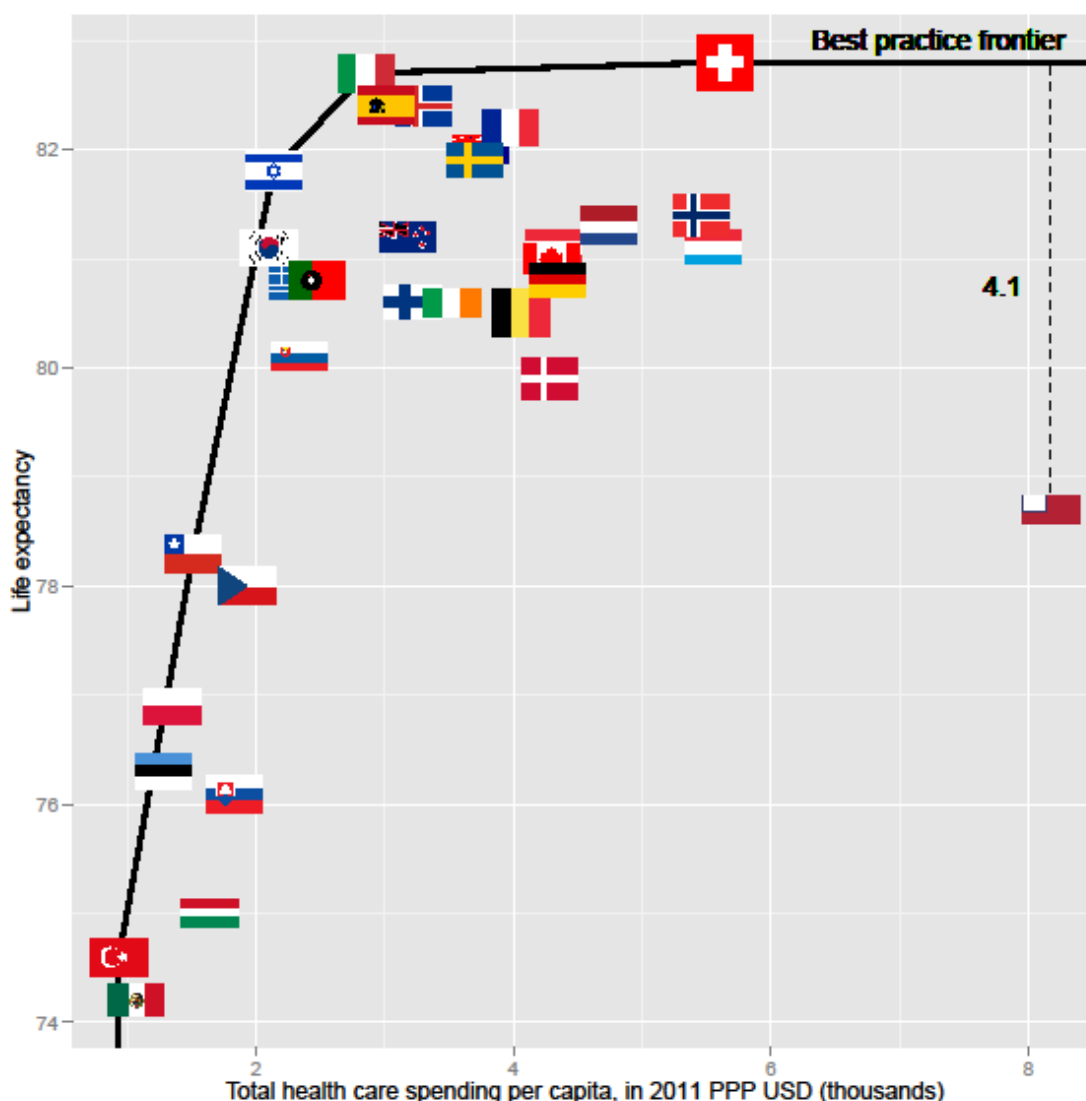
Predictors of health care performance

Examining the observed shape of the best practice frontier necessitates the assumption that all countries spend their resources as efficiently as the countries currently on the frontier. Health care spending manifests through non-monetary determinants of health such as the number of general practitioners, specialists or hospital beds. However, health systems are embedded in their social environment and interact with health behaviors such as alcohol and tobacco consumption. Individual health outcomes are likely to be influenced by the level of their education. In order to analyze the impact of the share of educational groups in a country on life expectancy in a regression setting, we need to first transform them to log-ratio coordinates to model their dependencies correctly. As a simple solution, to circumvent having coefficients of log-ratio coordinates in the regression, we performed k-means cluster analysis (k=2) on them and included those in the regression. We performed similar analysis on public and private share of health care spending. Our covariates then are a) alcohol consumption, b) educational level dummy, c) health care expenditure type dummy, d) general practitioners, e) specialists and f) tobacco consumption. We use a simple linear model with bootstrapped confidence intervals (Simar-Wilson 2008).

Results

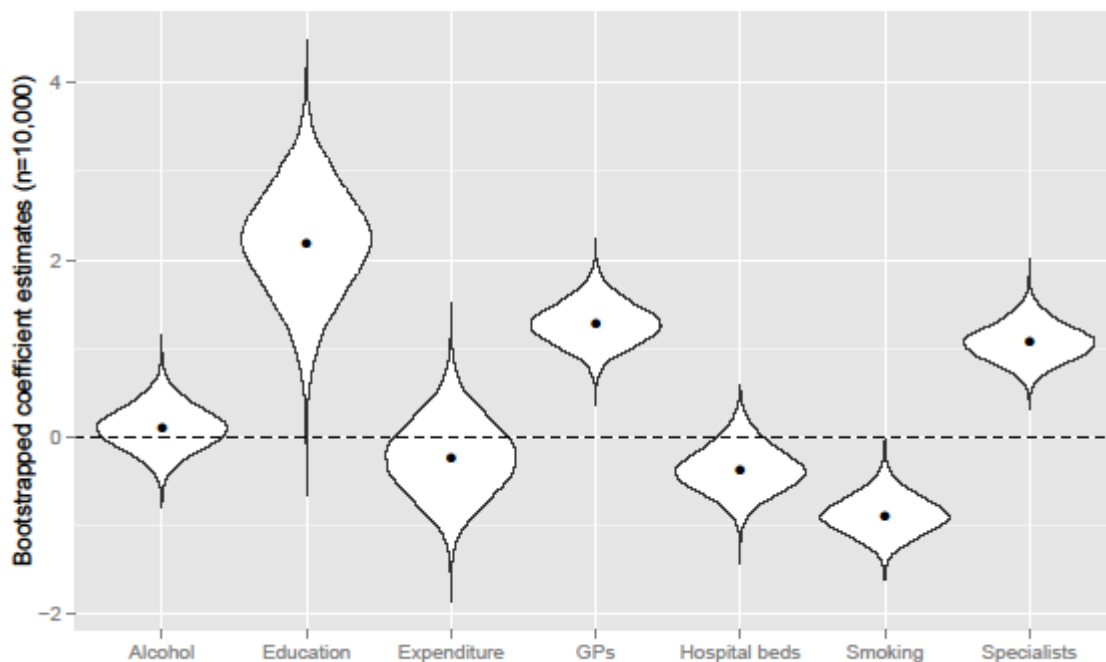
As Figure 1 shows, the best practice frontier of health care systems in providing life expectancy based only on per capita health care expenditure is set by Turkey, Chile, Israel, Italy and Switzerland among the OECD nations. This frontier demonstrates the level life expectancy that can be achieved at any amount of health care spending. For example, this analysis shows that the United States could improve its life expectancy at birth by 4.1 years if it followed the example of Switzerland as per capita spending is much higher in the United States than in Switzerland but life expectancy is 4.1 years lower. Please also note that 4.1 years is a conservative estimate as it is only the minimal number of years that life expectancy could be improved by.

Figure 1. Health care spending and life expectancy.



However, life expectancy is not only a function of money but of other covariates as well. Figure 2 shows the distribution of bootstrapped estimates of efficiency. The continuous covariates are standardized for easier comparison. At $\alpha=.05$, higher level of education, higher number of general practitioners and specialists improve while smoking decreases best practice life expectancy.

Figure 2. Distribution of bootstrapped parameter estimates of the predictors of efficiency in providing life expectancy



Note that on the violin plot above the distribution of the bootstrapped estimates can be seen by looking at either the left or right side of each shape, the other side is simply the mirror image of it. The predictors include: 1) standardized value of alcohol consumption per capita, 2) higher versus lower education dummy variable, 3) private versus public type of expenditure dummy, 4) standardized rate of number of general practitioners per 1000 people, 5) standardized rate of number of hospital beds per 1000 people, 6) standardized value of tobacco consumption per capita and 7) standardized rate of number of specialists per 1000 people.

Discussion

On the one hand, an inefficiently performing health care system means that it does not manage the money spent on it as well as health care systems of other countries do. However, on the other hand, it also means that these countries have potential for improving life expectancy (Figure 3). This possible increase could relatively easily be realized as it is calculated by other countries' example. The positive coefficients associated with general practitioners and specialists point at the importance of preventive and curative care in increasing life expectancy (Bunker 2001). The surprising finding that higher levels of alcohol consumption do not reduce life expectancy could be explained by the data envelopment methodology: if countries with higher levels of alcohol consumption per capita, such as Central-Eastern European countries, are clustered together (see Figure 1 lower left corner), their efficiencies will be given mainly relatively to each other. A similar level of alcohol consumption will not explain their differences as the efficiencies are simply a function of their distance from the best practice frontier. It might seem counterintuitive to claim that, for example, Poland is more efficient than Spain as Polish life expectancy at birth is well below the Spanish one. However, when one considers that the Polish health care system operates in a completely different environment than the Spanish, its peers should be mostly the neighbouring countries (and Chile) while Spain should rather be compared with countries such as Italy and Switzerland and their efficiency scores should respect that.

Conclusion

Data envelopment analysis separates the countries into groups of peers without any subjective judgement. As a consequence of this, the efficiency scores predicted by it reflect the environment the health care system are embedded in and it precludes the comparison of incomparable countries. The second step estimation of covariates of efficiency in providing life expectancy reveals the influence of those variables that differentiate efficient and inefficient countries from each other irrespective of their peer group belongings.

Increasing health expenditure is vital for providing gains in life expectancy. A more efficient use of resources can improve life expectancy in most countries; the currently inefficient countries could reap the highest benefits by the reorganization of their spending because the example of similar countries show that higher level of life expectancy at birth is achievable. This analysis shows that higher levels of education and higher number of physicians are important contributors to population health for all countries. The influence of general practitioners and specialists seem to be equal. Countries with many smokers tend to have lower life expectancy irrespectively whether they belong to higher or lower level of life expectancy group of countries.

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Figure 3. Life expectancy increase potential of selected OECD member states. Darker colors indicate higher efficiency, pie chart shows the distribution of higher, medium and lower education in the population.

