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A MULTI-STAGE EFFICIENCY ANALYSIS OF OECD HEALTHCARE SYSTEMS[1]

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ABSTRACT

This paper measures the multi-stage technical efficiency of healthcare systems across OECD Countries between 2000 and 2011, based on a 34 country panel data set, taking into account the impact of environmental variables and health expenditure levels. We measure technical efficiencies in a two-stage process—the production of health services and the subsequent provision of health outcomes—using output-oriented Data Envelopment Analysis (DEA). An overall inefficiency of 3.05% across OECD countries translates into an average loss of 1.38 years of life expectancy at birth and an additional 0.75 infant deaths per 1000 live births, exacerbated by environmental variables and inadequate healthcare spending, almost doubling the total OECD outcome loss to 5.65%, or 2.4 years of life expectancy and 1.5 infant deaths per 1000 live births. Measured inefficiency is split 21%/79% between production and provision. The type of inefficiencies exhibited, the solutions to these, and the resulting policy implications vary greatly.

Keywords: *Healthcare, Efficiency, Data Envelopment Analysis (DEA), OECD*

JEL Classification: *C44, D24, I11, L13*

OECD SAĞLIK SİSTEMLERİ ÇOK SAFHALI ETKİNLİK ANALİZİ

ABSTRACT

Bu makale, 2000 - 2011 yılları arasında, 34 OECD ülkesinin panel veri seti kullanarak ülkeleri çapındaki sağlık sistemlerinin teknik etkinliğini, çevresel faktörleri ve sağlık harcaması seviyelerinin etkilerini de dikkate alarak ölçmektedir. Çalışmada etkinlik seviyelerini, Veri Zarflama Analizi (DEA) tekniğini kullanarak, üretim ve tedarik olmak üzere 2 safhalı süreçte belirtilmiştir. OECD ülkeleri çapındaki % 3.05 düzeyinde bulunan etkinlik kaybı, 1.38 yıllık doğumda beklenen yaşam beklentisi kaybı ve 1000 canlı doğum başına 0.75 bebek ölümü anlamına gelmektedir. Diğer yandan çevresel etkenler ve yetersiz sağlık harcamaları nedeniyle bu kayıplar, neredeyse ikiye katlanıp, % 5.65 etkinlik

[1] This study is based on Doctoral Dissertation by Can Bekaroglu (2015) at University of Connecticut and A summary of this study is scheduled to be presented at ICEES' 18 on 27-28 Jun 2018

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kaybı ya da 2.4 yıl doğumda yaşam beklentisi ve 1.5 bebek ölümüne ulaşmaktadır. Ölçülen etkinlik kaybı, % 21 üretim ve % 79 tedarik merkezli olmakla beraber, ülkeden ülkeye büyük değişiklik göstermektedir; dolayısıyla da bu kayıpların telafisi için gerekli çözümler ve bunlara ilişkin politikalar da farklı olacaktır.

Anahtar Kelimeler: *Sağlık Sistemleri, Etkinlik, Veri Zarflama Analizi (DEA), OECD.*

JEL Sınıflandırması: *C44, D24, I11, L13*

1. INTRODUCTION

Governments in most developed countries allocate a significant share of public resources to healthcare, steadily rising to around 10% of global GDP (Martin et al., 2014), which is often cited as a source of increasing inefficiency in hospitals. Although there were signs of a slowdown (Lorenzoni et al. 2014), the latest OECD data show a bounce back in expenditure growth.

A World Bank Health, Nutrition and Population Paper (Wang et al., 1999) and a World Health Organization study (WHO, 2000) made early attempts to measure global healthcare efficiency using various performance indicators that revealed a large variance in health outcomes, even in the presence of similar income and education levels. Such findings have generated considerable interest in the measurement of healthcare efficiency. Among the seminal healthcare studies at the system level are Evans et al. (2001), Jamison et al. (2001), Salomon et al. (2001), and Hollingsworth and Wildman (2002).

Most countries, regardless of development level, produce healthcare inefficiently to some degree. However, the kinds of inefficiencies vary greatly by development level and market structure. Pinpointing the precise types of inefficiencies has important economic and political implications. Also, conflicting results due to the choice of outputs argues for a more comprehensive multi-stage efficiency analysis, where both health services and health outcomes are included in separate stages, while also controlling for other factors.

Following the seminal model of Färe and Grosskopf (2000), we conduct a multi-stage healthcare system analysis, where first-stage production uses resources to produce health services, which then, as intermediate goods, are transformed into health outcomes at the second (provision) stage. Additionally, non-discretionary inputs affect both the production and provision stages by shifting the frontiers, and therefore need to be measured and incorporated in the analysis.

To our knowledge, no study in the literature covers all 34 OECD countries in a multi-stage analysis using national panel data, which also measures the impact of environmental variables on health outcomes. Exploiting this multi-stage analysis, the paper's main contributions are to identify: where and what type of inefficiencies occur, the impact of environmental variables on health outcomes, and which specific adjustments or policies might improve efficiency and health outcomes in different OECD countries.

We mainly use OECD data (2013), which are largely standardized across fairly similar countries, so the quality of variable measurements, although spotty at times, is relatively good. The only non-OECD data are the World Health Organization BMI (Body Mass Index) figures (WHO, 2013), used as an average patient-risk characteristic. The inclusion of multiple (12) years of data also provides a better picture of each country, rather than a one-year snapshot.

Using panel data has several advantages over the use of cross-sectional data. Comparing the same unit with itself as well as others and creating a richer sample of observed units over multiple years provide additional insights and a further check on data accuracy and the validity of results. The pooled data analysis also may allow for increased discrimination among efficient units and the inclusion of additional variables.

Following the standard procedure, we are using additional variables to control for risk factors, outcome quality, and capital intensity, which will be further discussed in the following pages. To achieve our goal, we control for non-discretionary inputs, healthcare expenditures, and the quality of outputs. We aim to measure inefficiency levels, identify the sources of inefficiency, and assess the impacts of environmental variables and healthcare expenditures on health system performance.

2. EFFICIENCY ANALYSIS IN HEALTHCARE LITERATURE

A healthcare provider (e.g., hospital, physician, healthcare system) is efficient if it maximizes output for a given bundle of inputs or minimizes inputs used to produce a given output level. Data Envelopment Analysis (DEA) is a nonparametric analysis, which uses mathematical programming methods to construct a theoretical best-practice frontier from the observed data points to measure the relative efficiency of any observed input-output bundle. The method can accommodate multiple inputs and outputs, which are necessarily assumed to be homogeneous across units.

Introduced by Charnes, Cooper, and Rhodes in 1978 and further formalized by Banker, Charnes and Cooper in 1984, DEA was based on Farrell's (1957) simple measure of firm efficiency that accounted for multiple inputs. Today there is an extensive DEA healthcare literature. A survey by O'Neill et al. (2008) emphasizes research on national differences in hospital efficiency. Ozcan (2008) considers many aspects of healthcare delivery, as well as providing an overview of existing techniques. Hollingsworth (2008) classifies 317 published papers on frontier efficiency measurement into various subcategories, including parametric techniques such as stochastic frontier analysis, and comments on their usefulness.

Jacobs et al. (2006) stress that efficiency analysis should be based on healthcare outcomes. However, researchers often are forced to study efficiency using measured services, such as patients treated or hospital discharges. Many of the published studies use health services as outputs (e.g. Sahin & Özcan, 2000) but some studies include health outcomes as outputs (e.g. Skinner et al., 2005), and a few include quality, either explicitly (Häkkinen & Joumard, 2007) or as an explanatory variable (Zuckerman et al., 1994).

Either approach is problematic. Health services alone, as intermediate goods, do not tell us if patient health has improved, while health outcomes are not the direct products of the inputs used but of intermediate goods (health services) combined with other non-discretionary inputs. This critique was summarized in Newhouse (1994) and fully discussed in Jacobs et al. (2006), who conclude by recommending multivariate and multi-stage models as in Hauck & Street (2006), where objectives may include quality measures.

Recent healthcare studies that concentrate on OECD countries include Retzlaff-Roberts et al. (2004), who find that countries with less stellar results can also be relatively efficient; Varabyova et al. (2013), who use a panel data set and compare parametric and non parametric methods for a robustness check; and Cheng and Zervopoulos (2014), who extend their study to 171 countries and use a directional distance function to incorporate undesirable outputs as well.

A variety of other OECD based studies at the national level include Moscone et al (2013), who find a positive impact of scientific research on healthcare, based on a large set of panel data spanning from 1960 to 2008. Or et al. (2005) also find a positive impact of doctors on infant mortality, applying a multilevel analysis. Finally, Davies et al. (2013) evaluate three dimensions (efficiency, effectiveness, equity) of hospital performance.

3. METHODOLOGY

3.1. Network DEA

DEA was originally developed to measure the efficiency of a DMU (decision making unit) as a whole unit, without considering its internal structure, which was regarded as a “black box.” Within the system, inputs are supplied to produce outputs, generally with a positive correlation between the two, but this is not always the case (Wang et al., 1997). It is often necessary to study the internal structure of a system to identify the cause of any inefficiency.

The DEA technique to measure the efficiency of systems with a network structure is called “network DEA” (Färe & Grosskopf, 2000). The first study using this approach is probably Charnes et al. (1986), who observe two stages in army recruitment: creating awareness and creating service contracts. Separating large operations into multiple stages helps identify the real impact of input factors. The simplest approach is to separate the whole operation into two stages, as in Charnes et al. (1986) and Wang et al. (1997).

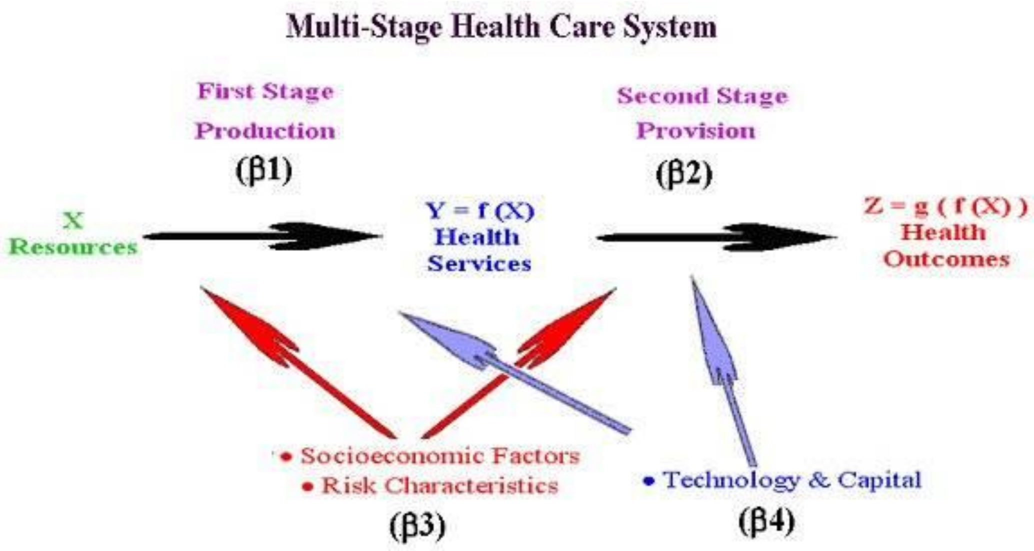
Our study is an extended form of basic two stage models, allowing both stages to also incorporate some exogenous, externally supplied inputs to produce final outputs. Examples include Simon, Simon, and Arias (2011), who analyse the productivity growth of 34 Spanish university libraries using a Medical Productivity Index (MPI), and Löthgren and Tambour (1999), who include customer satisfaction in studying the performance of 31 Swedish pharmacies. There are more complicated cases with more than two stages and in different structural forms such as a series structure, parallel structure, or a mixture of these approaches, which are collectively called "network structures."

3.2. Output-Oriented 2-Stage Model

We use panel data in this study, so each yearly data point for each country is treated as a separate decision making unit (DMU), i.e. the year 2000 data point for the U.S. is a different DMU than the U.S. data point for 2001. We assume a non-regressive technology, which implies that a currently available technology will also be available to all future DMUs, but was not necessarily available to past ones. This assumption requires control for technological progress over time and can be done by the in/exclusion of the relevant years.

An important methodological decision in DEA is whether to apply constant or variable returns to scale. The first nonparametric models for measuring efficiency by Charnes et al. (1978) assumed constant returns to scale (CRS). Later, Banker et al. (1984) relaxed the CRS assumption to account for firms that do not operate at their optimal scale, allowing variable returns to scale (VRS). Our analysis of OECD healthcare systems assumes CRS in the production of health services and VRS in the provision of health outcomes.

Exhibit 1. Multi-Stage Healthcare System



As depicted in Exhibit 1, the model consists of two output-oriented stages. For each DMU, the first stage measures the radial (equiproportional) efficiency levels of production under CRS, and obtains the efficient services (y*) that potentially could have been produced. The second stage, on the other hand, measures the non-radial efficiency levels of provision, under VRS, of desirable and undesirable health outcomes, due to countries improving asymmetrically in their health outcomes. This second stage uses the actual (y) and efficient (y*) quantities of services produced in the first stage as second stage inputs to measure the second stage (β_2) and overall (β) inefficiency levels, respectively, which allows us to also derive the first stage inefficiency (β_1). Weights are adjusted to be proportional to their impacts on the outcomes, in terms of years of life lost, and normalized to have equal impacts for comparable changes.

3.3. Model Specification

DEA relies on a number of fairly weak assumptions to construct the production technology, but it avoids any explicit functional relationship between inputs and outputs through a production function. These assumptions are summarized below. If Ψ denotes the feasible set, then:

a) all observed input-output combinations are feasible, or $(x, y) \in \Psi$;

b) the production possibility set is convex, or if (x1, y1), (x2, y2) $\in \Psi$, then $\alpha(x1, y1) + (1-\alpha)(x2, y2) \in \Psi$, where $\alpha \in [0, 1]$;

c) inputs and outputs are freely disposable, or if $x2 \geq x1$ and $y2 \leq y1$, and if $(x1, y1) \in \Psi$, then $(x2, y1) \in \Psi$ and $(x1, y2) \in \Psi$.

3.3.1. First Stage

Let (xi, yi) represent the input-output bundle of DMU i (or simply "firm i"), assuming input-output bundles are observed for N firms. Then, given the previous assumptions, the first-stage CRS production possibility set is:

$$\mathrm{T_c} = \{(\mathrm{x, y}); \mathrm{x} \geq \sum_{i}^{N} \lambda_i x_i ; \mathrm{y_i} \leq \sum_{i}^{N} \lambda_i y_i ; \lambda_i \geq 0; (i = 1,2,3,\ldots.,N)\} \tag{1}$$

By measuring the radial (equiproportional) efficiency levels of production under constant returns to scale (CRS), we obtain the efficient services (y*) that could have been produced. However, the convexity and the scalability of the control variables need to be addressed, because the quality (or risk) does not scale like the actual outputs. These controls are subject to VRS by definition, which further requires the condition $\sum_{i}^{N} \lambda_i = 1$, where q_{ik} is the control k for DMU i. The output-oriented radial efficiency of a particular DMU s is:

$$\mathrm{TE}\,(\mathrm{x_s}, \mathrm{y_s}) = \left(\frac{1}{1+\theta_{\mathrm{s}}}\right), \text{ where } \theta_{\mathrm{s}} = \max(\theta) : (x_s, (1+\theta) y_s) \in \mathrm{Tc} \tag{2}$$

In the first-stage DEA linear program, solved to estimate the efficiency of DMU s, relative to the contemporaneous CRS frontier (see {i} in Appendix), we ensure that the benchmark unit created from the convex combination of actually observed data points does not use any more inputs (resources) than the comparison unit, while also producing θ*y0k more outputs (services), where θ is the radial inefficiency rate for all outputs. If θ = 0, then the unit appears efficient in producing at least one output, given the observed data. The inclusion of an undesirable output acts like a control variable and ensures that the benchmark unit, created from the convex combination of reference DMUs, has at least the same quality of healthcare.

Among the various ways to incorporate environmental variables into the DEA framework, we use Ruggiero's 3-stage method (Ruggiero, 1998) to consolidate multiple risk factors into one risk variable, as it performed best in virtually all scenarios and was the only model robust to sample size and the number of nondiscretionary variables (Muniz et al., 2006) (see {ii} in Appendix).

3.3.2. Second Stage

Let (y_i, z_i) represent the second-stage input-output bundle of a firm i, assuming input-output bundles are observed for N firms. Given the aforementioned assumptions, the second-stage VRS production possibility set is:

$$T_v = \{(y, z);\ y \geq \sum_i^N \lambda_i y_i ; z_i \leq \sum_i^N \lambda_i z_i ; \sum_i^N \lambda_i = 1; \lambda_i \geq 0; (i = 1,2,3,...., N)\} \tag{3}$$

By measuring the non-radial efficiency levels of provision under variable returns to scale (VRS), we obtain the efficient outcomes (z*) that could have been produced. The output-oriented non-radial efficiency of a particular DMU s is:

$$TE\,(y_s, z_s) = \left(\frac{1}{1+\beta_s}\right) \text{, where } \quad \beta_s = \sum w_k \beta_{ks} = \max\left(\sum_{k=1}^{3} w_k \beta_k\right) : (y_{ks}, (1+\beta_k) z_{ks}) \in Tv \tag{4}$$

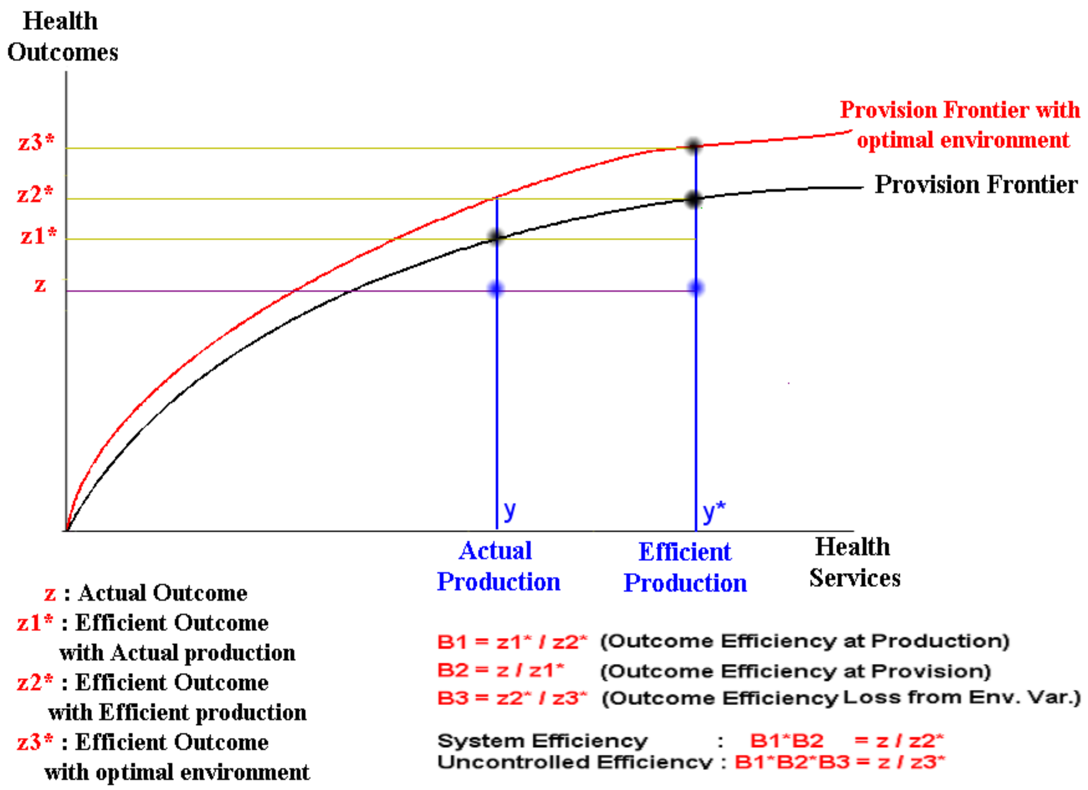
In the second-stage DEA linear program, solved to estimate the efficiency of a specific DMU s, relative to the contemporaneous VRS frontier (see {iii} in Appendix), we ensure that the benchmark unit created from the convex combination of actually observed data points does not use any more inputs (services) than the comparison unit, while producing $\beta_k * z_{0k}$ more of desirable and less of undesirable outputs, where the β_k is the non-radial inefficiency rate for output k, and $\beta = \sum w_k * \beta_k$ is the weighted non-radial outcome inefficiency. If $\beta_k = 0$, then the unit appears efficient at that specific individual output, given the observed data. However, this does not mean the unit produces the best possible amount for all outputs, as $\beta = \sum w_k * \beta_k$ may still exceed zero, implying inefficiency in other outputs.

The inclusion of healthcare expenditures helps to ensure that the benchmark unit is not any more capital intensive than the evaluated unit, which is also a proxy for its technological level. Finally, the controls for multiple risk factors and inequality of access to healthcare in the first stage are repeated.

3.4. Decomposition of Inefficiencies and the Impact of Environmental Variables

In the model, we initially decompose β (outcome inefficiency) into two parts. As in Chen, Cook, and Zhu (2010), the overall efficiency is defined as the product of efficiencies in two consecutive stages. Let $(1+\beta) = (1+\beta_1)*(1+\beta_2)$, where β_1 is the outcome inefficiency of first-stage production of health services and β_2 is the outcome inefficiency of second-stage provision of health outcomes.

Exhibit 2. Decomposition of Inefficiencies



Using the actual health services as given in the model implicitly assumes the first stage production is fully efficient and will only yield β_2, the outcome inefficiency of provision. On the other hand, using the efficient health services obtained from the first stage as the inputs implies no such assumption, and yields the total outcome inefficiency (β), from which β_1 can easily be derived. However, it should be noted that this decomposition, which allows us to distinguish between the first (production) and second (provision) stage inefficiencies, will be inexact due to the non-radial approach adopted in the second stage, compared to the radial approach in the first stage. Further relaxing the controls in the model, and alternating between the actual (y) and efficient (y*) levels of services as inputs, will allow us to gauge the separate and composite effects of the risk factors, inequality, and inadequate expenditure levels on the healthcare outcomes (see {iv} in Appendix). Exhibit 2 illustrates the decomposition process.

4. DATA

Data used in this study were obtained from the Organization for Economic Cooperation and Development (OECD) and consist of 34 OECD countries and 12 years, from 2000 through 2011, for a total of 408 DMUs. The sources and methods of data collection are described in detail in OECD documents (Health at a Glance 2013: OECD Indicators, 2013). Because countries are not uniform in their reporting practices and not all variables are recorded annually, some adjustment of data is necessary and common in OECD studies (O'Neil et al., 2008). In this study, linear interpolation is used to impute missing values in the time-series for particular countries, meaning some of the gaps are filled with estimates (5-10% of the data points), by either taking averages of the two closest years or using the last available data points and in some rare instances.

Categories of variables used to determine efficiency, shown in Table 1, include: resources, services, health outcomes, risk factors, inequality measures, quality of outputs, and healthcare expenditures per capita. We have only included control variables that directly affect healthcare and outcomes, in order to avoid diluting the results with too many control variables, causing underestimation of inefficiency. There are other variables that are commonly included in the literature, such as education (Cutler & Lleras-Muney, 2010), but this has produced mixed results and often ignores the endogeneity of education and health behaviour in regressions (Lochner, 2011). We attempt to control for the channels through which education might affect outcomes. Simply put, individuals with better education also tend to be richer (lower poverty rates), behave better and take better care of themselves (lower risk factors), and spend more on healthcare (per capita health expenditure).

Table 1. Variables

	Variables	**Definition**	**Measurement**
	Resources (1st Stage Input)		
1	**Physicians**	Professionally active physicians, including practicing physicians	per 1 000 population
2	**Nurses**	Professionally active nurses, including practicing nurses	per 1 000 population
3	**Hospital beds**	Regularly maintained & staffed, immediately available for use	per 1 000 population

	Services (Intermediate Product)		
4	**Doctor consultations**	Number of contacts with physicians, all causes.	per capita
5	**Hospital discharge rates**	Release of a patient who has stayed at least one night in hospital	per 100 000 population
6	**Patient Days**	Number of days patients stayed in hospital, each at least 1 night	per 100 000 population
	Outcomes (Second Stage Output)		
7	**Life Expectancy at birth**	How long on average a person at birth can expect to live	population average
8	**Life Expectancy at 65**	How long on average a person at 65 can expect to live	population average
9	**Infant Mortality**	Number of children deaths, less than one year of age	per 1 000 live births
	Risk Factors (Control)		
10	**Tobacco Consumption**	Tobacco consumption, % of all adult daily smokers	percentage of population
11	**Alcohol consumption**	Alcohol consumption, liters per capita aged 15+	liters per capita aged 15+
12	**BMI**	Overweight population, % of all population with a BMI>25 kg/m2	percentage of population
	Inequality / Poverty (Control)		
13a	**Gini Coefficient**	Measurement of Inequality in the population	between 0 and 1
13b	**Poverty**	Percentage of population below poverty threshold	percentage of population
	Expenditure (Control)		
14a	**Total Health Expenditure**	Total Healthcare Expenditures	per capita, US$ PPP

14b	**Public Health Expenditure**	Public Healthcare Expenditures	per capita, US$ PPP
	Control for Output Quality, less is better		
15	**PYLL**	Potential Years of Life Lost, All causes, 0-69 Years	per 100 000 population

Source: OECD Health Statistics 2013 - Frequently Requested Data http://www.oecd.org/health/oecdhealthdata2013-frequentlyrequesteddata.htm (31.12.2013)

5. RESULTS

5.1. Inefficiency over Time

The results indicate that the OECD health outcome inefficiency has been increasing over time, about 3% annually, even after controlling for inequality (the Gini coefficient or poverty rates). This translates into a loss of 1.38 years of life expectancy at birth and 0.75 more infant deaths per 1000 live births. Using public healthcare expenditures per capita instead of total healthcare expenditures per capita produces a slightly larger estimate of an increase in health outcome inefficiency, about 3.3%. This may reflect the increasing share of public expenditures in healthcare (Hauck, 2006), as public healthcare spending is often found to be more efficient than private in the literature (Gerdtham et al., 1992).

The change in inefficiency levels, however, is not uniform. Several countries (Estonia, Ireland, and Portugal) registered remarkable improvements in their healthcare efficiencies, while some others (Finland, Slovak Republic, and Turkey) became less efficient, possibly due to the time needed to adjust to sharp changes in the healthcare sectors of those countries (Bilsen & Davutyan, 2014; Sulku, 2011).

Infant mortality has exhibited a rise in overall inefficiency, from around 0.8 in 2001 to over 1 death per 1000 in 2011 (see Table 2). Infant mortality is particularly sensitive to technical change, and it seems like many healthcare systems are still trying to “catch up” to new technological frontiers, resulting in lower efficiency rates. Given the rapid developments in this field of medicine, this pattern might be expected and is a classic example of rising productivity with diminishing efficiency.

The major advantage of a multi-stage efficiency analysis is to be able to see the contribution of each stage to inefficiency. Similar to the term “effectiveness” in the literature (Häkkinen & Joumard, 2007; Murray & Evans, 2003; WHO, 2000], provision efficiency is defined here in terms of health services, rather than resources as inputs, and primarily depends on the quality of health services, social institutions and culture, and development levels.

Our analysis reveals that the lion's share of inefficiency is in the second-stage provision of health outcomes: about 79% of the overall efficiency loss occurs at the outcome provision stage, with the remaining 21% of inefficiency occurring in the initial production of health services. Production inefficiency, however, is a major issue for some countries. More than 60% of inefficiency in the U.S., for example, comes from health services production, in stark contrast to the OECD pattern. The countries that suffer most from production inefficiency are typically Nordic or English speaking countries, where relative price levels tend to be higher (Koechlin et al., 2010), in addition to Mexico and Portugal.

Table 2. Inefficiency for Infant Mortality

OECD	Total HC Exp. & Gini	Total HC Exp. & Poverty	Public HC Exp. & Gini
2001	0,78	0,72	0,85
2002	0,82	0,73	0,89
2003	0,86	0,84	0,97
2004	0,87	0,81	0,97
2005	0,85	0,86	0,89
2006	0,97	0,97	1,01
2007	1,00	0,99	1,03
2008	0,93	0,90	0,96
2009	1,06	1,06	1,09
2010	1,00	1,00	0,97
2011	1,04	1,10	0,98
Average	0,93	0,91	0,96

5.2. The Impacts of Environmental Variables on Health Outcomes

Production inefficiency (β_1) and provision inefficiency (β_2) collectively account for more than half of the total outcome losses. Environmental variables (0.54%) (β_3) and inadequate healthcare spending (1.94%) (β_4) almost double the total OECD outcome losses to 5.65%, or 2.4 years of life expectancy and 1.5 infant deaths per 1000 live births.

About 10% of the total outcome loss (β_3) is due to environmental variables, either at production stage ($\beta_{3\text{-}1}$: 2.65%) or the provision stage ($\beta_{3\text{-}2}$: 7.2%). Insufficient healthcare expenditure is an even more important factor in explaining a staggering 35% of the outcome losses (β_4), with potential gains from increased expenditures in the healthcare system ($\beta_{4\text{-}1,2}$: 26%), or allocating more resources to improve the environment ($\beta_{4\text{-}3}$: 9%). This is especially true for poorer countries like Estonia, Hungary, Poland, and Turkey, as well as, for Greece, Israel and Korea.

The slight increase in the average inefficiency is offset by the gains from the improvement of the environmental factors, most likely a result of reduction in the smoking rates and better healthcare coverage. Further inclusion of the impact of rising healthcare expenditures shows a substantial decrease in outcome losses from 6.3% to 5.1%. Drastic outcome gains are particularly true for Eastern European countries like Estonia, which not only considerably improved its inefficiency level from 2.7% in 2001 to 0.5% in 2011, but also further decreased the health outcomes losses by 7% through higher healthcare expenditures. A similar success story can be told about Ireland, which mostly eliminated its healthcare inefficiency (from 6.3% to 0.7%) and further reduced the outcome losses by increasing expenditures.

Not all OECD countries share the same kind of success stories though. Mexico suffers both from higher inefficiency and even worse expenditure losses, resulting in a 4.8% point increase in outcome losses. Turkey, on the other hand, experiences mixed results. The inefficiency level skyrockets by 6.7%, though the increasing healthcare expenditures keep the outcome losses at only 1.9% point. The recent healthcare reform in Turkey (Bilsen & Davutyan, 2014; Sulku, 2011) clearly needs time to take hold and deliver improvements.

We also see a pattern regarding the relative development levels of the countries. Less developed countries tend to suffer primarily from inadequate expenditures and provision inefficiencies while the more developed ones tend to suffer from production inefficiencies. Eastern Europeans countries are distinctly different in terms of outcome inefficiency, most likely as a result of weak social institutions and different cultural values and habits. Similarly developed countries like Turkey and Mexico tend to do a better job with life expectancies but suffer from poor infant mortality, with half of their gains in life expectancy coming from the improvements in infant mortality.

5.3. The Impacts of Inequality and Poverty

We see a small but statistically significant impact of inequality on overall OECD health outcomes. However, particularly the English speaking countries, where private markets are the norm, seem to be significantly affected by social inequality. The US, for instance, suffers an additional 2.37% outcome loss from inequality, followed by the UK (1.18%) and Australia (0.68%).

Considering the US as our prime example, about a 15% reduction in the Gini to 0.32, the upper end of the EU spectrum, would be sufficient to prevent most of the losses. Although market structure seems like the main factor in the U.S., with phenomenally high prices and the lack of universal coverage, a diverse immigrant population, as in other English speaking nations, may also be playing a role in these outcomes, without a universal healthcare and a greater share of public resources to cushion the impact of social inequality.

5.4. Scaling up Resources and Health Resources

DEA allows us to construct a health outcomes frontier to investigate the impact of increasing resources on health outcomes with the given observations and technology level. Scaling up the actual services will draw the frontier for the "actual production", while scaling directly the resources will implicitly assume "efficient production", resulting in a higher frontier. The difference comes down to the production inefficiency at different resource levels.

Given the 2011 technology level, doubling the overall OECD resources would lead to a 2.95 percentage point improvement in actual outcomes, from 2.37% to 5.32%, and a 2.49 percentage point increase in efficient outcomes, rising from 3.07% to 5.56%. However, rhe general OECD trend can be very different from the individual trends, especially if the bulk of the inefficiency of the country in question is in production. The large inefficiency in the US production leads to large outcome losses, and even a 10% boost in US health services would eliminate half the outcome inefficiency from production. At further levels, the efficient and the actual frontiers seem to converge due to sharply diminishing returns to scale.

Relatively efficient countries, such as Canada, would also benefit from increasing resources as well as inefficient ones such as the US, both by over 4% due to the relatively scarce use of services in both countries. Patient days in Canada and the US are 54% and 51% of the OECD average respectively, and doctor consultations in the US are merely 62% of the OECD average. Overall, the most scaled service in OECD countries, is "doctor consultations" (38%, binding for 25 countries), implying the relative scarcity of physicians.

6. CONCLUSION

6.1. Concluding Remarks

In this study, we have found around 3% inefficiency in healthcare, with a slightly increasing long run trend, which hides a significant variance in the individual efficiency changes at the country level and short run fluctuations due to technological shocks. A large portion of the fluctuations in inefficiency is reflected in infant mortality and is highly related to the poorer segments of OECD. The inefficiency loss is offset by gains from the improvement of environmental factors, while the inclusion of the impact of insufficient healthcare expenditures shows a substantial decrease in outcome losses from 6.3% to 5.1%.

Four-fifths of the OECD inefficiency is in the provision stage, leaving only one-fifth to the production, although production inefficiency is a major issue for the Nordic or English speaking countries such as the US with relatively high medical prices, in addition to Mexico and Portugal. The outcome losses are nearly doubled with the inclusion of inadequate healthcare spending which constitutes 35% of the outcome losses, and environmental variables, responsible for another 10%.

Development levels and social institutions also seem to be particularly important in determining the type of inefficiencies that countries tend to suffer. While less developed countries suffer more from provision inefficiency and inadequate healthcare expenditures, more developed ones suffer relatively more from production inefficiency, and to a smaller extent, social inequality. We see a significant impact of social inequality on the English speaking countries; especially where there are sizable diverse immigrant populations and private markets are more prevalent.

While there are success stories such as Ireland and Estonia, which substantially slashed their inefficiency rates, other countries such as Turkey and the Slovak Republic became less efficient between 2001 and 2011 partly due to the drastic changes in recent healthcare technologies. Rising expenditures, especially in the less developed countries, led to huge outcome gains, which is particularly true for Ireland and most Eastern European countries. Not all OECD countries share the same kind of success stories though. Mexico, for example, suffers both from higher inefficiency and even worse expenditure losses.

We find significant gains from scaling up the production of health services, especially for the countries that employ low quantities of resources or underutilize them. A 38% increase in health service production, especially doctor consultations would lead to a 2.6% increase in health outcomes, bringing the potential total outcome gains up to 7.8% in 2011.

6.2. Limitations of the Study

Radial efficiency analysis tends to underestimate the inefficiency as it assumes no substitution or trade-off between outputs and adopts a conservative way to determine the efficiency levels. The results should be evaluated with the slacks in mind. The countries with no slacks are usually in much better shape than those with large slacks.

Similarly the impact of environmental variables are likely underestimated as the study can only measure the impact of differences in environmental variables. Much lower alcohol consumption in Turkey relative the OECD average, for instance, masks its negative impacts due to the relatively more favorable environment. With the advent of additional and more up-to-date data, however, such limitations will be alleviated.

6.3. Policy Implications

The comprehensive nature of this study enabled us to pinpoint the sources of inefficiencies and outcome losses in each country. Although most countries are inefficient in one way or another, the type of inefficiencies they suffer and the solutions to those issues might be very different. First of all, allocating more resources and/or increased production of services will immensely help most OECD countries, especially those which are resource scarce, even if they are relatively efficient like Canada.

Secondly, English speaking and Northern European countries, as well as Portugal, suffer mostly from production inefficiency. This is primarily a market structure issue resulting from high medical prices and/or undersupply of health services. The US seems to be the pinnacle of these problems, and obviously healthcare systems with easily exploitable inelastic demand and a high level of provider concentration should not just be left to the forces of private oligopolistic markets. Increasing the share of public control and tighter market regulations, as well as unified consumer policies, will provide more leverage to reduce prices and expand the production of services.

Similarly, English speaking countries in particular are significantly affected by social inequality. A universal healthcare system which provides free basic healthcare and universal coverage may significantly help those countries remove the social inequality from access to healthcare, where private markets are the norm, and thereby avoid the associated outcome losses. The US, for instance, offers a relatively good healthcare for those who have access and can afford it, so it is rather the access to and supply of healthcare, than quality. The opposite situation holds for egalitarian Eastern European countries, which suffer from relatively high life expectancy inefficiencies but enjoy extremely low infant mortality inefficiency. Therefore the main problem for countries like Hungary, Estonia, as well as Turkey, is not the access to or supply of healthcare, but rather the quality of it.

Countries with low capital intensity and healthcare spending should primarily seek to increase their expenditures on the healthcare systems by employing higher quality and quantity of resources, as well as better technology and infrastructure, and investing in better social institutions. Relatively less developed countries will certainly benefit from increasing social awareness, establishing and empowering social institutions and norms, and promoting better human and national development, which directly or indirectly affect the health outcomes.

OECD countries have made considerable progress in recent years, fighting risk factors such as smoking. This is a relatively cheaper and more effective way to prevent premature health issues and deaths. Eastern European countries, for instance, are notorious for male binge drinking and premature deaths. Normalization of male life expectancy alone would tremendously improve the results for those countries. Therefore, particularly countries with high alcohol consumption should work to decrease binge drinking and the associated fatalities.

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7. APPENDIX

7.1. Stage 1 DEA LP Problem

Objective: Max θ (θ: radial output inefficiency) {i}

subject to:

- $\sum \lambda_i x_{ij} \leq x_{0j}$ *j = 1…3*   *(Input constraint)*   *(1)*
- $\sum \lambda_i y_{ik} \geq (1 + \boldsymbol{\theta})\, y_{0k}$ *k = 1…3*   *(Output constraint)*   *(2)*
- $\sum \lambda_i q_{i1} \leq q_{s1}$ *(Quality constraint with undesirable outcome)*   *(3)*
- $\sum \lambda_i q_{i2} \geq q_{s2}$ *(Risk factors fused into one variable)*   *(4a)*
- $\sum \lambda_i q_{i3} \geq q_{s3}$ *(Control for inequality)*   *(4b)*
- $\lambda_i \geq 0,$ *(5)*

The original DEA model without the risk factors (4a) is solved and the second-stage regression on the risk factors is performed. Let θ' be the estimated inefficiency regressed on the risk factors:

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$\hat{\theta} = q_{i2} = \alpha + \gamma_1 r_1 + \gamma_2 r_2 + \gamma_3 r_3 + \varepsilon$ {ii}

After construction of qi2 (the combined patient-risk control) from estimating the first inefficiency, the model {i} is solved again. Finally, inequality of access to healthcare enters the problem as yet another environmental variable that needs to be controlled for in the model. This is represented in the equation (4b), in a similar fashion to the risk factors, but introduced separately.

7.2. Stage 2 DEA LP Problem

Objective: $Max\ \beta = \sum w_k * \beta_k$, *(β: weighted non-radial outcome inefficiency)* {iii}

subject to:

- $\sum \lambda_i * y_{ij} \leq y_{0j}$ $j = 1 \ldots 3$ *(Input constraint)* (1)
- $\sum \lambda_i * z_{ik} \geq (1 + \beta_k) * z_{sk}$ $k = 1, 2$ *(Desirable Output constraint)* (2a)
- $\sum \lambda_i * z_{ik} \leq (1 - \beta_k) * z_{sk}$ $k = 3$ *(Undesirable Output constraint)* (2b)
- $\sum \lambda_i * q_{i1} \leq q_{s1}$ *(Per capita health expenditure)* (3)
- $\sum \lambda_i * q_{i2} \geq q_{s2}$ *(Risk factors fused into one variable)* (4a)
- $\sum \lambda_i * q_{i3} \geq q_{s3}$ *(Control for inequality)* (4b)
- $\lambda_i \geq 0, \quad \sum \lambda_i = 1$ *(Variable Returns to Scale)* (5)

7.3. Decomposition Of Inefficiencies And Impact Of Environmental Variables

Let $1 + \Phi = (1 + \beta) * (1 + \underline{\beta}) = (1 + \beta_1) * (1 + \beta_2) * (1 + \beta_3) * (1 + \beta_4)$, where: (iv)

Φ: Total Outcome Loss,

β: Loss from healthcare inefficiency, and $1 + \beta = (1 + \beta_1) * (1 + \beta_2)$

β_1: *Loss from production inefficiency* β_2: *Loss from provision inefficiency*

$\underline{\beta}$: *Loss from environmental factors, and* $1 + \underline{\beta} = (1 + \beta_3) * (1 + \beta_4)$

β_3: *Loss from risk factors and inequality* β_4: *Loss from inadequate expenditure*

Different controls enable us to further decompose the impact of environmental variables.

Let $(1 + \beta_3) = (1 + \beta_{3\text{-}1}) * (1 + \beta_{3\text{-}2})$ *where, Impact of risk factors and inequality,*

$\beta_{3\text{-}1}$: *on production* $\beta_{3\text{-}2}$: *on provision*

Likewise, let $(1 + \beta_4) = (1 + \beta_{4\text{-}12}) * (1 + \beta_{4\text{-}3})$ *where, Impact of inadequate expenditure,*

$\beta_{4\text{-}12}$: *on healthcare system* $\beta_{4\text{-}3}$: *on environmental variables*

Table 3. Decomposition of βs with different controls

	Controls dropped			
Input	None	(3) only	(4) only	(3) and (4)
y	$(1+\beta_2)$	$(1+\beta_2)(1+\beta_{3\text{-}2})$		
y*	$(1+\beta)$	$(1+\beta)(1+\beta_3)$	$(1+\beta)(1+\beta_{4\text{-}12})$	$(1+\beta)(1+\beta_3)(1+\beta_4)$
Derived	β_1	$\beta_{3\text{-}1}$	$\beta_{4\text{-}3}$	

The impact of inequality and risk factors can be further decomposed if desired. Such detailed decomposition may not only help to pinpoint where the inefficiencies exist for each country, but also what type of policies might be appropriate.