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A Multi-Stage Efficiency Analysis of OECD Healthcare and the Impact of Technical Change

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A Multi-Stage Efficiency Analysis of OECD Healthcare and the Impact of Technical Change

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This dissertation aims to measure the impact of technical change on OECD Healthcare in a multi-stage framework and identify the different sources of outcome losses to allow for comprehensive policy implications within a diverse dataset including countries from a large variety of development levels facing different healthcare issues. We adopt an output-oriented DEA (Data Envelopment Analysis) methodology to obtain the technical efficiencies in production and provision. Data used in this study is mainly obtained from the Organization for Economic Cooperation and Development (OECD) Health Data 2013 and consists of 34 OECD countries and 12 years between 2000 and 2011.

A Multi-Stage Efficiency Analysis of OECD Healthcare and the Impact of Technical Change

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APPROVAL PAGE

Doctor of Philosophy Dissertation

A Multi-Stage Efficiency Analysis of OECD Healthcare and the Impact of Technical Change

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Brief Contents

A Multi-Stage Efficiency Analysis of OECD Healthcare and the Impact of Technical Change: Introduction

Can Bekaroglu

Fall 2015

Abstract

This dissertation aims to measure the impact of technical change on OECD Healthcare in a multi-stage framework and identify the different sources of outcome losses to allow for comprehensive policy implications within a diverse dataset including countries from a large variety of development levels facing different healthcare issues.

We adopt an output-oriented DEA (Data Envelopment Analysis) methodology to obtain the technical efficiencies in production and provision. Data used in this study is mainly obtained from the Organization for Economic Cooperation and Development (OECD) Health Data 2013 and consists of 34 OECD countries and 12 years between 2000 and 2011. The following introductory chapter gives a general summary of the study and its background, contributions, methodology, and the dataset used in the study.

Keywords: Healthcare, Efficiency, DEA, Technical Change, Productivity Growth, OECD

1 Introduction

In most developed countries, the state devotes a considerable share of resources to healthcare [4], and healthcare costs have been steadily increasing, to current levels, over 10% of GDP globally [36, 40], with few signs of slowing down in the future [38, 50].

To explain this trend, many studies [5, 23, 31, 32, 42, 45, 56, 64, 70] have tried to diagnose the underlying factors such as an ageing population, increased social expectations, broader insurance coverage, supplier induced demand and relative prices that may affect the utilization and costs of healthcare services. Efficiency and productivity of the healthcare systems, as well as *technological change and productivity growth* in healthcare have also been claimed to have a major impact on healthcare costs [22, 23, 43, 49].

Technological advances in healthcare, notably hospital care, have been dramatic over the last four decades [19], but they have often been blamed for mounting costs of hospital care, especially in the United States. Various analysts (Aaron, (1991) [1]; Newhouse, (1993) [46]; Schwartz and Mendelson, (1994) [58]) have argued that technological change generates the underlying growth in expenditures.

Another possibility is that increasing inefficiency in the hospital industry is causing real expenditure growth; a World Bank Health, Nutrition and Population Paper by Wang, et al. (1999) [65] and a WHO study (2000) [66] made early attempts to measure global healthcare efficiency using different performance indicators, resulting in enormous variance in health outcomes, despite similar income and education levels. This generated considerable interest in the measurement of healthcare efficiency. Among the seminal healthcare studies at the system level are Hollingsworth and Wildman (2002) [29], Jamison et al. (2001) [34], Salomon et al. (2001) [59], and Evans et al. (2001) [16].

Much of the literature finds diverse results with respect to healthcare efficiency. While there are studies that find countries like Turkey with relatively poor health outcomes to be efficient [53, 68] others find the opposite results [44, 63]. The problem mainly stems from the output choice (services vs. outcomes) and lack of consistent and reliable quality measurements. Additionally, measuring the impact of the environmental factors is the goal of a growing body of studies with diverse implications [6, 28, 39, 52].

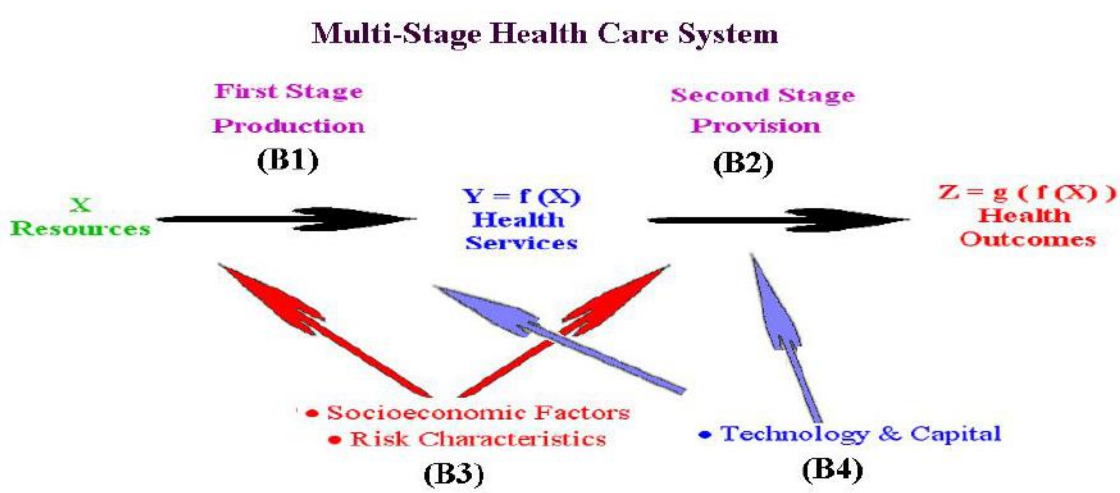
As stressed by Jacobs et al. (2006) [33], efficiency analysis should be based on outcomes of healthcare. However, researchers are often forced to study efficiency on the basis of measured services like patients treated or hospital discharges. Many of the published studies use health services as outputs [2,

15, 57] but some studies include health outcomes as outputs [8, 14, 35, 61], and a few include quality, either explicitly [25] or as an explanatory variable [69]. Either way is problematic; since health services as intermediate goods do not tell us whether the patient's health has improved, while the outcomes are not the direct products of the inputs used but of intermediate goods in conjunction with other non-discretionary inputs. This critique was summarized in Newhouse (1994) [47] and fully discussed in Jacobs et al. (2006) [33], who conclude by suggesting the use of multivariate models and multi-stage models [26], where the objectives may include quality.

Although there are numerous studies in the literature examining the technical changes of the OECD healthcare systems [7, 10, 15, 18, 19, 24, 41, 54, 62, 67], the relationship between the technical changes on *production* and *provision* is not well established. Fare et al. (1997) paper [19] for example, calculates the technical change for both health services and outcomes at one stage and from resources. However, health outcomes are a product of health services, rather than directly of resources, and skipping the production stage leads to underestimation of not only inefficiency but also the productivity growth of outcomes.

2 Multi-Stage Healthcare System

Färe and Grosskopf (2000) [20] introduced a multistage DEA (*Data Envelopment analysis*) model that later came to be known as *network DEA*. Following their paradigm, we devise a multi-stage healthcare system analysis where production takes place at the first stage and resources produce health services, which are, as intermediate goods, then transformed to health outcomes at the second (provision) stage. Additionally, non-discretionary inputs, which affect both the production and provision stages by shifting the frontiers, need to be controlled for.



The first paper is the initial step of a more comprehensive two-stage efficiency analysis and focuses on the production stage, by investigating the production efficiency in terms of health services and the impact of technical change on production. This helps us determine: a) if the rapid technical change still persists, b) what is the role of production inefficiency in health outcome losses.

The second paper takes the results from the first paper and continues the analysis with the second (provision) stage. The study aims to investigate; a) the multi-stage efficiency of health outcomes, b) the impact of technical change on health outcomes. This enables us to establish a consistent relationship between the impact of technical change between the first (production) and the second (provision) stage.

Finally, the third paper extends the results from the second paper, by analysing the impact of environmental variables such as patient-risk characteristics and healthcare inequality, as well as inadequate healthcare expenditures and increased use of resources. This is done through gradual relaxing of controls and by using hypothetical firms with increased resources. As part of this multi-stage analysis, this paper's main contribution will be *to pinpoint where exactly and what type of inefficiencies occur, what is the impact of environmental variables on health outcomes, and which policies might be used to improve efficiency and health outcomes.*

Overall, this study has two main contributions to the literature: *a) measure the impact of technical change on healthcare in a multi-stage framework, b) determine and quantify the sources of outcome losses along with the associated policy implications.*

3 Efficiency and Data Envelopment Analysis

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. *Data Envelopment Analysis (DEA)* is a nonparametric approach which constructs a theoretical *best-practice* frontier from the observed data points to measure the efficiency of any observed point. The method can simultaneously handle multiple inputs and outputs, which are assumed to be homogeneous across units. The technique was first introduced by Charnes, Cooper, and Rhodes in 1978 [9] and further formalized by Banker, Charnes and Cooper in 1984 [3] based on Farrell's (1959) [21] simple measure of firm efficiency that accounted for multiple inputs.

The first application of DEA to health issues (that we know of) is an unpublished work from 1979 regarding family planning centers in Costa Rica and Guatemala (Ray 2004, p. xi) [55]. Nunamaker and Lewin (1983) [48] is the first published work applying DEA to healthcare, whereas Sherman (1984) [60] was the first author to use DEA to evaluate overall hospital efficiency. Today there is a very extensive DEA literature surveyed by O'Neill et al. (2008) [51], who emphasize national differences in hospital efficiency research, and Ozcan (2008) [36] who considers many aspects of healthcare delivery, as well as providing an overview of existing techniques. Hollingsworth (2008) [30] classifies 317 published papers into various subcategories, including parametric techniques such as *stochastic frontier analysis*, and offers comments as to their practical usefulness.

DEA relies on a number of fairly weak assumptions to construct the production technology but avoids any explicit functional relationship between the inputs and outputs through a production function [12]. These assumptions are summarized below. Let Ψ be the feasible set:

a) all observed input-output combinations are possible; $(x_1, y_1) \in \Psi$.

b) the production possibility set is convex; Let $\alpha \in [0, 1]$; If $(x_1, y_1), (x_2, y_2) \in \Psi$, then $(x, y) = \alpha(x_1, y_1) + (1-\alpha)(x_2, y_2) \in \Psi$.

c) inputs and outputs are freely disposable; Let $x_2 \geq x_1$, and $y_2 \leq y_1$. If $(x_1, y_1) \in \Psi$ then $(x_2, y_1) \in \Psi$ and $(x_1, y_2) \in \Psi$

Let (x_i, y_i) represent the input-output bundle of a firm i, assuming input-output bundle observed for N firms. An important theoretical assumption in DEA is whether to apply constant or variable returns to scale. The first nonparametric models for efficiency estimation by Charnes et al. (1978) [9] assumed constant returns to scale (CRS) as shown in equation {1}.

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

Later, Banker et al. (1984) [3] relaxed the CRS assumption to account for firms that do not operate at their optimal scale, allowing VRS. This further requires the condition $\sum_i^N \lambda_i = 1$. The corresponding possibility set under VRS:

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

We apply a *CRS* approach in the first stage {1} and VRS in the second stage {2} of our model as it is generally accepted that the production stage exhibits CRS, while the provision of health services demonstrates VRS. In other words, doubling of all resources will lead to doubling of health services (CRS), but this will not necessarily lead to a similar increase in health outcomes (VRS). Therefore, the OECD healthcare system exhibits CRS in production but VRS in the provision stage and as a whole.

One decision to make when performing DEA is whether to use an input- or output-orientation. An input-oriented model holds the current level of output constant and minimizes inputs, whereas an output-oriented model maximizes output keeping the amount of inputs constant. Farrell [21] did not specify a formal definition of the contemporary "*Farrell measure*" of the technical efficiency of production and did not standardize the two different measures of technical efficiency [17]. As he was originally considering CRS, the difference between input and output orientation was irrelevant. Deprins and Simar [13] defined input technical efficiency as a measure between zero and one, whereas the inverse of output technical efficiency is a measure greater than one.

In our study, we adopt an *output-oriented* model to determine the overall efficiency measure as the input levels used in healthcare production is usually determined externally and highly influenced by the political system: Thus, it is much more plausible to argue the system should try to maximize its output levels, given the input levels it is provided. Therefore, the output-oriented efficiency of firm s:

$$\mathrm{TE}\,(\mathrm{x}_s, \mathrm{y}_s) = (\frac{1}{1+\beta_s}), \text{ where } \beta_s = \max(\beta) : (x_s, (1+\beta) y_s) \in \mathrm{T} \qquad \{3\}$$

An important distinction in healthcare efficiency should be made between technical and cost (allocative) efficiency, which additionally requires price data to assess scale efficiency [21, 33]. While technical efficiency measures the efficiency level with the given bundle only, cost efficiency analysis additionally investigates whether the optimum was also chosen given the input prices, allowing for substitution between inputs. In this study, we only focus on the technical efficiency side. This decision is necessitated both by theoretical and data considerations, as consistent international hospital cost statistics needed for the estimation of cost efficiency are not available.

4 Data

Data used in this study are mainly obtained from the Organization for Economic Cooperation and Development (OECD) Health Data 2013 [27], which is the broadest source of comparable statistics on diverse health systems across OECD countries. The sources and methods of data collection are described in detail in the OECD documentation [71]. The dataset consists of 34 OECD countries and 12 years between 2000 and 2011 for a total of 408 firms. The only non-OECD data are the BMI figures acquired from the World Health Organization as a patient-risk characteristic. The inclusion of multiple (12) years also serves to give a better picture of each country, rather than a one-year snapshot.

Using panel data has several advantages compared to 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 validity and data accuracy. For pooled analysis, such a comparison may allow for increased discrimination among efficient units and the inclusion of additional variables.

Each yearly data point for each country is treated as a separate decision making unit (DMU); e.g. the year 2000 data point for the US is an entirely different DMU than the US data point for 2011. We are assuming non-regressive technology, which implies that a currently available technology will also be available to all future DMUs, but was not available to the past ones. This assumption requires control for technological progress over time and can be done by the in/exclusion of the relevant DMUs.

The variables used in the analysis: Resources, health Services, health outcomes, quality of outputs, healthcare per capita expenditures, patient risk characteristics, inequality of access to healthcare (See the table below). We have only included the control variables that have direct effects on healthcare, in order to avoid diluting the results, although there are other variables that are also commonly included in the literature, such as education, income, and to a lesser extent, homicide and suicide rates.

While the existence of an "*education gradient*" on health outcomes is accepted in the literature [11], as Lochner (2011) [37] suggested, the literature has produced mixed results, and most studies fail to address the endogeneity of education and health behaviors in regressions. Basically we attempt to control for all channels, through which education can affect the data. Simply put, individuals with better education also tend to be richer (*poverty rates*), behave better and take better care of themselves (*risk factors*), and spend more money on healthcare (*per capita health expenditure*).

Variables Used In the Analysis

	#	Variables	Definition	Measurement
Resources	1	**Physicians**	Professionally active physicians, including practising physicians	per 1 000 population
	2	**Nurses**	Professionally active nurses, including practising nurses	per 1 000 population
	3	**Hospital beds**	Regularly maintained & staffed, immediately available for use	per 1 000 population
Services	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	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 factor	10	**Tobacco Consumption**	Tobacco consumption, % of all adult daily smokers	percentage of population
	11	**Alcohol consumption**	Alcohol consumption, litres per capita aged 15+	litres per capita aged 15+
	12	**BMI**	Overweight population, % of all population with a BMI>25 kg/m2	percentage of population
Ineq.	13a	**Gini Coefficient**	Measurement of Inequality in the population	between 0 and 1
	13b	**Poverty**	Percentage of population below poverty threshold	percentage of population
Exp.	14a	**Total Health Expenditure**	Total Healthcare Expenditures	per capita, US$ PPP
	14b	**Public Health Expenditure**	Public Healthcare Expenditures	per capita, US$ PPP
O	15	**PYLL**	Potential Years of Life Lost, All causes, 0-69 Years	per 100 000 population

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The Impact of Technical Change on OECD Healthcare Production

Can Bekaroglu

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Abstract

This paper measures the technical efficiency of healthcare production and estimates the impact of technical change on healthcare across OECD Countries between 2000 and 2011, based on a 12 year, 34 country panel data set, extending the study by Fare et al. (1997). We adopt a DEA (Data Envelopment Analysis) based output-oriented efficiency measure to obtain the productive efficiency of each country for all given years, and use the Malmquist Index to determine the productivity growth and decompose the technical change from efficiency changes over the years.

We find that the inefficiency in OECD healthcare systems has slightly increased over time, from 12% to 13%, while the production frontier shifted up around 0.8% annually between 2000 and 2011, with a cumulative 8.5% technical and 7.2% productivity increase over the period. Technological progress seems to be stable over time, while most of the fluctuations in productivity growth come from changes in efficiency due to utilization of new technologies.

Keywords: Healthcare, Efficiency, DEA, Technical Change, Productivity Growth, OECD

1 Introduction

In most developed countries, the state devotes a considerable share of resources to healthcare [7], and healthcare costs have been steadily increasing, to current levels, over 10% of GDP globally [78, 60], with few signs of slowing down in the future [55, 75].

To explain this trend, many studies [3, 9, 48, 49, 63, 67, 84, 98, 108] have tried to diagnose the underlying factors such as an ageing population, increased social expectations, broader insurance coverage, supplier induced demand and relative prices that may affect the utilization and costs of healthcare services. Efficiency and productivity of the healthcare systems, as well as *technological change and productivity growth* in healthcare have also been claimed to have a major impact on healthcare costs [3, 37, 62, 74].

Technological advances in healthcare, notably hospital care, have been dramatic over the last four decades [33], but they have often been blamed for mounting costs of hospital care, especially in the United States. Various analysts (Aaron, (1991) [1]; Newhouse, (1993) [71]; and Schwartz and Mendelson, (1994) [91]) have argued that technological change generates the underlying growth in expenditures.

On the other hand, many studies in the literature [11, 12, 41, 66, 80, 90] identify technical change as the main source of healthcare improvements. Fare et al. [31], for example, find widespread and rapid productivity growth for a sample of OECD countries from 1974 to 1989, especially for Denmark and the USA. Likewise, Moscone et al. [66] find a significant relationship between scientific research and the growth in healthcare productivity. Although technical change is found to constitute about a quarter of the healthcare expenditure growth, it also constitutes a large portion of the outcome growth. In this study, we find a similar increase in technical change, and identify it as the main source of healthcare improvements.

Another possibility is that increasing inefficiency in the hospital industry is causing real expenditure growth; a World Bank Health, Nutrition and Population Paper by Wang, et al. (1999) [103] and a WHO study (2000) [105] made early attempts to measure global healthcare efficiency using different performance indicators, showing enormous variance in health outcomes, despite similar income and education levels. This generated considerable interest in the measurement of healthcare efficiency.

Among the seminal healthcare studies at the system level are Hollingsworth and Wildman (2002) [46], Jamison et al. (2001) [50], Salomon et al. (2001) [92], and Evans et al. (2001) [25].

Schwartz and Mendelson [91] argue that almost a quarter of the real expenditure growth could be eliminated if inefficiency was curbed. Greene [42] argues that the main problems in the US are the access to healthcare and phenomenally high medical prices, rather than the quality of healthcare. Similarly recent studies suggest that if increases in healthcare costs are inevitable, the focus should shift from cost reduction to improving healthcare quality [97]. It is then much more plausible to argue the system should try to maximize its output levels given the input it is provided, as the resources and expenditure levels used in healthcare production are usually determined externally. This is why we adopt an *output-oriented* efficiency measure in our study.

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. The measured inputs and outputs are assumed to be homogeneous across units. We can talk about technological progress if the production frontier has shifted up over time, meaning the same input bundle can now produce more due to technological progress.

Although the initial Farrell analysis [36] is static, changes in efficiency can be measured over time, i.e. the frontier may shift due to technological advances. Productivity is defined as the ratio of an index of output to an index of input usage. Change of this measure over time is productivity change, which was initially attributed to technological changes, i.e. shifts of the production or cost frontier. However, it became increasingly recognized after Nishimuzu and Page (1982) [72] that productivity change can also be caused by changes in efficiency, that is, firms can move closer to the theoretical frontier over time, rather than showing genuine technological progress (shifts in the actual production frontier).

The Malmquist index [56], introduced in 1953 by the Swedish economist, Sten Malmquist, is a summary measure of the change in productivity of a given unit over time. Initially, Caves et. al. (1982) [13] adapted this index in order to evaluate productivity movements between different production units. Later, Fare et al. (1989) [26] derived the Malmquist productivity index as a geometric mean of the technologies of two periods of Caves et al.'s output productivity indices, and decomposed it into efficiency change and technological change components. Fare and Grosskopf (1992) [28] then generalized their non-parametric approach to eliminate assumptions on optimizing behavior, efficiency, and the need for price data, unlike previous studies such as Nishimizu and Page

(1982) [72] and Bauer (1990) [8], which required specification of a functional form for technology. Fare et al. (1997) [33] later used the technique to measure the productivity growth in healthcare across 10 OECD countries between 1974 and 1989.

Fa¨re et al. (1994) [31] operationalized and further the decomposed the approach to include scale changes, maintaining the constant returns to scale (CRS) assumption. However, the internal inconsistency of the approach, attempting to explain the scale changes under CRS, which requires the assumption of variable returns to scale (VRS) was criticized by Ray and Desli (1997) [82] who found significantly different results under VRS. Färe et al. (1997) [34] acknowledge the criticism and suggest that the CRS and VRS should be considered as the upper (long run) and lower (short run) boundaries of the production frontier of a given technology. Lovell et al. (1994) [54] also showed that the Malmquist productivity index can be expressed as the product of a Malmquist productivity index and a Malmquist scale index, as well as the ratio of a Malmquist output quantity index to a Malmquist input quantity index

Fa¨re et al. (1995) [32], who regard quality as an input in the production process, further extended the Malmquist index by incorporating quality 'attributes' into the technology of medical services and decomposing the index into three components: quality change, technical change and efficiency change. Maniadakis et al. (1999) [58] and Chen (2006) [15] use this method to evaluate the reform of the national health services and the implementation of the national health insurance program in the UK, respectively. Alternatively, Thanassoulis et al. (1995) [96] treat quality as an output in determining the performance of the district level health authorities in providing pre-natal care in the UK. Dismuke and Sena (2001) [24] define quality as the reduction in undesirable outputs and utilize the Malmquist-Luenberger productivity index developed by Chung et al. (1997) [21].

Other studies in the healthcare literature include, but are not limited to, Burgess and Wilson (1995) [10] who allow variable returns to scale (unlike Fare *et al.* (1994b) [30] who used CRS). McCallion G et. al. (2000) [61] use the input-based version of the Fare *et al.* (1994) [31] distance function approach, more suited to an input-oriented efficiency analysis. Sommersguter-Reichmann (2000) [95] follows Fa¨re et al. (1994) [31] and further decomposes the Malmquist index to scale efficiency changes in addition to the changes in technical efficiency and improvements in technology. Quellette and Vierstraete (2004) [79] generalize the Fare *et al*. (1994) [31] approach to incorporate quasi-fixed inputs. Some other noteworthy studies that used the Malmquist Index include Magnussen (1996) [57]; Lee and Wang (1998) [51]; Linna (1998) [52]; and Simar and Wilson (1999) [94].

2 Objectives

Färe and Grosskopf (2000) [35] introduced a multistage DEA (*Data Envelopment analysis*) model that later came to be known as *network DEA*. Following their paradigm, we devise a multi-stage healthcare system analysis where production takes place at the first stage and resources produce health services, which are, as intermediate goods, then transformed to health outcomes at the second (provision) stage. Additionally, non-discretionary inputs, which affect both the production and provision stages by shifting the frontiers, need to be controlled for.

In this paper, we focus on the production stage and investigate the efficiency and technical changes in production as the initial step of a more comprehensive efficiency analysis of the two-stage healthcare system. This will enable us to pinpoint where exactly the inefficiencies occur and to determine the role of technology in this process. The three objectives of this paper:

a) To measure productive efficiency levels of all 34 OECD countries and monitor their progress over time.

b) To obtain the efficient output quantities which will be used as alternative inputs in the second stage of multi-stage efficiency analysis in the following chapter.

c) To measure the productivity growth and decompose it to technical change and efficiency change, and see if the technological growth still persists, as shown by Fare et al. (1997) [33] for the 1974-1989 period.

Although there are numerous studies of the technical changes of the OECD healthcare systems [10, 15, 24, 30, 33, 40, 61, 79, 95, 106], the relationship between the technical changes in *production* and *provision* is not well established. The technological growth in production also leads to growth in outcomes, which further needs to be investigated in a multi-stage analysis.

As a part of multi-stage analysis, *this paper's main contribution will be to obtain the technical changes solely on the production side of a coherent multiple-stage framework, while a following study will analyze the subsequent impacts on the provision side, revealing either higher quantity or quality of services due to advancing technology.*

We mainly use OECD data [75], which are, for the most part, standardized across fairly similar countries; so the quality of the variable measurements, although spotty at times, is relatively good. The only non-OECD data are the BMI figures acquired from the World Health Organization as a

patient-risk characteristic. Inclusion of multiple (12) years also serves to give a better picture of each country, rather than a one-year snapshot.

Following the standard procedure, we are using additional variables to control for non-discretionary inputs and the quality of outputs, which will be further investigated in the following pages. We aim to measure inefficiency levels, identify the sources of inefficiency, and measure the productivity growth and decompose the technical change from the changes in technical efficiency.

3 Methodology

3.1 Literature

Two methodologies are most common in the literature: DEA (Data Envelopment Analysis) and SFA (Stochastic Frontier Analysis) [45]. Both approaches use "frontier analyses" for measuring efficiency. Frontier analysis compares a firm's (e.g., hospital, physician practice) use of actual inputs and outputs to efficient combinations of multiple inputs and/or outputs. Although the two methods use different approaches to calculate the ''frontier'' of efficient combinations used for comparison, they are constructed using similar types of inputs and outputs, typically those in publicly available data. Both DEA and SFA require appropriate conceptualization of the relationship between the measured inputs and outputs.

DEA is a nonparametric approach that can simultaneously handle multiple inputs and outputs while SFA is confined to a single output and requires specification of a functional form. On the other hand, SFA is better suited to situations where the functional form is known and policy deductions may be done with the included variables [65]. Banker, Gadh and Gorr (1993) [6] show that DEA is favoured when measurement error is unlikely, while SFA better deals with severe measurement errors.

SFA was independently developed by Aigner *et al*. (1977) [2] and Meeusen and van den Broeck (1977) [64]. The purpose of SFA is to decompose variations from the best practice cost frontier into a random error and a deterministic error, which is assumed to represent cost inefficiency. SFA results could be sensitive to variable specification as shown by Folland and Hofler (2001) [38], who indicated that frontier analysis can have a production or cost orientation (allowing only one dependent variable). The first healthcare application of SFA was published by Wagstaff (1989) [101], who examined 49 Spanish hospitals, followed by an increasing number of studies conducted in the United States [17-20, 59, 62, 86-88, 100, 107] and in Europe [52, 83, 102]. The literature tends to concentrate

on the cost efficiency analysis where the prices are known and the cost is fused into one dependent variable [47].

DEA was first introduced by Charnes, Cooper, and Rhodes in 1978 [14] and further formalized by Banker, Charnes and Cooper in 1984 [4] based on Farrell's (1959) [36] simple measure of firm efficiency that accounted for multiple inputs. The first application of DEA to health issues is an unpublished work from 1979 regarding family planning centers in Costa Rica and Guatemala (Ray 2004, p. xi) [83]. Nunamaker and Lewin (1983) [73] is the first published work applying DEA to healthcare, whereas Sherman (1984) [93] was the first author to use DEA to evaluate overall hospital efficiency. Today there is a very extensive literature surveyed by O'Neill et al. (2008) [76], who emphasize national differences in hospital efficiency research, and Ozcan (2008) [78] who considers many aspects of healthcare delivery, as well as providing an overview of existing techniques. Hollingsworth (2008) [47] classifies 317 published papers into various subcategories and offers comments as to their practical usefulness.

Recent healthcare studies that concentrate on OECD countries include Retzlaff-Roberts et al. (2004) [85], who find that countries with less stellar results can also be relatively efficient; Varabyova et al. (2013) [99] who use a panel data set and compare parametric and non parametric methods for a robustness check; and Cheng and Zervopoulos (2014) [16], who extend their study to 171 countries and use a directional distance function to incorporate undesirable outputs as well.

A variety of other DEA based OECD healthcare studies at the national level include Moscone et al (2013) [66], 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. [77] also find a positive impact of doctors on infant mortality, applying a multilevel analysis. Davies et al. [22] evaluate hospital performance in three dimensions (efficiency, effectiveness, equity), while Gholami [39] and Nayar et al. [70] question if the tradeoff between efficiency and quality is really inevitable.

3.2 Output-oriented Radial Model

As we are using panel data in this study, each yearly data point for each country is treated as a separate decision making unit (DMU); e.g. the year 2000 data point for the US is an entirely different DMU than the US data point for 2011. We are assuming non-regressive technology, which implies that a currently available technology will also be available to all future DMUs, but was not available to the past ones. This assumption requires control for technological progress over time and can be done by the in/exclusion of the relevant DMUs.

In our study, we adopt an *output-oriented radial* model with equiproportional changes in output to determine the overall efficiency measure as the input levels used in healthcare production is usually determined externally and highly influenced by the political system: Thus, it is much more plausible to argue the system should try to maximize its output levels, given the input levels it is provided. The implied inefficiencies in output levels are the least that all outputs should be increased to attain efficiency. In this study, we only focus on the technical efficiency side of the equation. This decision is necessitated both by theoretical and data considerations, as consistent international hospital cost statistics needed for the estimation of cost efficiency are not available.

3.3 Model Specification

In this study, we focus on the production side of a multi-stage healthcare model. DEA relies on a number of fairly weak assumptions to construct the production technology but avoids any explicit functional relationship between the inputs and outputs through a production function [23]. These assumptions are summarized below. Let Ψ be the feasible set:

a) all observed input-output combinations are possible; $(x_1, y_1) \in \Psi$.

b) the production possibility set is convex; Let $\alpha \in [0, 1]$; If $(x_1, y_1), (x_2, y_2) \in \Psi$, then $(x, y) = \alpha(x_1, y_1) + (1-\alpha)(x_2, y_2) \in \Psi$.

c) inputs and outputs are freely disposable; Let $x_2 \geq x_1$, and $y_2 \leq y_1$. If $(x_1, y_1) \in \Psi$ then $(x_2, y_1) \in \Psi$ and $(x_1, y_2) \in \Psi$

Let (x_i, y_i) represent the input-output bundle of a firm i, assuming input-output bundle observed for N firms. Then given the aforementioned assumptions, the CRS production possibility set is

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

By measuring the radial (equiproportional) efficiency levels of production under constant returns to scale (CRS), we obtain the efficient services (y*) that should 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, and these controls are subject to VRS by definition, which further requires the condition $\sum_i^N \lambda_i = 1$ for controls, where q_{ik} is the control k for DMU i. The output-oriented radial efficiency of a DMU s:

$$TE\,(x_s, y_s) = (\frac{1}{1+\beta_s}),\ \text{where}\ \beta_s = \max(\beta) : (x_s, (1+\beta) y_s) \in T_c \qquad \{ii\}$$

The standard DEA LP problem solved to estimate the efficiency of DMU s, relative to contemporaneous CRS frontier is

Objective: Max **β**, subject to {iii}

- $\sum \lambda_i x_{ij} \leq x_{0j}$ j = 1…3 (Input constraint) (1)
- $\sum \lambda_i y_{ik} \geq (1 + \boldsymbol{\beta})\, y_{0k}$ 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)
- $\lambda_i \geq 0$ (Reference Selection) (5)
- **β** : Radial Output inefficiency

In the maximization problem above (Max β), constraints (1), (2), and (5) 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 producing **β*** y_{0k} more outputs (services), where **β** is the radial inefficiency rate for all outputs. If **β** equals 0, then the unit appears efficient in producing at least at one output, given the observed data. The inclusion of undesirable output (3) in the first stage, first popularized by FGLP89 [27] and FGLY93 [29], acts like a control variable and ensures that the benchmark unit created from the convex combination of reference DMUs, which produce **β*** y_{0k} more output, 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 [89] to incorporate multiple risk factors into one risk variable (4a), as it performed best in virtually all scenarios, being the only model robust to sample size and the number of nondiscretionary variables [69], when compared to the other common methods such as Ray (1991) [81], Muñiz (2002) [68] and Banker and Morey [5]. The original DEA model without the risk factors (4a) is solved and the second-stage regression on the risk factors is performed. Let $\hat{\boldsymbol{\beta}}$ be the estimated inefficiency regressed on the risk factors:

$$\boldsymbol{\beta}^{*} = q_{i2} = \boldsymbol{\alpha} + \boldsymbol{\gamma_1}\, \mathbf{r_1} + \boldsymbol{\gamma_2}\, \mathbf{r_2} + \boldsymbol{\gamma_3}\, \mathbf{r_3} + \boldsymbol{\varepsilon} \qquad \{iv\}$$

After construction of q_{i2} (*the combined patient-risk control*) from estimating the first inefficiency, the model {iii} 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.

3.4 Malmquist Index and measuring technical change

The assumption of "*non-regressive technology*" allows us to include all current and past observations in the calculation of inefficiency for a certain DMU. However, the observations of the succeeding years have to be dropped to control for the technology that was not available to the DMU in question at the time.

Let the calculated inefficiency of the input-output bundle of a country **i** with respect to technology…
…in year **t** = $\boldsymbol{\beta}^{i}_{t,t}$, and in year **t+1** = $\boldsymbol{\beta}^{i}_{t,t+1}$

$\boldsymbol{\beta}^{i}_{t,t+1} \geq \boldsymbol{\beta}^{i}_{t,t}$ implies that the measured inefficiency of a DMU through time will tend to increase. The inclusion of new observations due to additional years will inevitably bring in more efficient DMUs, shifting up the constructed production frontier, causing past DMUs to appear more inefficient, due to two possible reasons:

a) The actual production frontier shifts up (technological progress),

b) The constructed frontier moves closer to the actual frontier (increase in efficiency).

Although this may not be clear from the calculation of inefficiency for a single country, using longitudinal data, calculation of an average inefficiency path for all countries through time will be much more representative of technological progress. Let the average OECD inefficiency in year **t** measured in year **t** = $\sum_{1}^{n} \beta^{i}_{tt} / n$

$\sum_{1}^{n} \beta^{i}_{tt+1} / n \geq \sum_{1}^{n} \beta^{i}_{tt} / n$ implies that the measured average inefficiency for a certain year will tend to increase over time, inevitably shifting up the production frontier. This fact must be invariant to the base year "t", and thus $\sum_{1}^{n} \beta^{i}_{t-1t+1} / n \geq \sum_{1}^{n} \beta^{i}_{t-1t} / n$ must also hold.

In other words, the measured inefficiency changes due to technological progress between two years must be equal, regardless of the base year it is based on. The discrepancies in the measurement are likely because of the changes in efficiency rather than technological progress. Therefore multiple year comparisons are necessary for a better assessment of the technological trend over the years.

In order to measure the productivity growth, we need to convert the *inefficiency* (**β**) values obtained in the DEA process to *efficiency* values (**D**) as in $D^{i}_{tt} = 1/(1+\beta^{i}_{tt})$. Then, following Färe *et al*. (1992) [28], we obtain the Malmquist productivity values and decompose them into technical change and efficiency change in the following way:

$$M_o(\mathbf{x}^{t+1},\mathbf{y}^{t+1},\mathbf{x}^{t},\mathbf{y}^{t}) = \frac{D_o^{t+1}(\mathbf{x}^{t+1},\mathbf{y}^{t+1})}{D_o^{t}(\mathbf{x}^{t},\mathbf{y}^{t})} \times \left[\left(\frac{D_o^{t}(\mathbf{x}^{t+1},\mathbf{y}^{t+1})}{D_o^{t+1}(\mathbf{x}^{t+1},\mathbf{y}^{t+1})}\right)\left(\frac{D_o^{t}(\mathbf{x}^{t},\mathbf{y}^{t})}{D_o^{t+1}(\mathbf{x}^{t},\mathbf{y}^{t})}\right)\right]^{1/2}$$

$$\text{technical change} = \left[\left(\frac{D_o^{t}(\mathbf{x}^{t+1},\mathbf{y}^{t+1})}{D_o^{t+1}(\mathbf{x}^{t+1},\mathbf{y}^{t+1})}\right) \times \left(\frac{D_o^{t}(\mathbf{x}^{t},\mathbf{y}^{t})}{D_o^{t+1}(\mathbf{x}^{t},\mathbf{y}^{t})}\right)\right]^{1/2}$$

$$\text{efficiency change} = \frac{D_o^{t+1}(\mathbf{x}^{t+1},\mathbf{y}^{t+1})}{D_o^{t}(\mathbf{x}^{t},\mathbf{y}^{t})}$$

4 Data

Data used in this study are obtained from the Organization for Economic Cooperation and Development (OECD) Health Data 2013 [110], which is the broadest source of comparable statistics on diverse health systems across OECD countries. The sources and methods of data collection are described in detail in the OECD documentation [43].

Because countries are not uniform in their reporting practices and not all variables are recorded each year, a slight adjustment of OECD data is unavoidable and common in OECD studies [85, 110]. Similarly, in this study, linear interpolation is applied to impute missing values in the time-series for particular countries, meaning some of the gaps are filled with average estimates (5-10% of the data points).

The dataset consists of 34 OECD countries and 12 years between 2000 and 2011 for a total of 408 decision making units (DMUs). However, the number of included DMUs in the measurements varies by year from a minimum of 5 years (170 DMUs) up to 11 years (378 DMUs) in order to control for technical change through time.

Variables

The variables used to determine efficiency include: *Inputs* (*resources*), *outputs (health services), quality of outputs (PYLL), patient risk characteristics, and inequality with access to healthcare* (see Table 1).

Table 1 – Variables

	#	Variables	Definition	Measurement	Mean	SD
Resources	1	Physicians	Professionally active physicians, including practising physicians	density per 1 000 population	2.95	0.84
	2	Nurses	Professionally active nurses, including practising nurses	density per 1 000 population	8.22	3.76
	3	Hospital beds	Regularly maintained & staffed, immediately available for use	density per 1 000 population	5.14	2.42
Services	4	Doctor consultations	Number of contacts with physicians, all causes.	per capita	6.49	2.91
	5	Hospital discharge rates	Release of a patient who has stayed at least one night in hospital	per 100 000 population	15,465	4,769
	6	Patient Days	Number of days patients stayed in hospital, each at least 1 night	per 100 000 population	123,753	58,102
Risk factors	7	Tobacco Consumption	Tobacco consumption, % of all adult daily smokers	percentage of population	23.5	5.0
	8	Alcohol consumption	Alcohol consumption, litres per capita aged 15+	litres per capita aged 15+	9.6	3.1
	9	BMI	Overweight population, % of all population with a BMI>25 kg/m2	percentage of population	14.0	4.9
Ineq.	10a	Gini Coefficient	Measurement of Inequality in the population	between 0 and 1	0.314	0.059
	10b	Poverty	Percentage of population below poverty threshold	percentage of population	10.8%	0.044
Q	11	PYLL	Potential Years of Life Lost, All causes, 0-69 Years	per 100 000 population	4,084	1,380

4.1 Resources (Inputs): The inclusion of physicians, nurses and hospital beds is standard across most healthcare studies [47, 76-78] and there is significant homogeneity in the data as well.

4.2 Health Services (Outputs): We use three of the most commonly used *hospital services, namely doctor consultations, hospital discharge rates, and patient days*, as the intermediate goods [47, 76-78], or in other words, the outputs of the first stage, later to be used as inputs of second stage. Because their homogeneity varies and effectiveness on health status depends on environmental variables, we control for per capita healthcare expenditure as a proxy for capital intensity, in addition to risk factors, and inequality.

4.3 Quality of Health Services (Control): We are using Potential years of life lost (PYLL)[1] as a proxy for service quality at the first stage. It is defined as "a summary measure of premature mortality which provides an explicit way of weighting deaths occurring at younger ages, which are, a priori, preventable" [111].

4.4 Patient-risk characteristics (Control): There are three highly standardized and commonly used risk characteristics defined in the OECD data set, namely tobacco and alcohol consumption, and obesity. Data regarding tobacco and alcohol consumption have been obtained from the OECD web site, while the BMI figures, as a proxy for overweight population, were obtained from the WHO data set [109].

4.5 Inequality in access to healthcare (Control): We use the Gini coefficient and alternatively poverty rates for each country as a proxy for inequality of access to healthcare. Although not a perfect match, the Gini is a sufficient indicator of healthcare inequality. There are various studies in the literature that show clear negative correlations between socioeconomic inequality and access to healthcare, both globally [104] and within a country [44]. We find that this correlation is stronger in privately oriented healthcare systems.

[1] The calculations for PYLL involve adding up deaths occurring at each age and multiplying this with the number of remaining years to live up to a selected age limit. The limit of 70 years has been chosen for the calculations in OECD Health Data.

5 Results

5.1 Inefficiency across time

The results in Graph and Table 2 indicate that the OECD radial productive inefficiency has slightly increased between 2000 and 2011, from about 12% to 13%. Individual outputs roughly agree with the radial results that the inefficiency has indeed increased. We see little difference with poverty rates when used as a proxy measure for inequality instead of the Gini.

Relative stability over time, however, does not necessarily imply there are no fluctuations. Socioeconomic variables obviously impact the utilization and efficiency of healthcare production, but those impacts do not seem to be permanent. The system tends to revert to the original path in the long run. Nevertheless this does not mean that resources do not become more productive and produce more over time, they actually do. However, it seems from the results that the increase in the production is similar to the shifts in production frontier; therefore the gap between the frontier and the actual production (output inefficiency) remains rather stable.

Graph 1 – OECD Inefficiency over the Years

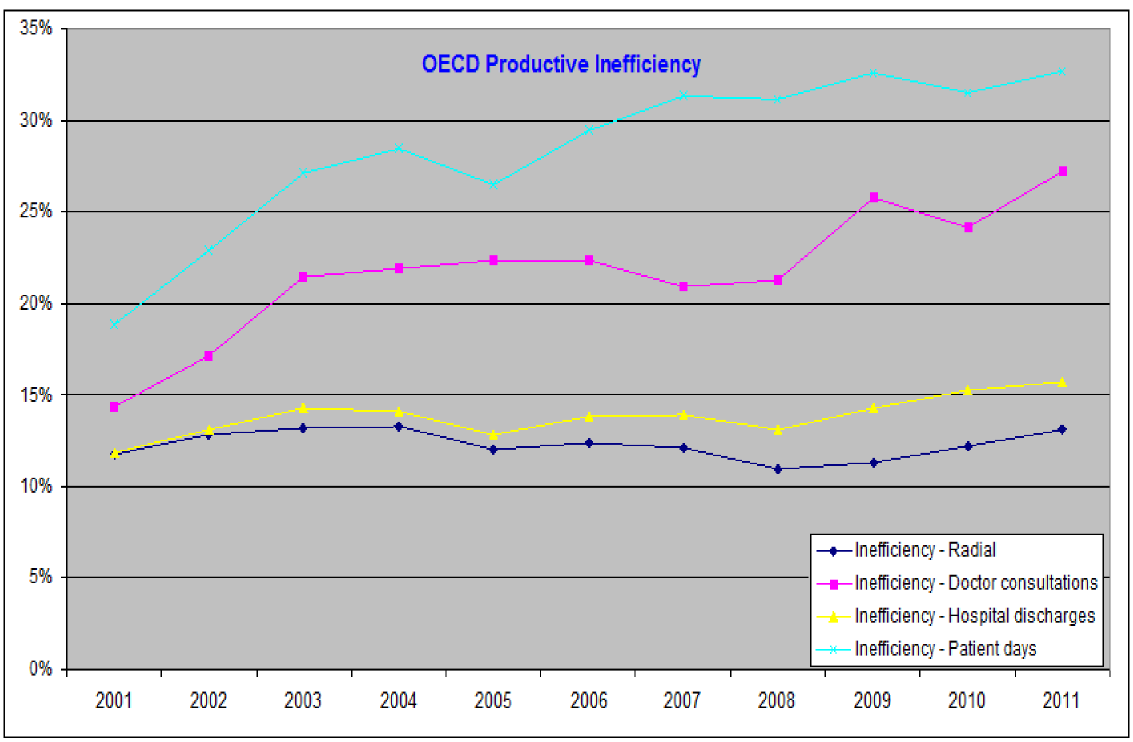


Table 2 – OECD Inefficiency over the Years

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Average
Efficiency -gini	11.77%	12.79%	13.19%	13.26%	12.02%	12.42%	12.09%	10.91%	11.31%	12.20%	13.11%	12.21%
Effic. -poverty	12.41%	12.84%	12.58%	12.78%	12.25%	12.75%	12.19%	10.63%	12.20%	13.24%	14.16%	13.20%
Doctor consult.	14.32%	17.12%	21.47%	21.92%	22.30%	22.38%	20.87%	21.23%	25.73%	24.16%	27.16%	25.68%
Hospital disc.	11.82%	13.14%	14.29%	14.06%	12.86%	13.80%	13.90%	13.10%	14.23%	15.25%	15.74%	15.07%
Patient days	18.84%	22.86%	27.13%	28.43%	26.51%	29.47%	31.30%	31.11%	32.55%	31.46%	32.68%	32.23%

5.2 Inefficiency level by country

Inefficiency - Radial	
Country	Average
Sweden	0.00%
Israel	0.00%
Turkey	0.00%
Korea	0.00%
Greece	0.00%
Italy	0.00%
Spain	0.05%
Chile	0.13%
Japan	0.35%
Switzerland	0.38%
Canada	0.60%
Czech	1.27%
New Zealand	1.70%
Austria	1.80%
Iceland	1.87%
Australia	3.60%
Luxembourg	3.64%
Hungary	4.92%
Slovenia	5.25%
Finland	5.28%
Germany	6.84%
UK	10.12%
Norway	11.01%
Average	12.21%
Denmark	18.09%
Slovak	20.51%
Belgium	22.63%
Ireland	22.71%
Estonia	29.14%
US	30.82%
France	31.32%
Mexico	35.11%
Netherlands	36.31%
Poland	39.78%
Portugal	72.30%

The average inefficiency between 2001 and 2011 is 12.21%. There are six countries (*Sweden, Israel, Turkey, Korea, Greece, and Italy*) that are found to be radially efficient in production. There is no clear economic or development pattern associated with those countries, other than that they are either resource-scarce or service-abundant, with relatively high productivity (output / input) levels based on the OECD data.

There are eleven countries with higher inefficiency rates than average. The least efficient countries are *Portugal, Poland, Netherlands, Mexico, France, and the US*. Again we do not see a clear pattern among these countries other than that they either have resource slacks, and/or do under-produce services, with relatively low productivity (output / input) levels.

However, the measured inefficiency of production may be misleading, as part of the inefficiency in production may be a result of this trade-off between quality and quantity as well as outputs not included in the analysis. Countries like *France, Poland*, and *Belgium* have relatively high health outcomes, with and a good chunk of their production inefficiency is likely due to this trade-off; which will further be investigated in the second stage of the analysis.

Other countries such as Germany and the UK have reasonable amounts of inefficiency while those like Spain, Chile and Japan are found to have very little inefficiency in production, if at all.

5.3 Sources of inefficiency

Employment of a radial (equiproportional) approach in the measurement of output inefficiency assumes no substitution or trade-off between the outputs, yielding rather conservative results assuring a minimum necessary increase in all outputs to reach efficiency. Nonetheless this does not prevent us from tracking the outputs and inputs slacks.

Table 3 – Sources of Inefficiency

	Doctor Consultations	Hospital Discharges	Patient Days	Nurses
US	109.2%	39.1%	39.1%	-70.5%
OECD	15.5%	11.5%	19.4%	-8.0%

It is clear from the results that "*Doctor Consultations*" is the most under-produced health service in the US with 109.2% inefficiency (less than half of the efficient figure), while OECD generally suffers inefficiency in producing "*patient days*", at 19.4%. Increasing the number of doctor consultations, in addition to more patient days, especially in US should help boost all other outputs[2].

Even though this study does not focus on the input efficiency, the huge slacks in the utilization of "nurses", exaggerated by, but not exclusive to, the US. There are other countries which suffer similar but smaller slacks in nurse utilization, such as Belgium, Denmark, Ireland, and Netherlands, creating a 10% slack (overuse) of nurses on average. Although this is most likely due to different use and allocation of resources (with respect to the substitutability of physicians and nurses), it is very unlikely that the huge slack in nurse utilization can only be attributed to that.

5.4 Productivity and Technical Change

The inclusion of the future observations inevitably increases the measured inefficiency for each year's OECD average. As argued earlier, this is either because of technological progress, which is a *shift in production frontier*, or DMUs moving closer to the actual frontier and helping us construct a more realistic one. As we discussed above, the measured efficiency across time is fairly stable in the long run; therefore the bulk of technical change in the long run largely reflects technological progress.

[2] The reason for identical numbers for the US *Hospital Discharges* and the *Patient Days* is the fact that the US *Average Length of Stay* is a binding constraint and much shorter than the OECD average.

When we look at the measured inefficiency figures for any base year (2001 to 2011), we find similar results which seem to be consistent and robust over time. In each of the cases, the evaluated year appears increasingly more inefficient due to the shifting frontier, albeit at slightly different levels (0.74% - 0.92%) due to short-run efficiency fluctuations as well as measurement issues with respect to the observed data. Long run averages, however, seem to agree with each other, at around 0.82%.

Graph 2 – Productivity Growth and Inefficiency Path over the Years

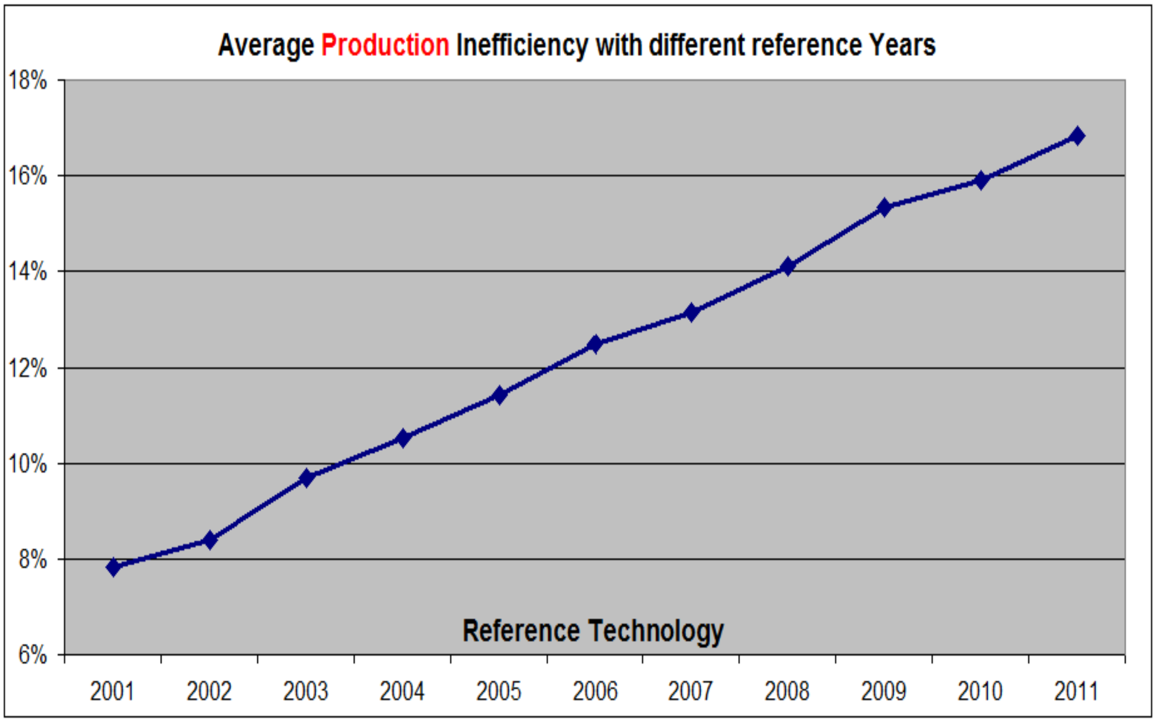


Table 4 – Inefficiency of Year i (left) with respect to the Technology of Year j (top)

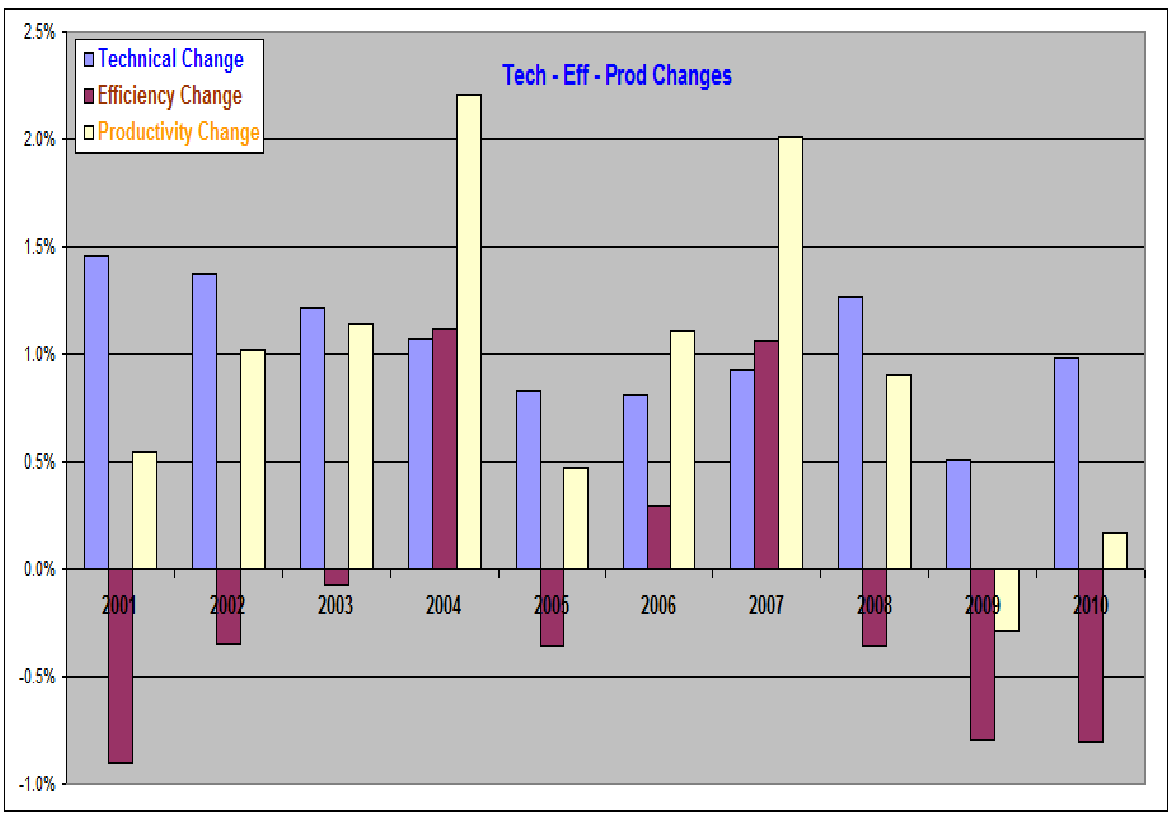
OECD	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Annual
2011	4.31%	4.59%	5.31%	5.64%	6.30%	7.45%	8.25%	9.76%	11.65%	12.12%	**13.11%**	0.80%
2010	4.56%	4.84%	5.68%	5.99%	6.91%	8.39%	9.15%	10.30%	11.83%	**12.20%**	13.42%	0.81%
2009	5.08%	5.38%	6.52%	6.96%	7.74%	8.84%	9.27%	10.08%	**11.31%**	12.07%	13.18%	0.74%
2008	5.83%	6.23%	7.43%	8.36%	8.92%	9.76%	10.25%	**10.91%**	12.48%	13.04%	13.87%	0.73%
2007	6.64%	7.08%	8.54%	9.14%	10.54%	11.35%	**12.09%**	13.51%	14.80%	15.64%	16.25%	0.87%
2006	7.38%	7.67%	9.40%	10.59%	11.68%	**12.42%**	13.49%	14.48%	15.59%	16.11%	17.50%	0.92%
2005	8.27%	8.70%	9.85%	10.46%	**12.02%**	13.14%	14.01%	14.87%	15.74%	16.50%	17.33%	0.82%
2004	10.13%	10.39%	11.52%	**13.26%**	14.10%	15.28%	16.12%	16.94%	18.07%	18.47%	19.08%	0.81%
2003	10.94%	11.47%	**13.19%**	14.17%	14.81%	15.92%	16.83%	17.54%	18.40%	18.80%	19.73%	0.80%
2002	11.06%	**12.79%**	14.14%	15.24%	16.05%	17.04%	17.43%	18.27%	19.31%	19.86%	20.76%	0.88%
2001	**11.77%**	13.29%	14.83%	15.77%	16.56%	17.55%	17.88%	18.47%	19.52%	20.12%	20.85%	0.82%

Table 5 – Decomposition of Productivity Growth, Technical and Efficiency Changes

OECD	Tech.Chng	Eff.Chng	Prod.Chng
Average	8.46%	-1.18%	7.18%
2001	1.46%	-0.90%	0.54%
2002	1.37%	-0.35%	1.02%
2003	1.21%	-0.07%	1.14%
2004	1.07%	1.11%	2.20%
2005	0.83%	-0.36%	0.47%
2006	0.81%	0.29%	1.11%
2007	0.93%	1.06%	2.00%
2008	1.26%	-0.36%	0.90%
2009	0.51%	-0.79%	-0.29%
2010	0.98%	-0.80%	0.17%

Cumulative productivity growth between 2001 and 2011 is 7.2% on average, somewhat less than the technical change at 8.5%, due to a slight decrease in technical efficiency, by around 1.2%. It is then plausible to assume that fluctuations are mostly due to short run changes in efficiency although the long run efficiency patterns seem to be relatively stable, as shown in the following graph 3.

Graph 3 – Decomposition of Productivity Growth, Technical and Efficiency Changes



Annual efficiency changes clearly take time to adjust. Whenever there is a significant change in technology, it leads to a disruption in the system and a temporary decrease in efficiency, which is then followed by a sequential increase and so on. In the long run, however, those fluctuations tend to smooth out. Productivity growth, integrating the inefficiency changes, clearly demonstrates these fluctuations, having a much greater variance than technical change, and sometimes going negative. Technical change however, is always positive (being non-regressive) and relatively stable (between 0.51% - 1.46%) though we see a slight decreasing trend. Considering the measurement errors in individual years, the fluctuations in technical change are likely even smaller, and from our study, it is not clear whether the technical change is increasing or decreasing.

Highest Techn. Change 2001-2011		
1	Mexico	52.20%
2	Netherlands	22.54%
3	Portugal	21.96%
4	Denmark	19.44%
5	France	19.75%
6	Slovak Republic	19.34%
7	United States	14.92%
8	Luxembourg	12.92%
9	Finland	12.23%
10	Belgium	11.74%

Countries with the highest technical change between 2001 and 2011 are mostly those which spend the most on healthcare and invest in technology. However, there are a few unexpected entries among the top countries such as Mexico and Slovak Republic, which seem to be rapidly catching up to their more developed neighbours. We should also note that all those countries also suffer from high inefficiency; none of the relatively efficient countries are among the top countries. This implies the technical change for relatively more efficient countries is underestimated in the analysis.

5.5 Limitations of the Study

a) *Radial efficiency analysis tends to underestimate the inefficiency*: The radial efficiency approach 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.

b) *Frontier analysis tends to underestimate technical changes:* There are two reasons for this: 1) technical changes for the efficient countries on the production frontier are inherently underestimated, and 2) technical spill-overs between countries do not shift the frontier but increase the efficiency through catch-up, which underestimates the role of technical change.

c) Production efficiency is just one part of the healthcare efficiency and only partially addresses the overall of the healthcare sector. Efficiency in provision as well as losses due to non-discretionary inputs (such as inequality) and lack of sufficient spending need to be considered. Some countries which excel at one particular stage often fail in another, and it is crucial to identify the exact sources of inefficiency.

6 Conclusion and Discussion

In this study, we have found that the OECD healthcare productive inefficiency has slightly increased from 12% to 13% between 2001 and 2011, which is also supported by the decomposition of individual outputs. However, this is not really surprising given the "catch-up" trend of the efficiency. According to our findings, whenever there is a larger technical change, efficiency levels tend to decrease, only to catch up in the subsequent periods. In other words, it takes time to adjust to the new technology, and efficiency will decrease when productivity increases do not keep up with the technical change.

In the literature, healthcare inefficiency often refers to "input based cost inefficiency", assuming the outputs are reasonably good, and the whole problem revolves around phenomenally high costs associated with inefficiency. Although the US has its fair share of input inefficiency, this is largely a "pricing issue" [43] rather than a cost efficiency issue, With a vastly different healthcare system, dominated by private oligopolistic firms, without sufficient government leverage and consumer-friendly bargaining power, the US is a special case. Our study, supporting this point, finds that there are substantial inefficiencies on the output side, resulting in severe under-production of health services, high prices and a very inefficient market for the delivery of the services.

Following the steps of Fare et al. (1997) [33], who examined the technical change in OECD countries in the 1974 - 1989 period and found a cumulative 33% growth with only 10 developed countries, we investigated whether the technological progress still persists in the modern era, and found supporting results. Unlike the bulk of the literature, we were able to include all 34 OECD countries, and found about 8.5% cumulative technical change and 7.2% productivity growth between 2001 and 2011, while technical inefficiency has increased by 1.2%. The technical change has slightly

speeded up in the recent years and most of the fluctuations seem to be due to the efficiency changes as a result of the catch-up process.

Given the aforementioned limitations of the methodology, the technical change is likely to be underestimated. Concentrating on the more developed countries boosts the annual technical change from 0.82% to around 1.2%. Therefore, it is plausible to assume a 1% annual technical change, which would accumulate to 16% in 15 years. Limiting the results to relatively more developed nations, on the other hand, as in Fare et al [33], would imply about 20% of cumulative change at the same time frame. The more comprehensive nature of our study and the spillover effects that are not typically detected in the analysis imply even larger technical change.

Although investment in technology is partially responsible for increasing healthcare costs, it more than pays back as it is also the main driver of the productivity increases. This study, however, only deals with the production side of the story and calculates the technical change for health services, which are intermediate goods in the healthcare system. The ultimate goal of the healthcare system, however, is to produce the best health outcomes.

We will devise a more coherent multi-stage framework in subsequent studies to further investigate and establish a clear link between output and outcome productivity growth and technical changes. This will also help us to better analyse the impact of technical changes on health outcomes, and whether the inefficiencies in the production of services reveal themselves as inefficiencies in health outcomes.

7 Appendix

Table 6 – Radial Inefficiency Levels between 2001 and 2011

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Average
Australia	0.00%	0.00%	3.23%	3.31%	0.56%	0.43%	5.10%	5.48%	6.34%	6.02%	9.11%	3.60%
Austria	0.12%	0.00%	0.99%	0.00%	0.39%	0.11%	0.11%	0.16%	4.54%	6.55%	6.84%	1.80%
Belgium	30.62%	26.48%	33.76%	33.44%	25.59%	21.92%	21.92%	16.75%	12.43%	11.14%	14.86%	22.63%
Canada	0.00%	1.62%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.47%	2.54%	0.60%
Chile	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.34%	0.00%	1.04%	0.13%
Czech R.	0.60%	0.50%	0.37%	0.36%	0.11%	0.73%	0.57%	3.22%	2.69%	3.32%	1.46%	1.27%
Denmark	0.50%	3.55%	21.91%	24.12%	16.62%	25.19%	24.02%	24.05%	20.11%	21.56%	17.35%	18.09%
Estonia	31.97%	31.65%	29.25%	17.55%	25.73%	29.11%	25.10%	30.32%	33.25%	32.65%	33.92%	29.14%
Finland	0.00%	0.00%	1.05%	3.80%	5.88%	4.83%	5.31%	8.11%	4.59%	12.97%	11.50%	5.28%
France	0.00%	30.94%	34.04%	35.35%	36.86%	37.69%	34.02%	35.93%	34.46%	32.19%	33.10%	31.32%
Germany	21.74%	21.73%	7.15%	6.93%	3.82%	1.59%	0.62%	2.82%	2.63%	3.00%	3.24%	6.84%
Greece	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Hungary	0.00%	0.60%	0.49%	0.65%	0.00%	3.90%	11.46%	8.21%	6.62%	13.70%	8.46%	4.92%
Iceland	0.00%	0.00%	0.00%	6.47%	0.00%	8.13%	4.84%	0.00%	1.13%	0.00%	0.00%	1.87%
Ireland	41.11%	42.12%	37.49%	36.68%	32.12%	24.94%	16.08%	15.54%	1.42%	1.12%	1.14%	22.71%
Israel	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Italy	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Japan	0.00%	0.00%	0.07%	0.00%	0.22%	0.00%	0.00%	0.00%	0.00%	0.00%	3.57%	0.35%
Korea	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Luxembourg	2.90%	0.81%	0.00%	0.00%	0.00%	7.49%	0.00%	0.00%	2.97%	12.09%	13.76%	3.64%
Mexico	20.71%	18.81%	23.98%	34.17%	25.79%	27.68%	33.53%	35.33%	42.50%	52.04%	71.63%	35.11%
Netherlands	40.42%	45.86%	45.67%	40.38%	40.71%	34.04%	34.75%	35.58%	36.92%	22.87%	22.21%	36.31%
N. Zealand	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	8.21%	10.46%	1.70%
Norway	16.29%	18.64%	11.35%	14.93%	8.66%	12.21%	8.98%	1.81%	7.61%	9.17%	11.52%	11.01%
Poland	65.86%	62.74%	60.63%	55.83%	38.07%	33.89%	35.48%	32.32%	20.16%	17.83%	14.79%	39.78%
Portugal	79.37%	73.17%	76.68%	80.80%	80.61%	70.27%	71.65%	60.01%	70.51%	65.95%	66.32%	72.30%
Slovak R.	13.33%	6.53%	7.79%	13.39%	17.67%	25.46%	29.20%	21.94%	26.41%	31.25%	32.61%	20.51%
Slovenia	0.00%	19.50%	17.37%	6.95%	8.18%	3.70%	1.96%	0.06%	0.00%	0.00%	0.00%	5.25%
Spain	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.54%	0.05%
Sweden	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Switzerland	0.47%	0.51%	0.98%	0.23%	0.00%	0.00%	0.00%	0.00%	2.00%	0.00%	0.00%	0.38%
Turkey	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
UK	2.37%	1.87%	7.04%	7.85%	13.34%	20.69%	16.73%	6.02%	14.27%	10.85%	10.24%	10.12%
USA	31.90%	27.27%	27.00%	27.78%	27.62%	28.25%	29.59%	27.34%	30.70%	37.95%	43.57%	30.82%
Average	11.77%	12.79%	13.19%	13.26%	12.02%	12.42%	12.09%	10.91%	11.31%	12.20%	13.11%	12.21%

Table 7 – Doctor Consultations Inefficiency Levels between 2001 and 2011

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Average
Australia	0.00%	0.00%	3.23%	3.31%	0.56%	0.43%	5.10%	5.48%	6.34%	6.02%	9.11%	3.60%
Austria	2.43%	27.56%	21.44%	31.12%	45.81%	20.77%	27.20%	32.62%	31.25%	37.32%	45.47%	29.36%
Belgium	30.62%	26.48%	33.76%	33.44%	25.59%	21.92%	21.92%	16.75%	12.43%	11.14%	14.86%	22.63%
Canada	0.00%	1.62%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.47%	2.54%	0.60%
Chile	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.34%	0.80%	1.04%	0.20%
Czech R.	0.60%	0.50%	0.37%	0.36%	0.11%	0.73%	0.57%	3.22%	2.69%	4.07%	1.46%	1.33%
Denmark	4.26%	13.75%	40.68%	44.86%	40.67%	43.37%	38.80%	32.11%	50.24%	41.08%	32.53%	34.76%
Estonia	53.87%	40.50%	29.25%	17.55%	25.73%	32.02%	25.10%	30.80%	38.62%	58.00%	52.14%	36.69%
Finland	0.00%	6.17%	6.99%	11.21%	6.30%	30.05%	12.54%	64.76%	150.44%	130.15%	138.96%	50.69%
France	0.00%	30.94%	34.04%	35.35%	36.86%	37.69%	34.02%	35.93%	34.46%	32.19%	33.10%	31.32%
Germany	21.74%	21.73%	7.15%	15.60%	5.93%	30.90%	26.73%	33.15%	26.54%	17.49%	18.15%	20.46%
Greece	0.00%	21.52%	21.79%	50.38%	55.25%	64.40%	64.38%	70.55%	24.22%	22.66%	72.21%	42.49%
Hungary	0.00%	0.60%	0.49%	0.65%	0.00%	3.90%	11.46%	8.21%	6.62%	13.70%	8.46%	4.92%
Iceland	0.00%	0.00%	0.00%	6.47%	0.00%	8.13%	4.84%	0.00%	1.13%	0.00%	0.00%	1.87%
Ireland	98.85%	107.18%	99.19%	93.92%	119.45%	96.14%	66.74%	53.46%	68.60%	13.26%	13.37%	75.47%
Israel	0.00%	0.12%	0.00%	0.00%	2.29%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.22%
Italy	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Japan	0.00%	0.00%	0.07%	0.00%	0.22%	0.00%	0.00%	1.52%	1.81%	0.80%	3.57%	0.73%
Korea	0.00%	0.00%	0.00%	0.00%	3.65%	2.44%	0.00%	0.37%	1.88%	9.69%	5.81%	2.17%
Luxembourg	2.90%	0.81%	0.00%	0.50%	0.00%	7.49%	0.00%	0.00%	2.97%	12.09%	13.76%	3.68%
Mexico	20.71%	18.81%	23.98%	34.17%	25.79%	27.68%	33.53%	35.33%	42.50%	52.04%	71.63%	35.11%
Netherlands	40.42%	45.86%	45.67%	40.38%	40.71%	34.04%	34.75%	35.58%	36.92%	22.87%	22.21%	36.31%
N. Zealand	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	18.60%	20.24%	3.53%
Norway	16.29%	22.01%	21.26%	25.96%	18.33%	17.79%	8.98%	1.81%	12.26%	13.51%	17.15%	15.94%
Poland	65.86%	62.74%	60.63%	55.83%	38.07%	33.89%	35.48%	32.32%	51.56%	47.08%	43.74%	47.93%
Portugal	79.37%	73.17%	76.68%	80.80%	80.61%	70.27%	71.65%	60.01%	75.84%	66.19%	66.32%	72.81%
Slovak R.	13.33%	6.53%	7.79%	13.39%	17.67%	25.46%	29.20%	21.94%	26.41%	31.25%	32.61%	20.51%
Slovenia	0.00%	19.50%	17.37%	6.95%	8.18%	3.70%	1.96%	0.06%	0.00%	1.51%	1.38%	5.51%
Spain	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.54%	0.05%
Sweden	0.00%	0.00%	17.63%	21.94%	79.94%	69.82%	42.05%	43.35%	49.28%	46.38%	63.22%	39.42%
Switzerland	1.23%	4.95%	125.34%	81.08%	39.59%	24.24%	66.15%	7.71%	8.18%	9.46%	11.10%	34.46%
Turkey	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.57%	0.00%	0.23%
UK	2.37%	1.87%	7.04%	7.85%	13.34%	20.69%	16.73%	6.02%	14.27%	10.85%	10.24%	10.12%
USA	31.90%	27.27%	28.11%	32.15%	27.62%	32.88%	29.59%	88.87%	97.02%	86.16%	96.58%	52.56%
Average	14.32%	17.12%	21.47%	21.92%	22.30%	22.38%	20.87%	21.23%	25.73%	24.16%	27.16%	25.68%

Table 8 – Hospital Discharges Inefficiency Levels between 2001 and 2011

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Average
Australia	0.00%	0.00%	3.23%	3.31%	0.56%	0.43%	5.10%	5.48%	6.34%	6.02%	9.11%	3.60%
Austria	0.12%	0.00%	0.99%	0.00%	0.39%	0.11%	0.11%	0.16%	4.54%	6.55%	6.84%	1.80%
Belgium	30.62%	26.48%	33.76%	33.44%	25.59%	21.92%	21.92%	16.75%	12.43%	11.14%	14.86%	22.63%
Canada	0.00%	4.78%	3.90%	10.30%	8.62%	32.26%	36.63%	23.12%	26.89%	36.93%	41.66%	20.46%
Chile	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.34%	0.00%	1.04%	0.13%
Czech R.	0.60%	0.50%	0.37%	0.36%	1.86%	0.73%	0.57%	3.22%	7.18%	3.32%	1.46%	1.83%
Denmark	0.50%	3.55%	21.91%	24.12%	16.62%	25.19%	24.02%	24.05%	20.11%	21.56%	17.35%	18.09%
Estonia	31.97%	31.65%	29.25%	17.55%	25.73%	29.11%	25.10%	30.32%	33.25%	32.65%	33.92%	29.14%
Finland	0.00%	2.96%	3.10%	5.51%	6.10%	8.10%	12.66%	11.37%	11.53%	15.21%	13.90%	8.22%
France	0.00%	30.94%	34.04%	35.35%	36.86%	37.69%	34.02%	35.93%	34.46%	32.19%	33.10%	31.32%
Germany	21.74%	21.73%	7.15%	6.93%	3.82%	1.59%	1.00%	2.82%	2.63%	3.00%	3.24%	6.88%
Greece	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Hungary	0.00%	0.78%	2.52%	3.18%	3.55%	6.35%	11.46%	8.21%	6.62%	13.70%	8.46%	5.89%
Iceland	0.00%	0.00%	0.00%	6.47%	0.00%	8.13%	9.61%	0.00%	1.13%	1.95%	0.00%	2.48%
Ireland	41.11%	42.12%	37.49%	36.68%	32.12%	24.94%	16.08%	15.54%	1.42%	1.12%	1.14%	22.71%
Israel	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Italy	0.00%	0.00%	0.00%	0.00%	0.00%	0.78%	0.00%	3.23%	3.28%	11.18%	2.91%	1.94%
Japan	0.00%	0.00%	0.07%	3.35%	0.22%	0.35%	0.92%	1.49%	1.62%	8.44%	3.57%	1.82%
Korea	0.00%	0.00%	0.00%	0.31%	0.06%	0.00%	0.00%	0.00%	10.04%	7.08%	4.57%	2.01%
Luxembourg	2.90%	3.19%	0.00%	0.00%	0.00%	7.49%	0.10%	0.00%	2.97%	12.09%	13.76%	3.86%
Mexico	20.71%	18.81%	23.98%	34.17%	25.79%	27.68%	33.53%	60.50%	76.91%	81.92%	90.66%	44.97%
Netherlands	40.42%	45.86%	45.67%	40.38%	40.71%	34.04%	34.75%	35.58%	36.92%	22.87%	22.21%	36.31%
N. Zealand	0.00%	0.00%	0.00%	0.70%	0.00%	4.52%	0.00%	0.00%	0.00%	8.21%	10.46%	2.17%
Norway	16.29%	18.64%	11.35%	14.93%	8.66%	12.21%	8.98%	1.81%	7.61%	9.17%	11.52%	11.01%
Poland	65.86%	62.74%	60.63%	55.83%	38.07%	33.89%	35.48%	32.32%	20.16%	17.83%	14.79%	39.78%
Portugal	79.37%	73.17%	76.68%	80.80%	80.61%	70.27%	71.65%	60.01%	70.51%	65.95%	66.32%	72.30%
Slovak R.	13.33%	6.53%	7.79%	13.39%	17.67%	25.46%	29.20%	21.94%	26.41%	35.87%	35.71%	21.21%
Slovenia	0.00%	19.50%	17.37%	6.95%	8.18%	3.70%	1.96%	0.06%	0.00%	0.00%	0.00%	5.25%
Spain	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.86%	16.63%	11.62%	0.00%	14.73%	4.17%
Sweden	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Switzerland	2.00%	3.85%	30.46%	8.51%	14.51%	3.35%	8.73%	1.45%	2.00%	3.74%	4.01%	7.51%
Turkey	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
UK	2.37%	1.87%	7.04%	7.85%	13.34%	20.69%	16.73%	6.02%	14.27%	10.85%	10.24%	10.12%
USA	31.90%	27.27%	27.00%	27.78%	27.62%	28.25%	29.59%	27.34%	30.70%	37.95%	43.57%	30.82%
Average	11.82%	13.14%	14.29%	14.06%	12.86%	13.80%	13.90%	13.10%	14.23%	15.25%	15.74%	15.07%

Table 9 – Hospital Discharges Inefficiency Levels between 2001 and 2011

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Average
Australia	0.00%	0.00%	24.85%	28.50%	28.48%	25.39%	25.17%	45.61%	39.78%	38.69%	43.22%	27.24%
Austria	0.12%	0.00%	0.99%	0.00%	0.39%	1.05%	0.11%	0.16%	4.54%	6.55%	6.84%	1.89%
Belgium	30.62%	26.48%	33.76%	33.44%	25.59%	21.92%	21.92%	16.75%	12.43%	11.14%	17.99%	22.91%
Canada	0.00%	3.34%	4.34%	7.88%	2.36%	12.77%	14.15%	7.88%	11.59%	2.47%	8.07%	6.80%
Chile	0.00%	0.00%	0.00%	2.56%	1.91%	2.68%	1.04%	1.51%	1.07%	1.40%	4.98%	1.56%
Czech R.	0.60%	0.50%	0.37%	0.36%	0.11%	0.73%	0.57%	3.22%	2.69%	3.32%	1.46%	1.27%
Denmark	0.50%	3.55%	92.90%	107.18%	95.17%	111.10%	135.82%	141.05%	123.69%	110.86%	94.94%	92.43%
Estonia	31.97%	31.65%	29.25%	17.55%	25.73%	29.11%	25.10%	30.32%	33.25%	32.65%	33.92%	29.14%
Finland	0.00%	0.00%	1.05%	3.80%	5.88%	4.83%	5.31%	8.11%	4.59%	12.97%	11.50%	5.28%
France	0.00%	63.83%	73.87%	72.06%	78.13%	80.42%	98.90%	79.17%	98.61%	75.94%	97.55%	74.41%
Germany	21.74%	21.73%	7.15%	6.93%	3.82%	1.59%	0.62%	2.82%	2.63%	3.00%	3.24%	6.84%
Greece	0.00%	0.00%	0.00%	6.55%	5.49%	8.48%	5.21%	0.00%	7.67%	10.78%	5.87%	4.55%
Hungary	0.00%	0.60%	1.13%	0.65%	1.03%	4.17%	11.46%	8.21%	6.62%	13.70%	8.46%	5.09%
Iceland	0.00%	10.48%	1.79%	18.91%	5.46%	16.21%	15.91%	1.79%	1.13%	0.00%	0.19%	6.53%
Ireland	67.65%	77.95%	80.70%	85.08%	75.06%	69.03%	56.26%	48.65%	48.25%	32.35%	33.65%	61.33%
Israel	0.00%	0.00%	2.24%	3.37%	1.55%	0.00%	2.34%	4.34%	2.39%	14.74%	4.87%	3.26%
Italy	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Japan	0.00%	0.00%	0.66%	0.00%	0.22%	0.00%	0.00%	1.26%	6.07%	0.17%	4.83%	1.20%
Korea	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	10.77%	0.00%	0.00%	0.98%
Luxembourg	5.18%	0.81%	0.00%	0.00%	0.00%	7.49%	0.00%	0.00%	2.97%	12.09%	13.76%	3.84%
Mexico	69.95%	67.83%	83.53%	101.56%	97.13%	90.15%	86.12%	100.63%	113.07%	120.57%	114.06%	94.96%
Netherlands	40.42%	45.86%	45.67%	40.38%	40.71%	34.04%	65.82%	82.67%	99.59%	98.42%	106.36%	63.63%
N. Zealand	0.00%	0.00%	1.78%	0.00%	2.69%	0.00%	5.54%	7.86%	0.00%	8.21%	10.46%	3.32%
Norway	51.80%	51.26%	33.76%	64.69%	54.09%	74.05%	56.34%	48.90%	76.39%	63.06%	66.00%	58.21%
Poland	75.05%	72.23%	75.21%	78.80%	41.92%	41.24%	50.58%	43.85%	27.97%	24.91%	25.60%	50.67%
Portugal	79.37%	73.17%	76.68%	80.80%	80.61%	125.28%	124.47%	109.01%	97.07%	99.68%	99.51%	95.06%
Slovak R.	13.33%	6.53%	7.79%	13.39%	17.67%	25.46%	29.20%	30.85%	31.95%	34.68%	34.03%	22.26%
Slovenia	0.00%	73.46%	81.94%	6.95%	8.18%	3.70%	1.96%	9.31%	4.45%	4.37%	8.22%	18.41%
Spain	0.00%	0.00%	0.00%	13.01%	14.77%	19.05%	10.22%	13.54%	23.87%	12.17%	25.92%	12.05%
Sweden	0.00%	0.00%	14.26%	18.98%	22.19%	20.60%	33.94%	38.91%	48.25%	57.92%	62.57%	28.87%
Switzerland	0.47%	0.51%	0.98%	0.23%	0.00%	0.00%	0.00%	0.00%	2.00%	0.00%	0.00%	0.38%
Turkey	0.00%	0.00%	0.00%	0.00%	1.17%	2.18%	5.38%	19.10%	2.59%	6.38%	6.57%	3.94%
UK	2.37%	1.87%	7.04%	7.85%	13.34%	20.69%	16.73%	6.02%	14.27%	10.85%	10.24%	10.12%
USA	149.28%	143.60%	138.78%	145.17%	150.68%	148.60%	158.18%	146.22%	144.39%	145.59%	146.12%	146.96%
Average	18.84%	22.86%	27.13%	28.43%	26.51%	29.47%	31.30%	31.11%	32.55%	31.46%	32.68%	32.23%

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The Impact of Technical Change on OECD Healthcare Outcomes and Efficiency

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Abstract

This paper measures the technical efficiency of healthcare systems and estimates the impact of technical change on health outcomes across OECD Countries between 2000 and 2011, based on a 12 year, 34 country panel dataset, extending our previous study of productive efficiency in OECD as a part of a multi-stage analysis. We adopt a DEA (Data Envelopment Analysis) based output-oriented efficiency methodology to obtain the productive efficiency of each country for all given years, and use the Malmquist Index to determine the productivity growth and decompose the technical change from efficiency changes over the years.

We find that the inefficiency in OECD health outcomes has slightly increased over time, from 2.8% to 3.1%, while the production frontier shifted up around 2% between 2000 and 2010. Technical change alone explains 30-50% of the improvement in health outcomes (6.4%) in the given period. 1% technical change in production leads to a 0.2% change in health outcomes, and technological progress seems to be fairly stable over time while most of the fluctuations in productivity growth come from changes in efficiency due to utilization of new technologies.

Keywords: Healthcare, Efficiency, DEA, Technical Change, Productivity Growth, OECD

1 Introduction

In most developed countries, the state devotes a considerable share of resources to healthcare [6], and healthcare costs have been steadily increasing to current levels, over 10% of GDP globally [76, 61], with few signs of slowing down in the future [58, 74].

To explain this trend, many studies [3, 8, 39, 49, 50, 64, 68, 82, 103] have tried to diagnose the underlying factors such as an ageing population, increased social expectations, broader insurance coverage, supplier induced demand and relative prices that may affect the utilization and costs of healthcare services. Efficiency and productivity of the healthcare systems, as well as *technological change and productivity growth* in healthcare have also been claimed to have a major impact on healthcare costs [3, 38, 63, 73].

Technological advances in healthcare, notably hospital care, have been dramatic over the last four decades [34], but they have often been blamed for the mounting costs of hospital care, especially in the United States. Various analysts (Aaron, (1991) [1]; Newhouse, (1993) [69]; and Schwartz and Mendelson, (1994) [88]) have argued that technological change generates the underlying growth in expenditures.

On the other hand, many studies in the literature [12, 13, 40, 65, 78, 86] identify technical change as the main source of healthcare improvements. Fare et al. [31], for example, find widespread and rapid productivity growth for a sample of OECD countries from 1974 to 1989, especially for Denmark and the USA. Likewise, Francesco Moscone et al. [65] find a significant relationship between scientific research and the growth in healthcare productivity. Although technical change is found to constitute about a quarter of the healthcare expenditure growth, it also constitutes a large portion of the outcome growth. In this study, we find a similar increase in technical change, and identify it as the main source of healthcare improvements.

Another possibility is that increasing inefficiency in the hospital industry is causing real expenditure growth; a World Bank Health, Nutrition and Population Paper by Wang, et al. (1999) [98] and a WHO study (2000) [100] made early attempts to measure global healthcare efficiency using different performance indicators, showing enormous variance in health outcomes, despite similar income and education levels. This generated considerable interest in the measurement of healthcare efficiency.

Among the seminal healthcare studies at the system level are Hollingsworth and Wildman (2002) [47], Jamison et al. (2001) [52], Salomon et al. (2001) [87], and Evans et al. (2001) [28].

Schwartz and Mendelson [88] argue that almost a quarter of the real expenditure growth could be eliminated if inefficiency was curbed. Greene [41] argues that the main problems in the US are the access to healthcare and phenomenally high medical prices, rather than the quality of healthcare. Similarly recent studies suggest that if increases in healthcare costs are inevitable, the focus should shift from cost reduction to improving healthcare quality [95]. It is then much more plausible to argue the system should try to maximize its output levels given the input it is provided, as the resources and expenditure levels used in healthcare production are usually determined externally. This is why we adopt an *output-oriented* efficiency measure in our study.

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. The measured inputs and outputs are assumed to be homogeneous across units. *Data Envelopment Analysis (DEA)* is a nonparametric approach which constructs a theoretical *best-practice* frontier from the observed data points to measure the efficiency of any observed point. The method can simultaneously handle multiple inputs and outputs, originally developed to measure the efficiency of a DMU as a whole unit, without considering its internal structure. Within this black box, inputs are supplied to produce outputs, generally with a positive correlation between the two, which is not always the case [25, 97]. It is often necessary to study the internal structure of a system so that the cause of any inefficiency can be identified.

The first study using this approach is probably Charnes et al. (1986) [18], who observes two stages in army recruitment; the first one is creating awareness through advertisements, and the second one is creating contracts. *Separating large operations into multiple stages helps identify the real impact of input factors.* The simplest case is to separate the whole operation into two stages, as in Charnes et al. (1986) and Wang et al. (1997) [97] studies. There are more complicated cases with more than two stages and in different structural forms such as series structure, a parallel structure, or a mixture of these, which are overall called "network structures", and the DEA technique to measure the efficiency of systems with a network structure is called network DEA after (Färe & Grosskopf, 2000) [36].

Another issue is that an overall system may be efficient, even when all of its stages are not [53]. Although a DMU which is efficient in all stages is also efficient overall, there are cases in which a DMU is less efficient in all stages than another DMU, and yet the former still has better system

efficiency [54]. Similarly, in healthcare production, a DMU inefficient at production can still appear efficient in overall outcomes. This is because a) in the case of overuse of health resources, the inefficiency in production does not automatically lead to inefficiency in health outcomes; b) constant returns in production is often linked with rapidly diminishing returns in provision, so a fairly large efficiency loss in production will not always result in similar losses in outcomes.

Measuring efficiency in healthcare directly from resources to outcomes ignores the inefficiencies in production. Although the system may be efficient overall, the inefficiencies within the system are still costly and should be eliminated. We show in this study that the inefficiency in production also leads to decreases in productivity growth, which remains underestimated or undetected without a multi-stage analysis. These findings indicate that a network DEA model is required to produce correct results when measuring efficiencies.

Countless studies that discuss network DEA have been published since Charnes et al. (1986). Cook, Liang, and Zhu (2010) [24] reviewed a number of models for the basic two-stage systems, connected in series, where the second stage only consumes all the outputs from the first production. Castelli, Pesenti, and Ukovich (2010) [15] reviewed shared-flow, multilevel, and some network models. The network models they reviewed are of the general network DEA form developed by Färe and Grosskopf (2000) [36], leaving many others untouched.

Our study falls under "General two stage-structure", which is an extended form of basic two stage models, allowing both stages to consume exogenous inputs supplied from outside and to produce final outputs. Examples include Simon, Simon, and Arias (2011) [90] who analysed the productivity growth of 34 Spanish university libraries using an MPI, or Löthgren and Tambour (1999) [57] who included customer satisfaction in studying the performance of 31 Swedish pharmacies.

2 Objectives

As stressed by Jacobs et al. (2006) [51], efficiency analysis should be based on outcomes of care. However researchers are often forced to study efficiency on the basis of measured services like patients treated or hospital discharges. Many of the published studies use health services as outputs [2, 27, 85], but some studies include health outcomes as outputs [14, 26, 55, 91], and a few include quality, either explicitly [43] or as an explanatory variable [102]. Either way is problematic, since health services as intermediate goods do not tell us whether the patient's health has improved, while the outcomes are not the direct products of the inputs used but of intermediate goods in conjunction

with other non-discretionary inputs. This critique was summarized in Newhouse (1994) [70] and fully discussed in Jacobs et al. (2006) [51], who conclude by suggesting the use of multivariate models and multi-stage models [44], where the objectives may include quality.

Färe and Grosskopf (2000) [36] introduced a multistage DEA (*Data Envelopment analysis*) model that later came to be known as *network DEA*. Following their paradigm, we devise a multi-stage healthcare system analysis where production takes place at the first stage and resources produce health services, which are, as intermediate goods, then transformed to health outcomes at the second (provision) stage. Additionally, non-discretionary inputs, which affect both the production and provision stages by shifting the frontiers, need to be controlled for.

Although there are numerous studies in the literature examining the technical changes of the OECD healthcare systems [11, 19, 27, 31, 34, 42, 62, 77, 92, 101], the focus is on the production side, with little emphasis of the technical change on *provision* (the actual health outcomes), and the relationship between the technical changes on *production* and *provision* is not well established.

Fare et al. (1997) paper [34] for example, calculates the technical change for both health services and outcomes at one stage and from resources. However, health outcomes are a product of health services, rather than directly of resources, and skipping the production stage leads to underestimation of not only inefficiency but also the productivity growth of outcomes.

In this paper, we do not only investigate the second (provision) stage but also combine the results obtained from our previous study [9] which investigated the first (production) stage. This will enable us to pinpoint where exactly the inefficiencies occur and what is the role of technology in all of this.

As part of a multi-stage analysis, *this paper's main contribution will be to analyze the subsequent impact of productivity growth and technical inefficiency of production on the provision side, as a follow up to our previous study investigating the production stage*. The purpose of this paper can be expressed in three parts:

a) To measure the outcome efficiency levels of all 34 OECD Countries, by discriminating between production and provision inefficiencies, and monitor their progress over time.

b) To measure the technical change and productivity growth between 2000 and 2010, and to gauge the impact of productive inefficiency on the technical change of outcomes.

c) To gauge the impact of technical change in production on technical change in provision.

We mainly use OECD data [74], which are, for the most part, standardized across fairly similar countries; so the quality of the variable measurements, although spotty at times, is relatively good. The only non-OECD data are the BMI figures acquired from the World Health Organization as a patient risk characteristic. Inclusion of multiple (12) years also serves to give a better picture of each country, rather than a one-year snapshot.

Following the standard procedure, we are using additional variables to control for non-discretionary inputs and the quality of outputs, which will be further investigated in the following pages. We aim to measure inefficiency levels, identify the sources of inefficiency, and measure the productivity growth and decompose the technical change from the changes in technical efficiency.

3 Methodology

3.1 Literature

DEA was first introduced by Charnes, Cooper, and Rhodes in 1978 [17] and further formalized by Banker, Charnes and Cooper in 1984 [4] based on Farrell's (1959) [37] simple measure of firm efficiency that accounted for multiple inputs. The first application of DEA to health issues is an unpublished work from 1979 regarding family planning centers in Costa Rica and Guatemala (Ray 2004, p. xi) [81]. Nunamaker and Lewin (1983) [72] is the first published work applying DEA to healthcare, whereas Sherman (1984) [89] was the first author to use DEA to evaluate overall hospital efficiency. Today there is a very extensive literature surveyed by O'Neill et al. (2008) [75], who emphasize national differences in hospital efficiency research, and Ozcan (2008) [76] who encompasses many aspects of healthcare delivery, as well as providing an overview of existing techniques, while Hollingsworth (2008) [48] classifies 317 published papers into various subcategories and offers comments as to their practical usefulness.

Recent healthcare studies that concentrate on OECD countries include Retzlaff-Roberts et al. (2004) [83], who find that countries with less stellar results can also be relatively efficient; Varabyova et al. (2013) [96] who use a panel data set and compare parametric and non parametric methods for a robustness check; and Cheng and Zervopoulos (2014) [23], who extend their study to 171 countries and use a directional distance function to incorporate undesirable outputs as well.

Although the initial Farrell analysis [37] is static, changes in efficiency can be measured over time, i.e. the frontier may shift due to technological advances. Productivity is defined as the ratio of an index of output to an index of input usage. Change of this measure over time is productivity change, which was initially attributed to technological changes, i.e. shifts of the production or cost frontier. However, it became increasingly recognized after Nishimuzu and Page (1982) [71] that productivity change can also be caused by changes in efficiency, that is, firms move closer to the theoretical frontier over time, rather than show genuine technological progress (shifts in the actual production frontier).

The Malmquist index [59], introduced in 1953 by the Swedish economist, Sten Malmquist, is a summary measure of the change in productivity of a given unit over time. Initially, Caves et. al. (1982) [16] adapted this index in order to evaluate productivity movements between different production units. Later, Fare et al. (1989) [29] derived the Malmquist productivity index as a geometric mean of the technologies of two periods of Caves et al.'s output productivity indices, and decomposed it into efficiency change and technological change components. Fare and Grosskopf (1992) [30] then generalized their non-parametric approach to eliminate assumptions on optimizing behavior, efficiency, and the need for price data, unlike previous studies such as Nishimizu and Page (1982) [71] and Bauer (1990) [7], which required specification of a functional form for technology. Fare et al. (1997) [34] later used the technique to measure the productivity growth in healthcare across 10 OECD countries between 1974 and 1989.

Fa¨re et al. (1994) [31] operationalized and further the decomposed the approach to include scale changes, maintaining the constant returns to scale (CRS) assumption. However, the internal inconsistency of the approach, attempting to explain the scale changes under CRS, which requires the assumption of variable returns to scale (VRS) was criticized by Ray and Desli (1997) [80] who found significantly different results under VRS. Färe et al. (1997) [35] acknowledge the criticism and suggest that the CRS and VRS should be considered as the upper (long run) and lower (short run) boundaries of the production frontier of a given technology. Lovell et al. (1994) [56] also showed that the Malmquist productivity index can be expressed as the product of a Malmquist productivity index and a Malmquist scale index, as well as the ratio of a Malmquist output quantity index to a Malmquist input quantity index

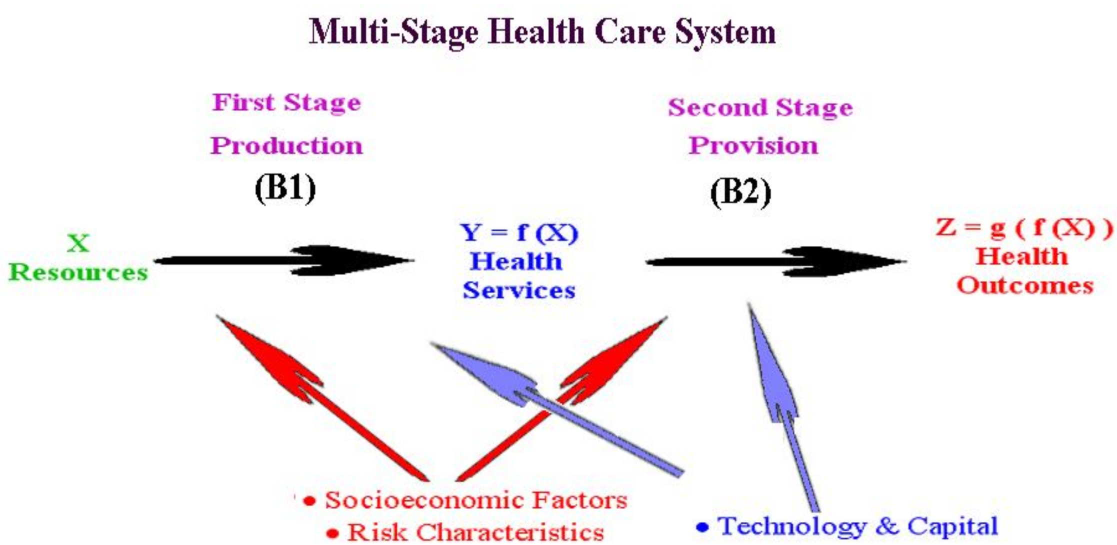
Fa¨re et al. (1995) [33], who regard quality as an input in the production process, further extended the Malmquist index by incorporating quality 'attributes' into the technology of medical services and decomposing the index into three components: quality change, technical change and efficiency

change. Maniadakis et al. (1999) [60] and Chen (2006) [19] use this method to evaluate the reform of the national health services and the implementation of the national health insurance program in the UK, respectively.

Alternatively, Thanassoulis et al. (1995) [94] treat quality as an output in determining the performance of the district level health authorities in providing pre-natal care in the UK. Dismuke and Sena (2001) [27] define quality as the reduction in undesirable outputs and utilize the Malmquist-Luenberger productivity index developed by Chung et al. (1997) [21].

3.2 Output-oriented two-stage Model

Graph 1 – Multi-Stage Healthcare System



As we are using panel data in this study, each yearly data point for each country is treated as a separate decision making unit (DMU); e.g. the year 2000 data point for the US is an entirely different DMU than the US data point for 2011. We are assuming non-regressive technology, which implies that a currently available technology will also be available to all future DMUs, but was not available to the past ones. This assumption requires control for technological progress over time and can be done by the in/exclusion of the relevant DMUs.

Although it is generally accepted that the production stage exhibits CRS, the provision of health services demonstrates VRS, and most OECD countries operate at a sharply diminishing returns region. In other words, although doubling of all resources will lead to doubling of health services

(CRS), this will not necessarily lead to a similar increase in health outcomes (VRS). Therefore, the OECD healthcare system exhibits CRS in production but VRS in the provision stage and as a whole.

The model consists of two output-oriented stages. In this paper, however, we concentrate on the second stage, where we measure the *non-radial* efficiency levels of *provision* under VRS with desirable and undesirable health outcomes. This stage alternatively uses the actual (y) and efficient (y*) quantities of services (obtained in the previous chapter) as inputs to measure the second stage ($\boldsymbol{\beta_2}$), and overall ($\boldsymbol{\beta}$) inefficiency levels respectively, which allows us to also derive the first stage inefficiency ($\boldsymbol{\beta_1}$) in terms of *health outcomes*.

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. For example, a 1% change in *life expectancy at birth* of an 80 year average is equivalent to a 4% change in *life expectancy at age 65* of a 20 year average, which requires a relative weight of 4 to 1 (80 to 20) respectively.

3.3 Model Specification

DEA relies on a number of fairly weak assumptions to construct the production technology but avoids any explicit functional relationship between the inputs and outputs through a production function [22]. These assumptions are summarized below. Let Ψ be the feasible set:

a) all observed input-output combinations are possible; $(x_1, y_1) \in \Psi$.

b) the production possibility set is convex; Let $\alpha \in [0, 1]$; If $(x_1, y_1), (x_2, y_2) \in \Psi$, then $(x, y) = \alpha(x_1, y_1) + (1-\alpha)(x_2, y_2) \in \Psi$.

c) inputs and outputs are freely disposable; Let $x_2 \geq x_1$, and $y_2 \leq y_1$. If $(x_1, y_1) \in \Psi$ then $(x_2, y_1) \in \Psi$ and $(x_1, y_2) \in \Psi$

Let (y_i, z_i) represent the input-output bundle of a firm i, assuming input-output bundle observed for N firms. Then given the aforementioned assumptions, the VRS production possibility set is

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

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

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

The standard DEA LP problem solved to estimate the efficiency of DMU s, relative to contemporaneous VRS frontier is

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

subject to {iii}

- $\sum\lambda_i * y_{ij} \leq y_{0j}$ $j = 1\ldots3$ (Input constraint) (1)
- $\sum\lambda_i * z_{ik} \geq (1 + \boldsymbol{\beta_k}) * z_{sk}$ $k = 1, 2$ (Desirable Output constraint) (2a)
- $\sum\lambda_i * z_{ik} \leq (1 - \boldsymbol{\beta_k}) * z_{sk}$ $k = 3$ (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)

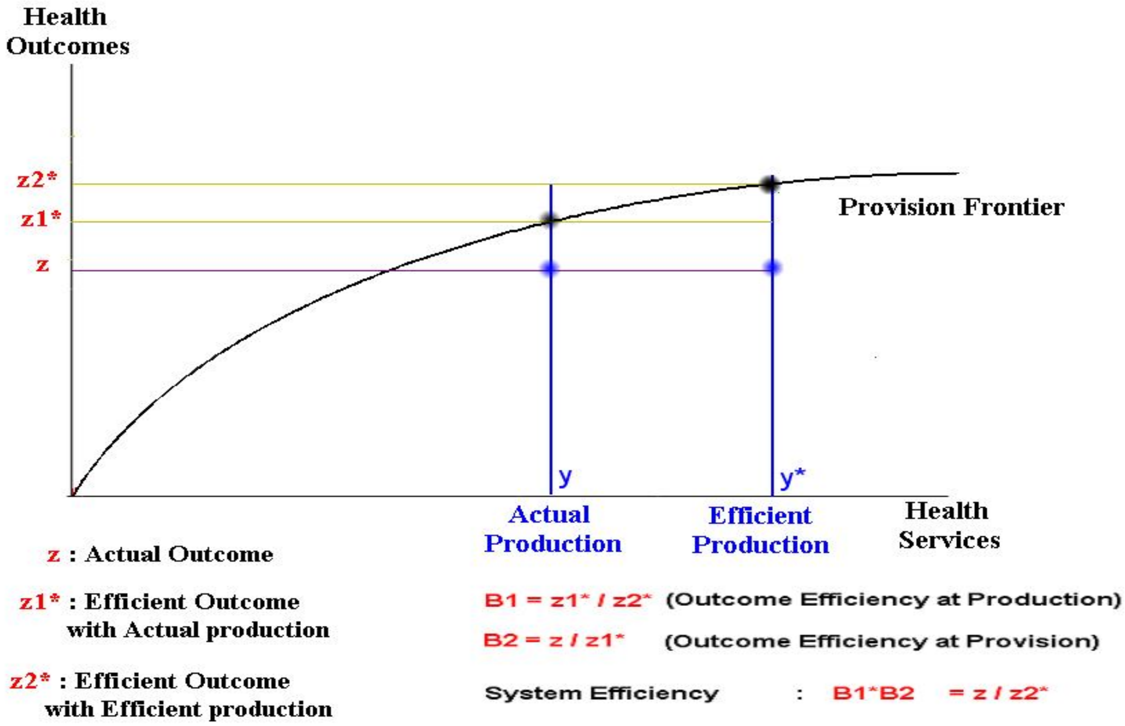
In the maximization problem above (Max **β**), constraints (1), (2a), (2b), and (5) ensure that the benchmark unit created from the convex combination of actually observed data points does not use any more inputs (services) than the comparison unit while producing $\boldsymbol{\beta_k} * z_{0k}$ more of desirable and less of undesirable outputs, where $\mathbf{w_k}$ is the weight of output k, $\boldsymbol{\beta_k}$ is the non-radial inefficiency rate for output k, and $\boldsymbol{\beta} = \sum \mathbf{w_k} * \boldsymbol{\beta_k}$ is t*he weighted non-radial outcome inefficiency*. If $\boldsymbol{\beta_k}$ equals 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 $\boldsymbol{\beta} = \sum \mathbf{w_k} * \boldsymbol{\beta_k}$ may still be greater than zero, implying inefficiency in other outputs. The inclusion of healthcare expenditures (3) ensures that the benchmark unit is not any more capital intensive than the evaluated unit, which is also a proxy for its technological level.

Among the various ways to incorporate environmental variables into the DEA framework, we use Ruggiero's 3-stage method [84] to incorporate multiple risk factors into one risk variable (4a), as it performed best in virtually all scenarios, being the only model robust to sample size and the number of nondiscretionary variables [67], when compared to the other common methods such as Ray (1991)

[79], Muñiz (2002) [66] and Banker and Morey [5]. The original DEA model without the risk factors (4a) is solved and the second-stage regression on the risk factors is performed. Let $\hat{\beta}$ be the estimated inefficiency regressed on the risk factors:

$$\hat{\beta} = q_{i2} = \alpha + \gamma_1 r_1 + \gamma_2 r_2 + \gamma_3 r_3 + \varepsilon \qquad \{iv\}$$

After construction of q_{i2} (*the combined patient-risk control*) from estimating the first inefficiency, the model {iii} 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.



In the model, we initially decompose β (outcome inefficiency) into two parts. As in Chen, Cook, and Zhu (2010) [20], the overall efficiency is the product of efficiencies in two consecutive stages. Let "$1 + \beta = (1 + \beta_1) * (1 + \beta_2)$" where,

β_1: Outcome inefficiency of production, β_2: Outcome inefficiency of provision

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. Using the efficient health services obtained from our previous study as the input, on the other hand, implies no such assumption,

and yields the total outcome inefficiency (**β**) from which, **β_1** can easily be derived. This decomposition will allow us to not only distinguish between the first and second stage inefficiencies, but also gauge the impact of production inefficiency on technical change.

3.5 Malmquist Index and measuring technical change

The assumption of "*non-regressive technology*" allows us to include all current and past observations in the calculation of inefficiency for a certain DMU. However, the observations of the succeeding years have to be dropped to control for the technology that was not available to the DMU in question at the time.

Let the calculated inefficiency of the input-output bundle of a country **i** with respect to technology…
…in year **t** = $\boldsymbol{\beta^i_{t,t}}$, and in year **t+1** = $\boldsymbol{\beta^i_{t,t+1}}$

$\boldsymbol{\beta^i_{t,t+1}} \geq \boldsymbol{\beta^i_{t,t}}$ implies that the measured inefficiency of a DMU through time will tend to increase. The inclusion of new observations due to additional years will inevitably bring in more efficient DMUs, shifting up the constructed frontier, causing past DMUs to appear more inefficient, due to two possible reasons:

a) The actual production frontier shifts up (technological progress),

b) The constructed frontier moves closer to the actual frontier (increase in efficiency).

Although this may not be clear from the calculation of inefficiency for a single country, using longitudinal data, calculation of an average inefficiency path for all countries through time will be much more representative of technological progress. Let the average OECD inefficiency in year **t** measured in year **t** = $\sum_1^n \beta^{\mathrm{i}}_{\mathrm{tt}} / n$

$\sum_1^n \beta^{\mathrm{i}}_{\mathrm{tt+1}} / n \geq \sum_1^n \beta^{\mathrm{i}}_{\mathrm{tt}} / n$ implies that the measured average inefficiency for a certain year will tend to increase over time, inevitably shifting up the production frontier. This fact must be invariant to the base year "t", and thus $\sum_1^n \beta^{\mathrm{i}}_{\mathrm{t\text{-}1t+1}} / n \geq \sum_1^n \beta^{\mathrm{i}}_{\mathrm{t\text{-}1t}} / n$ must also hold.

In other words, the measured inefficiency changes due to technological progress between two years must be equal, regardless of the base year it is based on. The discrepancies in the

measurement are likely due to the changes in efficiency rather than technological progress. Therefore multiple year comparisons are necessary for a better assessment of the technological trend over the years.

In order to measure the productivity growth, we convert the *inefficiency* (**β**) values obtained in the DEA process to *efficiency* values (**D**) as in $D_{\mathrm{tt}}^{\mathrm{i}} = 1/(1+\beta_{\mathrm{tt}}^{\mathrm{i}})$. Then, following Färe *et al.* (1994) [32], we obtain the Malmquist productivity values and decompose them into technical change and efficiency change in the following way:

$$M_o(\mathbf{x}^{t+1},\mathbf{y}^{t+1},\mathbf{x}^t,\mathbf{y}^t) = \frac{D_o^{t+1}(\mathbf{x}^{t+1},\mathbf{y}^{t+1})}{D_o^t(\mathbf{x}^t,\mathbf{y}^t)} \times \left[\left(\frac{D_o^t(\mathbf{x}^{t+1},\mathbf{y}^{t+1})}{D_o^{t+1}(\mathbf{x}^{t+1},\mathbf{y}^{t+1})}\right)\left(\frac{D_o^t(\mathbf{x}^t,\mathbf{y}^t)}{D_o^{t+1}(\mathbf{x}^t,\mathbf{y}^t)}\right)\right]^{1/2}$$

$$\text{technical change} = \left[\left(\frac{D_o^t(\mathbf{x}^{t+1},\mathbf{y}^{t+1})}{D_o^{t+1}(\mathbf{x}^{t+1},\mathbf{y}^{t+1})}\right) \times \left(\frac{D_o^t(\mathbf{x}^t,\mathbf{y}^t)}{D_o^{t+1}(\mathbf{x}^t,\mathbf{y}^t)}\right)\right]^{1/2}$$

$$\text{efficiency change} = \frac{D_o^{t+1}(\mathbf{x}^{t+1},\mathbf{y}^{t+1})}{D_o^t(\mathbf{x}^t,\mathbf{y}^t)}$$

4 Data

Data used in this study are obtained from the Organization for Economic Cooperation and Development (OECD) Health Data 2013 [105], which is the broadest source of comparable statistics on diverse health systems across OECD countries. The sources and methods of data collection are described in detail in the OECD documentation [45].

Because countries are not uniform in their reporting practices and not all variables are recorded each year, a slight adjustment of OECD data is unavoidable and common in OECD studies [83, 105]. Similarly, in this study, linear interpolation is applied to impute missing values in the time-series for particular countries, meaning some of the gaps are filled with average estimates (5-10% of the data points).

The dataset consists of 34 OECD countries and 12 years between 2000 and 2011 for a total of 408 decision making units (DMUs). However, the number of included DMUs in the measurements varies by year, from a minimum of 5 years (170 DMUs) up to 11 years (378 DMUs), in order to control for technical change through time.

Variables

The variables used to determine efficiency include: *Inputs* (health services*), outputs (health outcomes), per capita health expenditure, patient risk characteristics, and inequality of access to healthcare* (see Table 1).

Table 1- Variables

	#	Variables	Definition	Measurement
Services	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	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	10	Tobacco Consumption	Tobacco consumption, % of all adult daily smokers	percentage of population
	11	Alcohol consumption	Alcohol consumption, litres per capita aged 15+	litres per capita aged 15+
	12	BMI	Overweight population, % of all population with a BMI>25 kg/m2	percentage of population
Ineq.	13a	Gini Coefficient	Measurement of Inequality in the population	between 0 and 1
	13b	Poverty	Percentage of population below poverty threshold	percentage of population
Exp.	14a	Total Health Expenditure	Total Healthcare Expenditures	per capita, US$ PPP
	14b	Public Health Expenditure	Public Healthcare Expenditures	per capita, US$ PPP

4.1 Health Services (Inputs of the Provision Stage): We use three of the most commonly used hospital services [48, 75, 76] as the inputs of the provision stage, and intermediary products between first and second stages. Because their homogeneity varies and effectiveness on health status depends on environmental variables, we control for per capita healthcare expenditure as a proxy for capital intensity, in addition to risk factors, and inequality.

4.2 Health Outcomes (Final Outputs): We use three of the most commonly used health outcomes as our outputs of the provision stage [48, 75, 76]. *Life expectancy at birth* is a good proxy for general healthcare, and *life expectancy at age 65* is a better proxy for senior and chronic healthcare, while *infant mortality* is particularly useful to measure more basic and youth healthcare efficiency.

4.3 Per capita Health Expenditures (Control): We use healthcare expenditure per capita at the second stage, as a proxy for capital intensity and technology level. Both total and public health expenditures are employed for robustness checks.

4.4 Patient-risk characteristics (General Control): There are three highly standardized and commonly used risk characteristics defined in the OECD data set, namely tobacco and alcohol consumption, and obesity. Data regarding tobacco and alcohol consumption have been obtained from the OECD web site, while the BMI figures, as a proxy for overweight population, were obtained from the WHO data set [104].

4.5 Inequality in access to healthcare (General Control): We use the Gini coefficient and alternatively poverty rates for each country as a proxy for inequality of access to healthcare. Although not a perfect match, the Gini is a sufficient indicator of healthcare inequality. There are various studies in the literature that show clear negative correlations between socioeconomic inequality and access to healthcare, both globally [99] and within a country [46]. We find that this correlation is stronger in privately oriented healthcare systems.

5 Results

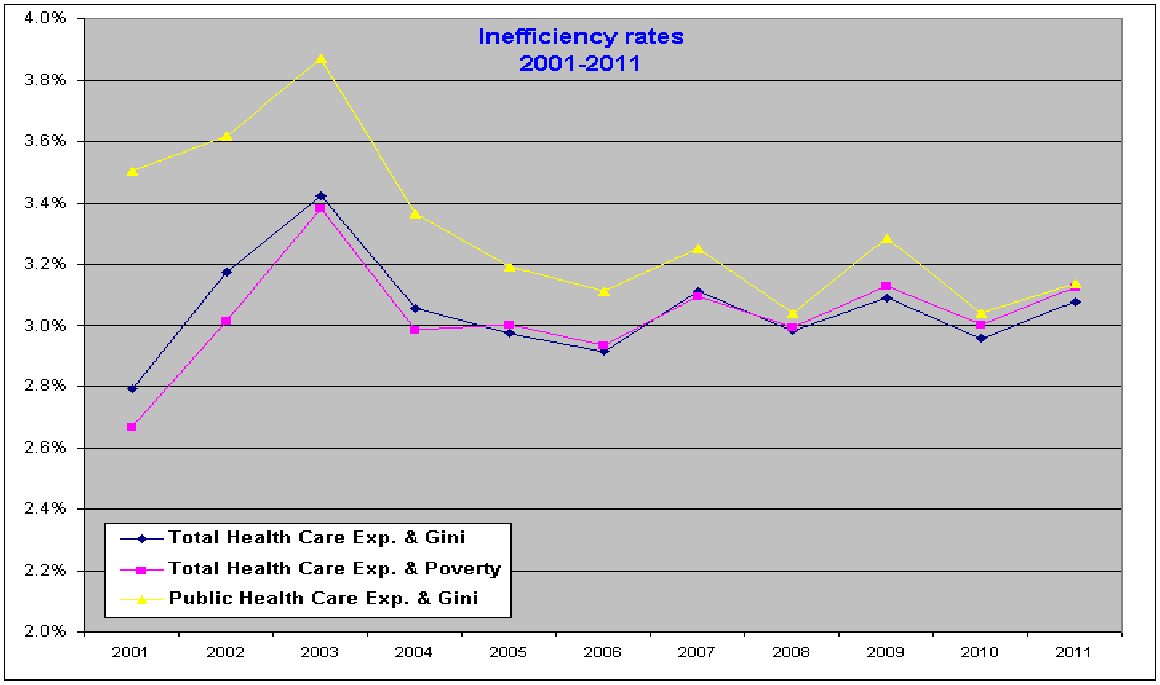
5.1 Inefficiency across time

Table 2 – OECD Health Outcome Inefficiency over the Years

	Inefficiency over the years		
OECD	Total HC Exp. & Gini	Total HC Exp. & Poverty	Public HC Exp. & Gini
2011	3.08%	3.12%	3.14%
2010	2.96%	3.00%	3.04%
2009	3.09%	3.13%	3.28%
2008	2.98%	2.99%	3.04%
2007	3.11%	3.09%	3.25%
2006	2.91%	2.94%	3.11%
2005	2.97%	3.00%	3.19%
2004	3.06%	2.99%	3.36%
2003	3.42%	3.38%	3.87%
2002	3.17%	3.02%	3.62%
2001	2.79%	2.67%	3.50%
Average	3.05%	3.03%	3.31%

The results in Table 2 and Graph 3 indicate that the OECD health outcome inefficiency is mostly stable around 3% over time. Our baseline control with total per capita health expenditure and gini for inequality indicates a slight increase in inefficiency by 0.28%, which is replicated with the use of poverty rates instead, yielding a similar 0.44 increase in inefficiency and almost identical trend over the years. Using public healthcare expenditures, on the other hand, produced somewhat different results. The average inefficiency is slightly greater at around 3.3%, and indicates a decrease in inefficiency by 0.35% instead, although the general trend is virtually the same.

Graph 3 – OECD Inefficiency over the Years



This result may reflect the increasing share of public expenditures in healthcare [45], as public expenditure is often found to be more efficient than private in the literature [39]. This is likely why the trend is reversed with the inclusion of the relatively less efficient private expenditures.

However, the change in inefficiency levels is not homogenous across the board. Some countries such as Estonia, Ireland, and Portugal have seen remarkable improvements in their healthcare efficiencies while some others such as Finland, Slovak Republic, and Turkey became less efficient, probably because these countries had a hard time adjusting to the drastic changes in the healthcare sector [10, 93].

5.2 Decomposition of Inefficiency

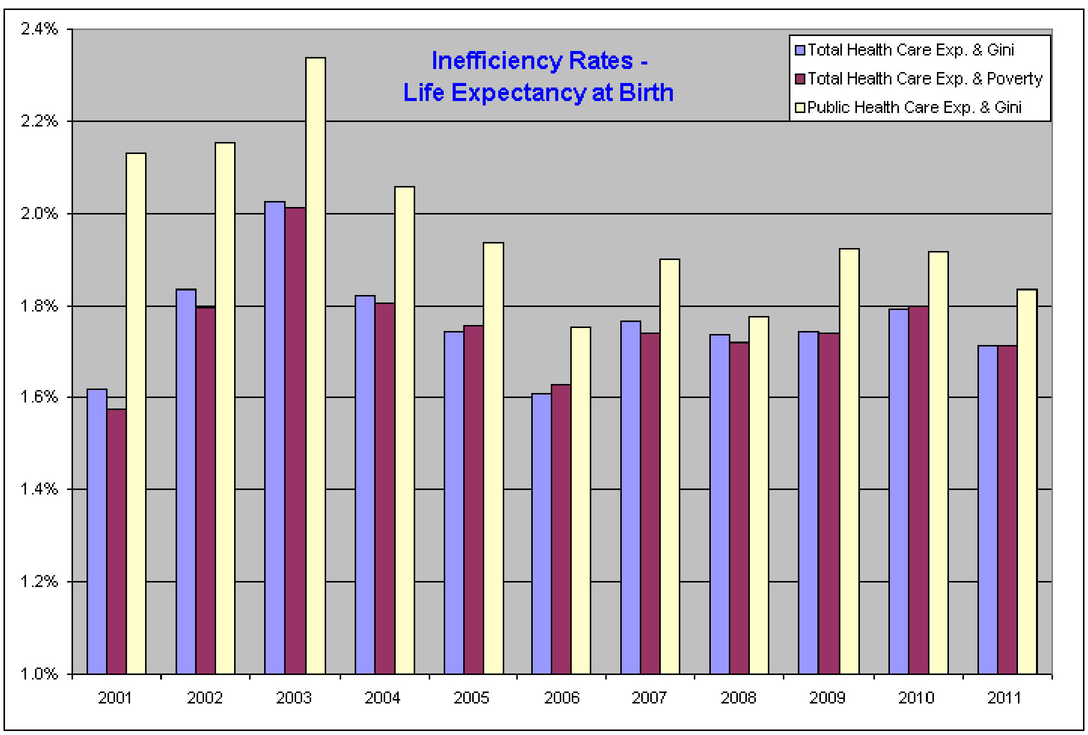
Both life expectancy at birth and at 65 replicate the overall trend, albeit at different levels. Inefficiency levels for life expectancy at birth hover around 1.8% regardless of gini or the poverty rates for control. Using public expenditures, however, leads to a noticeable rise in average inefficiency. Life expectancy at 65 yields around 5% inefficiency across the board, also resulting in a similar rise in inefficiency with the use of public expenditures for control. In both cases, control for total expenditure shows a fairly stable trend while public expenditures show a slight decrease in inefficiency.

Table 3 & 4 – OECD Inefficiency Life Expectancy at Birth & 65

Table 3	Inefficiency in Life Expectancy at Birth		
OECD	Total HC Exp. & Gini	Total HC Exp. & Poverty	Public HC Exp. & Gini
2011	1.71%	1.71%	1.84%
2010	1.79%	1.80%	1.92%
2009	1.74%	1.74%	1.92%
2008	1.74%	1.72%	1.78%
2007	1.77%	1.74%	1.90%
2006	1.61%	1.63%	1.75%
2005	1.74%	1.75%	1.94%
2004	1.82%	1.80%	2.06%
2003	2.02%	2.01%	2.34%
2002	1.83%	1.80%	2.15%
2001	1.62%	1.57%	2.13%
Average	1.76%	1.75%	1.97%

Table 4	Inefficiency in Life Expectancy at 65		
OECD	Total HC Exp. & Gini	Total HC Exp. & Poverty	Public HC Exp. & Gini
2011	4.76%	4.72%	4.95%
2010	4.99%	5.00%	5.25%
2009	4.74%	4.70%	4.97%
2008	4.62%	4.59%	4.56%
2007	4.87%	4.83%	5.08%
2006	4.50%	4.56%	4.78%
2005	4.94%	4.97%	5.25%
2004	4.99%	4.90%	5.58%
2003	6.28%	6.15%	6.86%
2002	5.78%	5.61%	6.50%
2001	4.59%	4.37%	5.99%
Average	5.01%	4.95%	5.43%

Graph 4 – OECD Inefficiency Rates for Life Expectancy at Birth



Graph 5 – OECD Inefficiency Rates for Life Expectancy at 65

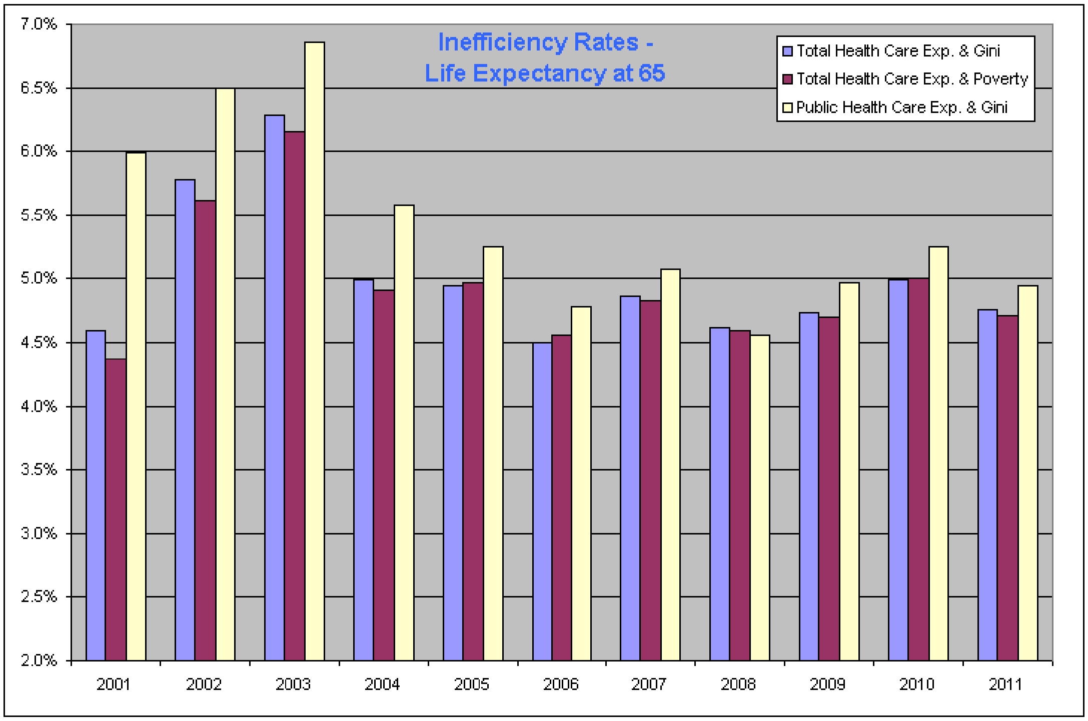
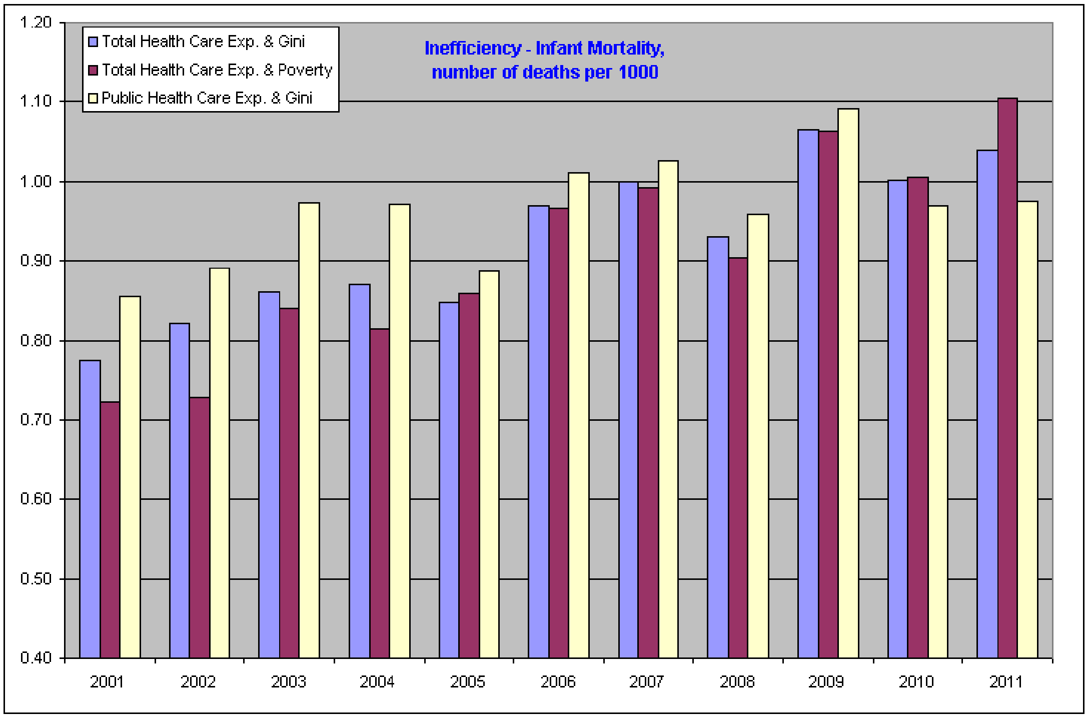


Table 5	Inefficiency in Infant Mortality (number of deaths)		
OECD	Total HC Exp. & Gini	Total HC Exp. & Poverty	Public HC Exp. & Gini
2001	0.78	0.72	0.85
2002	0.82	0.73	0.89
2003	0.86	0.84	0.97
2004	0.87	0.81	0.97
2005	0.85	0.86	0.89
2006	0.97	0.97	1.01
2007	1.00	0.99	1.03
2008	0.93	0.90	0.96
2009	1.06	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

The results show that it is the infant mortality that actually leads to a rise in the overall inefficiency, with consistency across different controls. We are using the actual number of deaths here, rather than percentages to avoid distortion on the relative magnitudes.

The infant mortality inefficiency increases from around 0.8 to over 1 death (per 1000) between 2001 and 2011. The results show that although technology has rapidly increased, healthcare systems are still trying to catch up to the new frontiers, resulting in lower efficiency rates, which is expected given the rapid developments in this field. This is a classic example of rising productivity with diminishing efficiency.

Graph 6 – OECD Inefficiency Rates for Infant Mortality



5.3 Production vs. Provision Inefficiency

The major advantage of a multi-stage efficiency analysis is to be able to see the contribution of each stage on inefficiency. Our analysis reveals that the lion's share of inefficiency is in provision; with about 79% of the efficiency loss occurs at the provision stage, leaving 21% for the production inefficiency, though not every country is affected the same way. More than 60% of US's inefficiency, for example, comes from production, which is in stark contrast to the OECD trend. Additionally production inefficiency has a serious negative effect on technical change and productivity growth of health outcomes as well, which we will discuss more in detail shortly.

Table 6	Inefficiency over the years		
OECD	**β1 + β2**	**β1**	**β2**
2011	3.08%	0.69%	2.37%
2010	2.96%	0.76%	2.19%
2009	3.09%	0.76%	2.32%
2008	2.98%	0.62%	2.35%
2007	3.11%	0.63%	2.47%
2006	2.91%	0.52%	2.38%
2005	2.97%	0.47%	2.49%
2004	3.06%	0.56%	2.48%
2003	3.42%	0.63%	2.77%
2002	3.17%	0.72%	2.44%
2001	2.79%	0.69%	2.09%
Average	**3.05%**	**0.65%**	**2.39%**
Share of Inefficiency		**21.31%**	**78.69%**

5.4 Productivity Growth and Technical Change

The inclusion of the future observations gradually increases the measured inefficiency for each year's OECD average. This is either because of technological progress, which is a *shift in production frontiers*, or DMUs moving closer to the actual frontier and helping us construct a more realistic one. As we discussed earlier, in the long run, healthcare efficiency is largely stable albeit slightly down. Therefore the bulk of technical change in the long run largely reflects technological progress.

Relative stability over time, however, does not necessarily mean no fluctuations in the short run. Socioeconomic variables obviously impact the healthcare utilization and efficiency but those impacts do not seem to be permanent. The system tends to go back to the original path in the long run that it seems to deviate from. This, however, does not imply that resources do not become more productive and produce more over time, they actually do. The study reveals that the outcome growth is similar to the shifts in production frontier; therefore the gap between the frontier and the actual outcome (outcome inefficiency) remains largely the same.

Graph 7 – Health Outcomes Productivity Growth and Inefficiency Path over the Years

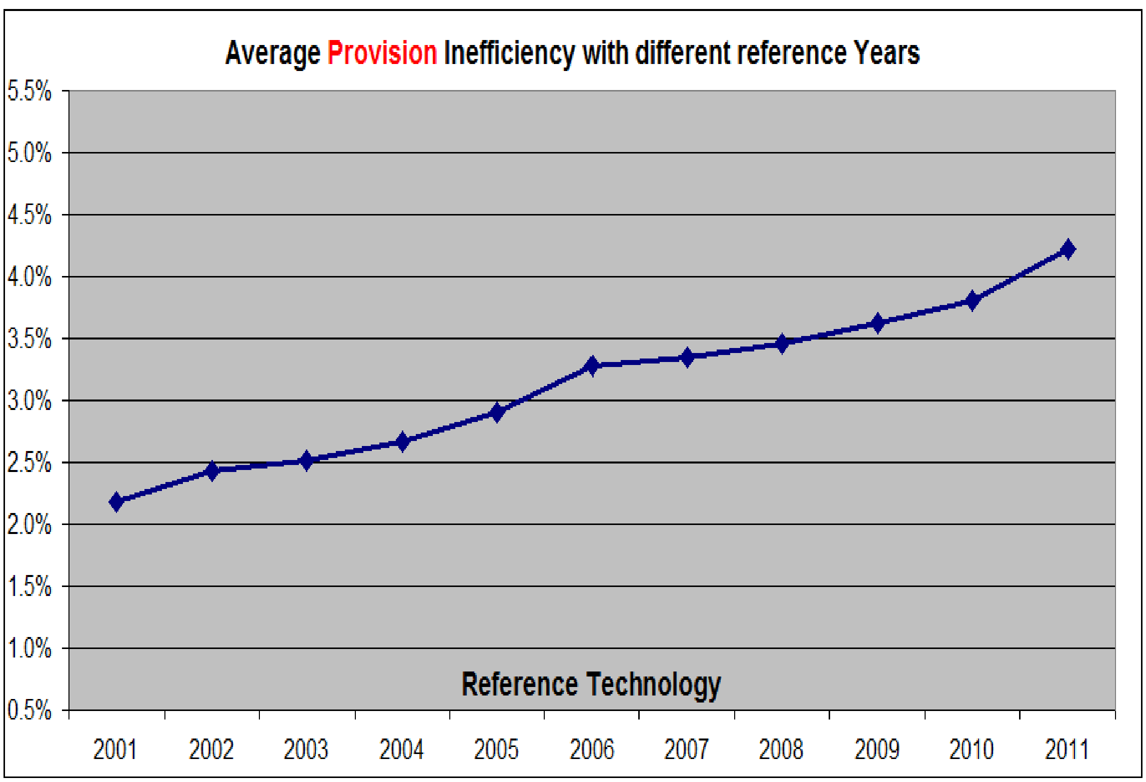


Table 7 – Inefficiency Path and Productivity Growth of Year i (left) and Annual Change (right)

	Inefficiency of Year i (left) with respect to the Technology of Year j (top)											
OECD	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Annual
2011	1.40%	1.58%	1.66%	1.78%	2.00%	2.29%	2.32%	2.35%	2.50%	2.66%	**3.08%**	0.15%
2010	1.56%	1.80%	1.89%	1.98%	2.22%	2.59%	2.61%	2.65%	2.80%	**2.96%**	3.62%	0.19%
2009	1.78%	2.00%	2.05%	2.14%	2.41%	2.79%	2.83%	2.94%	**3.09%**	3.34%	3.95%	0.20%
2008	1.91%	2.12%	2.19%	2.28%	2.47%	2.80%	2.88%	**2.98%**	3.28%	3.50%	4.01%	0.19%
2007	2.04%	2.24%	2.33%	2.41%	2.62%	3.01%	**3.11%**	3.29%	3.47%	3.68%	4.16%	0.19%
2006	1.99%	2.25%	2.29%	2.37%	2.57%	**2.91%**	3.02%	3.21%	3.39%	3.56%	4.03%	0.19%
2005	2.19%	2.51%	2.60%	2.70%	**2.97%**	3.44%	3.52%	3.68%	3.88%	4.06%	4.49%	0.21%
2004	2.48%	2.69%	2.77%	**3.06%**	3.41%	3.80%	3.91%	4.02%	4.16%	4.31%	4.67%	0.20%
2003	2.95%	3.32%	**3.42%**	3.70%	4.00%	4.39%	4.45%	4.55%	4.68%	4.83%	5.13%	0.20%
2002	2.86%	**3.17%**	3.30%	3.51%	3.76%	4.13%	4.21%	4.32%	4.46%	4.63%	4.83%	0.18%
2001	**2.79%**	3.07%	3.21%	3.39%	3.58%	3.85%	3.92%	4.01%	4.14%	4.30%	4.46%	0.15%
												0.19%

We find similar results with different base years between 2001 and 2011, which seem to be consistent and robust over time. In each of these cases, the evaluated year appears increasingly more inefficient due to the shifting frontier, albeit at slightly different levels (0.15% - 0.21%) due to short-run efficiency fluctuations as well as measurement issues with respect to the observed data. Long run averages, however, seem to agree with each other, at around 0.19%.

Table 8 – Decomposition of Productivity Growth, Technical and Efficiency Changes

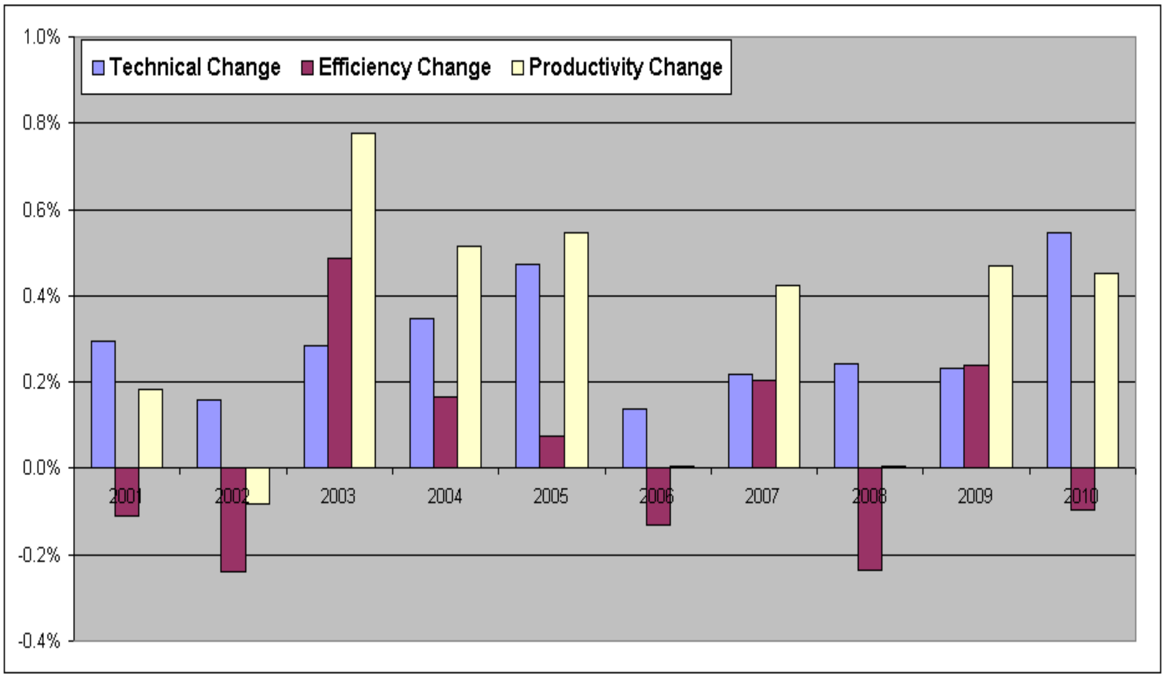
OECD	**Tech**	**Eff**	**Prod**
Average	**1.84%**	**-0.28%**	**1.56%**
2001	0.29%	-0.37%	-0.08%
2002	0.11%	-0.24%	-0.13%
2003	0.27%	0.35%	0.63%
2004	0.30%	0.08%	0.38%
2005	0.40%	0.05%	0.45%
2006	0.10%	-0.19%	-0.09%
2007	0.13%	0.13%	0.26%
2008	0.22%	-0.10%	0.11%
2009	0.20%	0.13%	0.33%
2010	0.52%	-0.12%	0.41%

The cumulative technical change between 2001 and 2011 is 1.84%, and efficiency change is -0.28%, leading to a smaller productivity growth at 1.56%. These figures are 2.05%, 0.35%, and 2.41% when only the public expenditures are used for control instead. Note that the technical change is robust to the type of control used. Therefore fluctuations are mostly due to short run changes and technical change has a much lower variance, as shown in graph 6.

Technical changes in health outcomes have a greater variance compared to the technical changes in production only [9], which is expected due to the various stochastic environmental effects. Still, technical change, mostly ranging around 0.2 – 0.4%, has a much smaller variance than both productivity growth and efficiency changes, which clearly take time to adjust. Whenever there is a significant change in technology, it leads to a disruption in the

system and a temporary decrease in efficiency, which is then followed by a sequential increase and so on. In the long run, however, those fluctuations tend to smooth out. Productivity growth has a much greater variance than technical change and even occasionally goes negative due to the fluctuations in efficiency integrated in its composition.

Graph 8 – Decomposition of Productivity Growth, Technical and Efficiency Changes



5.5 Single vs. Multi-Stage Technical Change

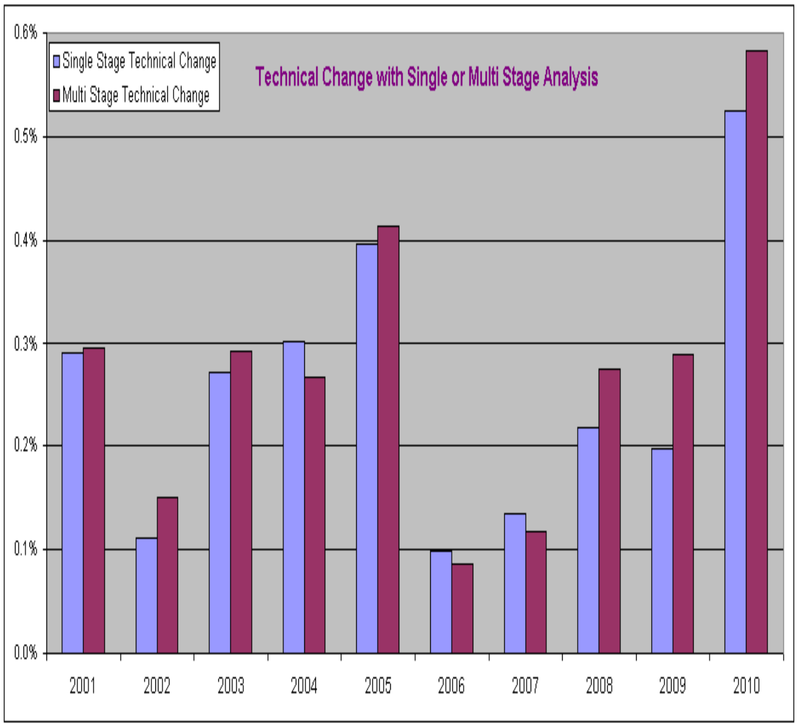
Table 9 - Technical Change

OECD	Single Stage	Multi-Stage	Ratio
Total	**1.55%**	**1.84%**	**118.6%**
2001	0.29%	0.29%	101.4%
2002	0.11%	0.15%	135.3%
2003	0.27%	0.29%	107.6%
2004	0.30%	0.27%	88.4%
2005	0.40%	0.41%	104.4%
2006	0.10%	0.09%	86.8%
2007	0.13%	0.12%	87.0%
2008	0.27%	0.22%	126.3%
2009	0.20%	0.29%	145.7%
2010	0.52%	0.58%	111.0%

As mentioned earlier, inefficiency in production does not only negatively affect outcome inefficiency but also leads to underestimation of the technical change in a single stage efficiency analyses. Measuring technical change in a single stage, by using either resources or health services as inputs reveals a mere 1.55% technical change between 2001 and 2010. A multi stage analysis, however, raises this figure to 1.84%. Controlling for public healthcare expenditures yield 1.78% and 2.04% respectively,

producing a very similar gap. In other words, a single stage analysis leads to 19% under-estimation of technical change, which is already a conservative estimate based due to the limitations of our study.

Graph 9 – Technical Change with Single or Multi-Stage Analysis



Considering the share of the production inefficiency, which is found to be 20% earlier in the study, this figure seems logical. Under-supply of health services due to inefficiency also leads to a diminishing impact of technical change on health outcomes.

5.6 Share of Technical Change on Improvement of Healthcare

Table 10 - Share of Technical Change

	Explanation	LE Total population at birth	LE Total Population at 65	Infant mortality rate	Average Change
	2010	79.8	19.1	4.2	
	2000	77.1	17.3	6.7	
	Average	78.5	18.2	5.3	
	Total Change	3.48%	10.15%	37.01%	6.42%
Total Exp & Gini	Tech Change (1)	1.01%	2.73%	18.12%	2.21%
	Share (1)	29.03%	26.89%	48.96%	**29.69%**
Total Exp & Poverty	Tech Change (2)	1.22%	3.19%	17.32%	2.41%
	Share (2)	35.06%	31.46%	46.80%	**35.03%**
Public Exp & Gini	Tech Change (3)	1.10%	2.83%	19.69%	2.38%
	Share (3)	31.47%	27.89%	53.20%	**31.97%**

Our study shows that technical change alone is responsible for at least 30-35% of the total improvement in healthcare development between 2000 and 2010. The same amount of resources and health services result in an average of 2.2 - 2.4 % better outcome by the virtue of technical change alone. This translates to approximately 1 year increase in life expectancy at birth and 65, and a 20% reduction in infant mortality, while the rest of the improvement comes from employment of more resources, and higher healthcare spending among others. However, there are two fundamental reasons that cause significant underestimation of technical change in the analysis:

Table 11 - Technical Change for Select Countries

Country	Total Exp. Gini	Total Exp. Poverty	Public Exp. Gini
Finland	4.56%	4.48%	4.56%
Austria	4.10%	4.10%	4.10%
Germany	3.72%	3.72%	3.76%
Netherlands	3.66%	3.66%	3.77%
Denmark	3.50%	3.50%	3.50%
Belgium	3.34%	3.34%	3.77%
USA	3.34%	3.34%	4.00%
N. Zealand	3.16%	3.32%	3.34%
Norway	3.03%	3.03%	2.97%
UK	2.88%	3.02%	3.50%
Average	3.53%	3.55%	3.73%
Share	**54.96%**	**55.30%**	**58.03%**

a) Technical changes for the efficient countries on the production frontier are inherently underestimated,

b) Technical spill-over between countries do not shift the frontier but increase the efficiency through catch-up, which underestimates the role of technical change.

Focusing on developed but relatively less efficient countries paints a highly different picture. The average technical change of select OECD Countries on table 11 reveals over 55% contribution of technical change on healthcare development, double the overall average.

This implies that, technical change in relatively more developed OECD Countries has a higher contribution than relatively less developed ones, which tend to use the readily available technologies to catch up with the rest, rather than produce new ones.

5.7 Production Inefficiency and Its Impact on Health Outcomes

The productive efficiency figures obtained in our previous study and their impact on health outcomes will be different and not necessarily homogenous. The average inefficiency rate of the US between 2000 and 2011 e.g. is 30.8%, while the outcome inefficiency of the production stage is 3.7%. This means US health services are under-produced by 30.8% causing a 3.7% drop in health outcomes. However, the above relationship is not automatic and affects some countries more seriously than others. There are two major reasons for this:

a) Standardized measurements may not cover all services produced by diverse healthcare systems combined with highly different environmental conditions. Non-standard services such as extensive home care and family physician services may cause production inefficiencies to be overestimated.

b) Potential tradeoffs between quantity and quality of services are likely to be registered as productive inefficiency, which leads to an overestimation of the inefficiency of services.

Table 12 - Country	Production Inefficiency	Decrease in Outcome	Share of Inefficiency
Belgium	22.63%	0.02%	0.43%
Denmark	18.09%	1.17%	20.29%
Estonia	29.14%	0.43%	11.87%
France	31.32%	0.00%	0.00%
Ireland	22.71%	1.98%	82.01%
Mexico	35.11%	2.71%	100.00%
Netherlands	36.31%	4.24%	85.21%
Norway	11.01%	1.16%	42.69%
Poland	39.78%	0.23%	4.72%
Portugal	72.30%	3.26%	99.36%
Slovak Rep.	20.51%	0.18%	1.81%
UK	10.12%	0.42%	11.97%
USA	30.82%	3.70%	61.23%

Countries like Ireland, Mexico, Netherlands, Portugal, and US suffer high degrees of production inefficiency which also has clear dire effects on health outcomes. 61% of US healthcare inefficiency is a direct result of production for instance. That figure is even higher for Netherlands (85%), Portugal (99%), and Mexico (100%). Basically those countries have primarily a production inefficiency problem.

Countries like France, Slovak Republic, or Poland, on the other hand, appear somewhat inefficient in their production with minimal impact on health outcomes. They are either producing other health services not counted in the analysis due to diversity of healthcare systems (such as unaccounted family physician services), or their production deficits do not lead to a significant loss on outcome due to increasing quality of services that positively affect health outcomes.

5.8 Limitations of the Study

Well known limitations of the study are;

a) *Nonparametric frontier analyses tend to underestimate the inefficiency and productivity growth*. Due to its general construction, the firms on the frontier are assumed to be efficient in the analysis and the productivity growth of the DMUs which are on or close to the frontier will also be underestimated since they will eventually appear efficient compared to older data set only having access to older technology. Concentrating on relatively more inefficient DMUs avoid this problem but leads to bias in the analysis.

b) Country level aggregate data is far from precise but it can still present profound insights, especially when applied at multiple stages and with different controls for robustness check. A single-stage efficiency analysis based on only health services or health outcome is inherently inferior to a multi-stage analysis that combines production and provision.

c) Healthcare system efficiency is just part of the problem. We observe in our study that further outcome losses stem from inadequate healthcare spending and environmental conditions like inequality and risk factors. To have a more complete understanding of the issue, the impact of those external variables and their interaction with the system efficiency must also be tackled

6 Conclusion and Discussion

In this study, we have found that the OECD health outcome inefficiency has slightly increased from 2.8% to 3.1% between 2001 and 2011, although, controlling for public expenditures only finds a slight decrease instead. This roughly translates to "1.4 years of life expectancy at birth, 1 year at 65, and 1 infant death". Decreased inefficiency with respect to public resources is obviously dominated by the increase in total expenditures, which is most likely aided by the increasing share of private and especially out of pocket expenditures in OECD countries [45]. Despite the short run fluctuations, efficiency appears to have a fairly stable trend in the long run.

On a closer look, we find that "infant mortality" is the main reason behind the diverging results and most of the fluctuations. Although drastic improvements in hospital care and infant mortality rates have significantly increased productivity rates, hospitals are still lagging to adjust to the new technologies resulting in lower overall efficiency levels.

On average, 79% of the healthcare inefficiency comes from the provision side, leaving merely 21% to the production. This does not bode the same way for all countries though. Countries like the US, Netherlands, Ireland and Portugal suffer primarily from production inefficiency with rates in excess of 60%. Interestingly production inefficiency does not only negatively affect outcomes, but is also detrimental to productivity growth and technical change. We find that technical change is underestimated by 19% solely because of the production inefficiency.

Following the steps of Fare et al. (1997) [34], who examined the technical change in OECD countries in the 1974 – 1989 period, we investigated whether the technological progress still persists in the modern era, and found a similar result. Unlike the bulk of the literature, we were able to include all 34 countries in OECD, devise a more coherent multi-stage framework, and establish a clear distinction between output and outcome productivity growth and technical change.

In our previous study [9], we had found similar results to Fare et al., around 8.5% cumulative and 0.8% annual technical change in production for a 10 year period, which is matched with our current results, namely about a 2% cumulative and 0.2% annual change in provision, which is robust to different controls for healthcare expenditure or inequality. Technical change has slightly speeded up in the recent years and most of the fluctuations seem to be due to the efficiency changes as a result of the catch up process.

2% technical change alone, which is a highly conservative figure given the limitations of our analysis, means that at least 30-35% of the total improvement in healthcare development between 2001 and 2010 (6.4%) comes from technical change. This translates to approximately 1 year increase in life expectancy at birth and 65, and a 20% reduction in infant mortality. Focusing on developed but relatively less efficient countries, however, raises the cumulative technical change to 3.6% and its contribution to over 55%. Technical change in relatively more developed OECD Countries is found to have a higher contribution than relatively less developed ones, which tend to use the readily available technologies to catch up with the rest, rather than produce new ones.

Finally we conclude that healthcare system efficiency is just part of the problem. Further outcome losses stem from inadequate healthcare spending and environmental conditions like inequality and risk factors. To have a more complete understanding of the issue, the impact of those external variables and their interaction with the system efficiency must also be tackled. This will not only help identify the exact points of inefficiency but also form a contiguous and robust relationship between resources and health outcomes through health services.

7 Appendix

Table 13 – Non-Radial Inefficiency Levels between 2001 and 2011

	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	Average
Australia	2.16%	2.04%	2.19%	1.31%	2.30%	1.80%	1.25%	1.72%	1.36%	2.36%	2.83%	1.94%
Austria	4.03%	3.85%	3.91%	3.48%	3.66%	3.80%	4.59%	4.35%	5.17%	4.44%	5.07%	4.21%
Belgium	4.97%	4.35%	4.49%	4.99%	4.64%	5.65%	5.43%	4.88%	6.43%	6.51%	6.30%	5.33%
Canada	0.68%	0.40%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.31%	0.00%	0.13%
Chile	1.76%	0.00%	0.25%	0.33%	1.42%	0.00%	0.00%	0.20%	0.25%	0.00%	0.00%	0.38%
Czech R.	2.44%	1.29%	3.22%	1.31%	1.35%	1.45%	1.73%	2.79%	5.15%	3.43%	1.40%	2.32%
Denmark	6.58%	6.26%	6.58%	6.56%	6.89%	6.37%	5.24%	5.40%	4.54%	5.40%	4.21%	5.82%
Estonia	0.45%	0.80%	1.55%	8.22%	6.39%	1.03%	3.47%	6.71%	7.60%	1.13%	2.67%	3.64%
Finland	4.43%	3.19%	3.76%	3.62%	2.19%	2.57%	1.81%	1.72%	1.35%	0.69%	0.65%	2.36%
France	1.80%	1.90%	1.46%	1.33%	1.34%	1.35%	1.71%	1.64%	3.67%	2.83%	2.96%	2.00%
Germany	4.17%	4.10%	4.11%	3.84%	4.02%	4.00%	4.17%	3.99%	5.10%	4.89%	4.76%	4.29%
Greece	0.46%	0.48%	1.01%	0.41%	0.68%	0.63%	0.73%	0.67%	0.73%	1.01%	0.92%	0.70%
Hungary	10.42%	10.98%	10.34%	10.76%	11.35%	11.90%	12.75%	12.02%	13.37%	11.60%	10.21%	11.43%
Iceland	0.00%	0.00%	0.01%	0.18%	0.27%	0.00%	0.00%	0.52%	0.00%	0.00%	0.00%	0.09%
Ireland	0.65%	0.29%	0.39%	0.83%	1.48%	1.83%	2.30%	3.25%	4.40%	5.00%	6.25%	2.42%
Israel	0.48%	0.50%	0.47%	0.44%	0.57%	0.28%	0.51%	0.85%	1.09%	2.16%	1.95%	0.85%
Italy	0.48%	0.21%	1.44%	0.30%	0.71%	0.82%	1.32%	1.34%	1.32%	0.88%	1.08%	0.90%
Japan	0.50%	0.00%	0.00%	0.00%	0.00%	0.00%	0.17%	0.00%	0.00%	0.00%	0.00%	0.06%
Korea	1.91%	2.33%	0.68%	1.55%	1.53%	1.11%	0.84%	0.50%	0.62%	0.47%	0.77%	1.12%
Luxembourg	4.09%	3.14%	1.67%	0.52%	1.96%	2.02%	1.37%	0.91%	4.08%	3.47%	4.81%	2.55%
Mexico	4.67%	4.85%	4.70%	4.01%	2.24%	1.83%	1.62%	2.10%	1.48%	1.17%	1.13%	2.71%
Netherlands	4.35%	3.95%	4.08%	4.35%	4.85%	5.38%	5.55%	4.82%	5.94%	6.04%	5.72%	5.00%
N. Zealand	3.05%	2.80%	0.86%	0.79%	0.50%	0.82%	0.32%	0.69%	0.78%	1.35%	0.93%	1.17%
Norway	1.76%	2.25%	2.85%	0.48%	3.54%	3.62%	1.28%	2.52%	3.58%	4.05%	4.26%	2.74%
Poland	4.35%	5.09%	6.41%	5.60%	4.88%	3.73%	4.03%	4.51%	4.63%	5.45%	4.03%	4.79%
Portugal	2.28%	2.90%	4.37%	3.48%	3.30%	2.70%	2.88%	2.45%	3.11%	4.56%	4.02%	3.28%
Slovak R.	10.93%	13.34%	13.15%	13.32%	12.38%	10.96%	9.99%	8.99%	8.28%	7.54%	2.06%	10.09%
Slovenia	2.58%	0.84%	1.74%	1.23%	1.22%	3.27%	5.47%	4.50%	6.72%	5.55%	3.73%	3.35%
Spain	0.07%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.21%	0.00%	0.03%
Sweden	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Switzerland	0.00%	0.00%	0.09%	0.00%	0.00%	0.00%	0.00%	0.43%	1.12%	0.07%	0.06%	0.16%
Turkey	9.17%	9.24%	10.23%	8.92%	10.32%	10.40%	10.74%	9.25%	4.55%	4.90%	2.55%	8.21%
UK	2.56%	2.88%	3.06%	3.56%	3.69%	3.89%	3.72%	3.63%	4.07%	4.05%	3.35%	3.50%
USA	6.38%	6.31%	5.97%	5.68%	6.19%	5.88%	6.00%	6.56%	5.85%	6.40%	6.21%	6.13%
Average	3.08%	2.96%	3.09%	2.98%	3.11%	2.91%	2.97%	3.06%	3.42%	3.17%	2.79%	3.05%

Table 14 – Life Expectancy at Birth Inefficiency Levels between 2001 and 2011

	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	Average
Australia	0.45%	0.69%	0.38%	0.13%	0.07%	0.00%	0.28%	0.27%	0.28%	0.29%	0.70%	0.32%
Austria	1.60%	1.91%	1.63%	0.87%	1.25%	1.35%	1.92%	1.91%	2.51%	2.32%	2.40%	1.79%
Belgium	2.36%	2.71%	1.94%	2.11%	1.80%	2.47%	2.87%	2.72%	3.49%	3.30%	3.40%	2.65%
Canada	0.30%	0.17%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.08%	0.00%	0.05%
Chile	0.99%	0.00%	0.02%	0.43%	0.65%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%
Czech R.	1.30%	0.88%	2.25%	0.94%	0.97%	1.04%	1.18%	1.92%	3.60%	2.38%	0.93%	1.58%
Denmark	3.34%	3.31%	3.34%	3.10%	3.37%	3.20%	2.81%	3.27%	2.98%	3.51%	2.73%	3.18%
Estonia	0.39%	0.67%	1.39%	7.13%	5.85%	0.96%	3.30%	6.27%	6.78%	1.16%	2.43%	3.30%
Finland	2.23%	2.53%	2.58%	2.00%	1.45%	1.83%	1.79%	1.62%	1.29%	0.58%	0.56%	1.68%
France	0.14%	0.32%	0.28%	0.19%	0.15%	0.23%	0.82%	0.96%	1.96%	1.42%	1.46%	0.72%
Germany	2.14%	2.49%	2.41%	1.48%	1.50%	1.75%	1.75%	2.07%	2.61%	2.54%	2.49%	2.11%
Greece	0.14%	0.25%	0.54%	0.23%	0.42%	0.16%	0.34%	0.25%	0.32%	0.33%	0.35%	0.30%
Hungary	7.33%	7.60%	7.66%	7.77%	8.33%	8.66%	9.10%	8.69%	9.21%	8.59%	7.56%	8.23%
Iceland	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Ireland	0.44%	0.04%	0.19%	0.24%	0.91%	0.39%	0.82%	1.49%	2.29%	2.75%	3.35%	1.17%
Israel	0.05%	0.03%	0.00%	0.03%	0.06%	0.05%	0.11%	0.07%	0.19%	0.61%	0.60%	0.16%
Italy	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.09%	0.00%	0.45%	0.00%	0.02%	0.05%
Japan	0.24%	0.00%	0.00%	0.00%	0.00%	0.00%	0.11%	0.00%	0.00%	0.00%	0.00%	0.03%
Korea	1.09%	1.45%	0.37%	1.02%	0.99%	0.63%	0.52%	0.32%	0.41%	0.28%	0.37%	0.68%
Luxembourg	1.64%	1.69%	0.53%	0.19%	1.43%	1.41%	1.10%	0.45%	2.11%	2.18%	2.62%	1.40%
Mexico	3.86%	3.93%	3.78%	3.02%	1.61%	1.33%	1.15%	1.41%	0.95%	0.76%	0.72%	2.05%
Netherlands	1.46%	1.79%	1.02%	1.21%	1.34%	1.76%	2.21%	2.14%	2.62%	2.61%	2.51%	1.88%
N. Zealand	0.97%	0.93%	0.27%	0.23%	0.21%	0.19%	0.08%	0.18%	0.14%	0.24%	0.32%	0.34%
Norway	0.48%	0.71%	0.54%	0.00%	0.92%	0.91%	0.49%	1.13%	1.76%	2.13%	2.22%	1.03%
Poland	3.73%	4.26%	5.04%	4.70%	4.18%	3.39%	3.45%	3.71%	3.63%	4.15%	3.20%	3.95%
Portugal	1.62%	2.27%	2.33%	2.53%	2.28%	2.20%	2.15%	1.92%	2.39%	3.29%	3.15%	2.38%
Slovak R.	6.73%	8.02%	8.02%	8.17%	7.90%	7.03%	6.44%	6.09%	5.53%	5.27%	1.58%	6.43%
Slovenia	1.96%	0.69%	1.34%	1.01%	1.02%	2.49%	3.58%	3.41%	4.79%	4.30%	2.65%	2.48%
Spain	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sweden	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Switzerland	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.01%	0.01%	0.00%
Turkey	5.73%	5.89%	5.95%	4.85%	5.51%	5.39%	4.97%	3.79%	0.78%	1.12%	0.88%	4.08%
UK	1.28%	1.67%	1.71%	1.86%	1.77%	1.82%	1.76%	1.73%	2.04%	2.11%	1.73%	1.77%
USA	4.21%	3.99%	3.79%	3.57%	4.10%	4.03%	4.06%	4.16%	3.74%	4.04%	4.03%	3.97%
Average	1.71%	1.79%	1.74%	1.74%	1.77%	1.61%	1.74%	1.82%	2.02%	1.83%	1.62%	1.76%

Table 15 – Life Expectancy at Birth Inefficiency Levels (in Years of Life Lost)

	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	Average
Australia	0.37	0.56	0.31	0.10	0.05	0.00	0.22	0.22	0.22	0.23	0.56	0.26
Austria	1.30	1.54	1.31	0.70	1.00	1.08	1.53	1.51	1.98	1.83	1.89	1.42
Belgium	1.90	2.18	1.55	1.69	1.44	1.96	2.27	2.15	2.73	2.58	2.66	2.10
Canada	0.25	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.04
Chile	0.77	0.00	0.01	0.34	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.15
Czech R.	1.01	0.68	1.74	0.72	0.75	0.80	0.90	1.46	2.71	1.79	0.70	1.21
Denmark	2.67	2.63	2.64	2.44	2.64	2.51	2.20	2.54	2.30	2.71	2.10	2.49
Estonia	0.30	0.50	1.04	5.29	4.27	0.70	2.40	4.52	4.85	0.82	1.72	2.40
Finland	1.80	2.03	2.06	1.60	1.16	1.46	1.41	1.28	1.01	0.46	0.44	1.34
France	0.12	0.26	0.23	0.15	0.13	0.19	0.65	0.77	1.55	1.12	1.15	0.57
Germany	1.73	2.01	1.94	1.18	1.20	1.40	1.39	1.64	2.05	1.99	1.95	1.68
Greece	0.11	0.20	0.43	0.19	0.33	0.13	0.27	0.19	0.25	0.26	0.28	0.24
Hungary	5.49	5.68	5.70	5.77	6.13	6.36	6.65	6.34	6.69	6.23	5.48	6.05
Iceland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ireland	0.36	0.03	0.15	0.19	0.73	0.31	0.65	1.17	1.79	2.14	2.59	0.92
Israel	0.04	0.02	0.00	0.02	0.05	0.04	0.09	0.06	0.15	0.49	0.48	0.13
Italy	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.36	0.00	0.02	0.04
Japan	0.20	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.03
Korea	0.88	1.17	0.30	0.82	0.79	0.50	0.41	0.25	0.32	0.21	0.28	0.54
Luxembourg	1.33	1.36	0.43	0.15	1.13	1.12	0.88	0.36	1.64	1.70	2.04	1.10
Mexico	2.86	2.91	2.80	2.24	1.20	0.99	0.85	1.04	0.70	0.56	0.53	1.52
Netherlands	1.18	1.45	0.83	0.97	1.07	1.41	1.75	1.70	2.06	2.04	1.97	1.49
N. Zealand	0.79	0.75	0.22	0.19	0.17	0.16	0.06	0.14	0.11	0.19	0.25	0.27
Norway	0.39	0.58	0.44	0.00	0.74	0.74	0.40	0.91	1.40	1.68	1.75	0.82
Poland	2.87	3.25	3.82	3.56	3.15	2.55	2.59	2.78	2.71	3.10	2.38	2.98
Portugal	1.31	1.81	1.86	2.01	1.80	1.73	1.68	1.50	1.85	2.54	2.43	1.87
Slovak R.	5.12	6.06	6.04	6.12	5.89	5.23	4.78	4.52	4.08	3.89	1.16	4.81
Slovenia	1.57	0.55	1.06	0.80	0.80	1.95	2.77	2.64	3.66	3.30	2.02	1.92
Spain	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sweden	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Switzerland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00
Turkey	4.28	4.38	4.41	3.59	4.06	3.96	3.63	2.76	0.56	0.81	0.63	3.01
UK	1.04	1.35	1.37	1.49	1.41	1.45	1.39	1.36	1.60	1.65	1.35	1.41
USA	3.31	3.14	2.98	2.79	3.19	3.13	3.14	3.22	2.88	3.11	3.09	3.09
Average	1.33	1.39	1.34	1.33	1.35	1.23	1.33	1.38	1.54	1.40	1.23	1.35

Table 16 – Life Expectancy at 65 Inefficiency Levels between 2001 and 2011

	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	Average
Australia	0.51%	1.57%	0.28%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.13%	0.97%	0.31%
Austria	2.87%	4.47%	3.72%	1.59%	2.34%	2.93%	3.65%	4.21%	6.70%	6.63%	5.95%	4.10%
Belgium	5.37%	6.90%	4.25%	4.28%	2.72%	4.47%	6.63%	7.40%	8.97%	9.32%	8.63%	6.27%
Canada	0.42%	0.30%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.17%	0.00%	0.08%
Chile	4.91%	0.00%	0.00%	0.00%	3.23%	0.00%	0.00%	0.85%	0.44%	0.00%	0.00%	0.86%
Czech R.	7.80%	6.20%	10.47%	5.63%	7.73%	8.28%	10.03%	7.61%	13.83%	9.32%	4.01%	8.26%
Denmark	12.10%	8.98%	9.37%	8.08%	9.44%	9.14%	7.78%	7.73%	8.68%	11.10%	8.39%	9.16%
Estonia	0.82%	1.56%	2.63%	15.88%	11.12%	1.66%	5.39%	10.99%	13.98%	1.41%	3.60%	6.28%
Finland	4.17%	6.05%	6.51%	1.27%	0.45%	1.44%	0.67%	1.29%	2.08%	1.41%	1.29%	2.42%
France	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.23%	0.22%	0.00%	0.13%
Germany	6.49%	8.30%	8.07%	3.92%	3.80%	5.02%	4.70%	5.32%	7.84%	7.43%	7.05%	6.18%
Greece	0.20%	0.41%	0.64%	0.53%	1.03%	0.71%	0.91%	1.08%	1.99%	1.84%	1.24%	0.96%
Hungary	19.82%	20.41%	19.76%	20.07%	20.99%	21.93%	24.39%	22.51%	25.51%	22.50%	19.68%	21.60%
Iceland	0.00%	0.00%	0.04%	1.03%	0.34%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.13%
Ireland	1.69%	0.04%	0.35%	1.64%	3.40%	2.23%	4.37%	6.63%	9.53%	11.25%	12.62%	4.89%
Israel	0.00%	0.04%	0.00%	0.03%	1.20%	0.09%	0.24%	0.18%	1.76%	2.30%	3.41%	0.84%
Italy	0.00%	0.00%	1.23%	0.00%	0.02%	0.00%	0.49%	0.00%	2.97%	1.10%	0.63%	0.59%
Japan	0.31%	0.00%	0.00%	0.00%	0.00%	0.00%	0.42%	0.00%	0.00%	0.00%	0.00%	0.07%
Korea	5.03%	5.43%	2.98%	4.22%	4.40%	3.63%	2.57%	1.46%	1.80%	1.48%	1.88%	3.17%
Luxembourg	5.62%	4.53%	0.12%	0.53%	4.90%	2.71%	3.05%	0.74%	8.07%	5.45%	6.50%	3.84%
Mexico	4.28%	4.13%	3.84%	2.86%	1.68%	1.21%	1.18%	1.44%	1.04%	0.47%	0.00%	2.01%
Netherlands	5.48%	7.12%	4.03%	4.26%	4.82%	6.89%	7.67%	7.07%	9.26%	10.47%	9.53%	6.96%
N. Zealand	0.00%	0.34%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.03%
Norway	1.46%	2.42%	0.53%	0.15%	2.27%	1.51%	0.53%	2.66%	3.68%	7.25%	6.93%	2.67%
Poland	8.29%	10.39%	12.69%	11.50%	9.65%	6.48%	7.94%	9.60%	10.72%	13.04%	9.23%	9.96%
Portugal	1.98%	6.11%	5.77%	6.84%	6.07%	5.72%	7.04%	5.63%	7.42%	8.88%	7.92%	6.31%
Slovak R.	22.13%	26.53%	25.47%	25.90%	26.21%	25.46%	23.68%	22.65%	20.54%	19.76%	4.97%	22.12%
Slovenia	5.48%	1.67%	3.87%	2.52%	2.47%	6.65%	10.60%	9.66%	15.28%	13.10%	9.91%	7.38%
Spain	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.27%	0.00%	0.02%
Sweden	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Switzerland	0.00%	0.00%	0.06%	0.00%	0.00%	0.00%	0.00%	0.00%	0.09%	0.00%	0.00%	0.01%
Turkey	23.85%	23.99%	23.77%	22.60%	23.15%	21.84%	20.54%	18.90%	14.75%	13.71%	7.51%	19.51%
UK	2.75%	3.97%	4.17%	5.49%	4.63%	4.85%	6.16%	5.65%	7.51%	7.33%	5.88%	5.31%
USA	7.84%	7.88%	6.55%	6.33%	7.48%	8.19%	7.41%	8.48%	7.89%	8.99%	8.45%	7.77%
Average	4.76%	4.99%	4.74%	4.62%	4.87%	4.50%	4.94%	4.99%	6.28%	5.78%	4.59%	5.01%

Table 17 – Life Expectancy at 65 Inefficiency Levels (in Years of Life Lost)

	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	Average
Australia	0.10	0.32	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.18	0.06
Austria	0.57	0.88	0.72	0.31	0.45	0.56	0.68	0.78	1.21	1.20	1.08	0.77
Belgium	1.06	1.34	0.82	0.82	0.52	0.84	1.22	1.36	1.59	1.65	1.54	1.16
Canada	0.09	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.02
Chile	0.89	0.00	0.00	0.00	0.58	0.00	0.00	0.15	0.08	0.00	0.00	0.15
Czech R.	1.36	1.07	1.78	0.96	1.30	1.37	1.61	1.21	2.14	1.45	0.63	1.35
Denmark	2.25	1.65	1.70	1.46	1.69	1.62	1.37	1.35	1.48	1.86	1.41	1.62
Estonia	0.14	0.26	0.44	2.58	1.76	0.26	0.84	1.69	2.10	0.21	0.54	0.98
Finland	0.82	1.18	1.26	0.25	0.09	0.27	0.13	0.24	0.38	0.25	0.23	0.46
France	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.04	0.00	0.03
Germany	1.28	1.61	1.55	0.75	0.72	0.95	0.87	0.98	1.40	1.33	1.27	1.15
Greece	0.04	0.08	0.12	0.10	0.19	0.13	0.16	0.19	0.35	0.32	0.22	0.17
Hungary	3.23	3.30	3.18	3.21	3.31	3.43	3.72	3.46	3.81	3.40	2.97	3.36
Iceland	0.00	0.00	0.01	0.20	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Ireland	0.33	0.01	0.07	0.30	0.63	0.41	0.80	1.19	1.66	1.93	2.11	0.86
Israel	0.00	0.01	0.00	0.01	0.23	0.02	0.05	0.03	0.33	0.43	0.63	0.16
Italy	0.00	0.00	0.25	0.00	0.00	0.00	0.10	0.00	0.55	0.21	0.12	0.11
Japan	0.06	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.01
Korea	0.99	1.05	0.58	0.79	0.81	0.66	0.46	0.25	0.31	0.25	0.31	0.59
Luxembourg	1.11	0.88	0.02	0.10	0.90	0.51	0.57	0.14	1.38	0.98	1.16	0.70
Mexico	0.75	0.72	0.67	0.50	0.30	0.21	0.21	0.25	0.18	0.08	0.00	0.35
Netherlands	1.08	1.38	0.78	0.81	0.91	1.28	1.40	1.28	1.63	1.83	1.67	1.28
N. Zealand	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Norway	0.29	0.47	0.10	0.03	0.43	0.29	0.10	0.50	0.68	1.30	1.25	0.50
Poland	1.46	1.80	2.16	1.95	1.62	1.08	1.30	1.56	1.71	2.08	1.45	1.65
Portugal	0.39	1.15	1.08	1.27	1.12	1.05	1.25	1.01	1.29	1.55	1.38	1.14
Slovak R.	3.64	4.25	4.09	4.09	4.08	3.90	3.60	3.44	3.09	2.97	0.74	3.44
Slovenia	1.04	0.32	0.71	0.46	0.45	1.19	1.83	1.66	2.52	2.19	1.66	1.28
Spain	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00
Sweden	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Switzerland	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00
Turkey	3.60	3.60	3.55	3.37	3.43	3.23	3.03	2.77	2.15	1.98	1.08	2.89
UK	0.55	0.78	0.81	1.04	0.87	0.91	1.13	1.03	1.33	1.30	1.04	0.98
USA	1.50	1.50	1.24	1.18	1.39	1.50	1.34	1.54	1.41	1.59	1.49	1.42
Average	0.84	0.87	0.82	0.78	0.82	0.75	0.82	0.83	1.03	0.96	0.77	0.84

Table 18 – Infant Mortality (in Number of preventable deaths)

	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	Average
Australia	1.33	1.31	1.48	1.02	1.56	1.34	0.90	1.17	1.01	1.70	1.75	1.33
Austria	2.00	2.21	2.01	2.04	1.63	1.48	1.80	1.73	1.71	0.98	1.65	1.75
Belgium	1.97	2.18	2.03	2.23	2.17	2.35	1.42	1.53	1.70	1.79	1.59	1.91
Canada	0.42	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.08
Chile	0.38	0.00	0.36	0.00	0.68	0.00	0.00	0.07	0.21	0.00	0.00	0.15
Czech R.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Denmark	2.28	2.00	1.60	2.29	2.23	1.63	1.32	1.13	0.56	0.56	0.52	1.46
Estonia	0.00	0.00	0.00	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.06
Finland	1.23	0.90	1.20	1.12	0.54	0.58	0.17	0.16	0.00	0.00	0.00	0.54
France	1.02	1.11	0.91	0.82	0.82	0.81	0.79	0.60	1.53	1.27	1.32	1.00
Germany	1.68	1.87	1.42	1.43	1.69	1.35	1.38	1.33	1.37	1.27	1.10	1.44
Greece	0.24	0.25	0.32	0.08	0.24	0.25	0.21	0.20	0.18	0.35	0.35	0.24
Hungary	1.23	1.55	1.12	1.45	1.34	1.48	1.61	1.56	2.23	1.31	1.33	1.47
Iceland	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.24	0.00	0.00	0.00	0.03
Ireland	0.00	0.22	0.13	0.34	0.47	0.75	0.91	0.76	0.94	0.84	1.34	0.61
Israel	0.30	0.29	0.28	0.26	0.35	0.16	0.35	0.61	0.50	1.11	0.72	0.45
Italy	0.30	0.15	1.03	0.20	0.48	0.54	0.79	0.82	0.29	0.51	0.65	0.52
Japan	0.16	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01
Korea	0.15	0.21	0.05	0.02	0.00	0.01	0.18	0.00	0.06	0.06	0.14	0.08
Luxembourg	2.22	1.77	0.76	0.10	0.10	0.39	0.05	0.28	0.89	0.73	1.55	0.80
Mexico	3.19	3.77	3.93	3.81	2.28	1.77	1.76	2.33	1.92	1.56	1.80	2.56
Netherlands	2.08	2.08	2.36	2.15	2.31	2.26	2.14	1.42	1.82	1.83	1.82	2.02
N. Zealand	2.98	2.52	0.73	0.63	0.32	0.63	0.23	0.53	0.65	1.15	0.60	1.00
Norway	0.63	1.23	1.55	0.25	1.52	1.68	0.43	0.88	0.99	0.69	0.84	0.97
Poland	1.80	0.42	0.41	0.14	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.25
Portugal	0.51	0.02	1.19	0.40	0.32	0.00	0.00	0.00	0.00	0.41	0.20	0.28
Slovak R.	1.60	2.53	2.47	2.50	2.02	1.26	1.12	0.44	0.63	0.12	0.00	1.33
Slovenia	0.25	0.00	0.00	0.00	0.00	0.17	0.63	0.13	0.27	0.16	0.00	0.15
Spain	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.01
Sweden	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Switzerland	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.55	0.75	0.04	0.04	0.13
Turkey	1.16	0.62	2.80	2.78	5.25	7.49	11.55	12.54	6.38	8.23	2.61	5.58
UK	1.07	1.11	1.84	1.79	2.06	1.50	1.36	1.11	1.05	0.96	0.87	1.34
USA	2.62	2.71	2.94	2.98	2.24	1.67	1.94	2.14	1.86	1.95	1.81	2.26
Average	1.02	0.98	1.03	0.92	0.96	0.93	0.97	1.01	0.87	0.88	0.73	0.94

Table 19 – Life Expectancy at Birth Productivity Growth and Inefficiency Path over the Years

Inefficiency - Measured in year t

OECD	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Annual
2011	0.79%	0.87%	0.89%	0.92%	1.07%	1.11%	1.13%	1.19%	1.33%	1.58%	**1.71%**	0.08%
2010	0.88%	0.97%	1.02%	1.07%	1.23%	1.29%	1.31%	1.37%	1.54%	**1.79%**	2.00%	0.10%
2009	0.95%	1.05%	1.11%	1.15%	1.34%	1.44%	1.49%	1.59%	**1.74%**	2.08%	2.31%	0.12%
2008	1.16%	1.26%	1.32%	1.37%	1.50%	1.59%	1.65%	**1.74%**	1.95%	2.21%	2.42%	0.12%
2007	1.16%	1.26%	1.34%	1.40%	1.51%	1.65%	**1.77%**	1.87%	2.06%	2.36%	2.53%	0.13%
2006	1.13%	1.25%	1.28%	1.35%	1.47%	**1.61%**	1.69%	1.79%	1.98%	2.22%	2.42%	0.12%
2005	1.24%	1.45%	1.53%	1.61%	**1.74%**	1.92%	1.97%	2.08%	2.30%	2.56%	2.68%	0.13%
2004	1.51%	1.62%	1.69%	**1.82%**	1.97%	2.09%	2.15%	2.27%	2.49%	2.66%	2.78%	0.12%
2003	1.76%	1.93%	**2.02%**	2.21%	2.34%	2.48%	2.56%	2.66%	2.85%	3.01%	3.13%	0.13%
2002	1.64%	**1.83%**	1.91%	2.06%	2.14%	2.31%	2.39%	2.49%	2.69%	2.88%	2.96%	0.12%
2001	**1.62%**	1.77%	1.84%	1.97%	2.05%	2.21%	2.28%	2.36%	2.55%	2.72%	2.81%	0.11%
												0.12%

Table 20 – Life Expectancy at 65 Productivity Growth and Inefficiency Path over the Years

Inefficiency - Measured in year t

OECD	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Annual
2011	2.17%	2.47%	2.49%	2.64%	2.87%	3.05%	3.06%	3.24%	3.76%	4.51%	**4.76%**	0.23%
2010	2.48%	2.77%	2.85%	2.99%	3.20%	3.47%	3.57%	3.70%	4.25%	**4.99%**	5.48%	0.27%
2009	2.81%	3.11%	3.20%	3.33%	3.55%	3.81%	3.97%	4.14%	**4.74%**	5.77%	6.29%	0.32%
2008	3.16%	3.46%	3.47%	3.66%	3.90%	4.26%	4.43%	**4.62%**	5.34%	6.10%	6.66%	0.32%
2007	3.32%	3.61%	3.62%	3.82%	4.00%	4.63%	**4.87%**	5.22%	5.74%	6.67%	7.17%	0.35%
2006	3.46%	3.77%	3.77%	4.02%	4.14%	**4.50%**	4.71%	5.03%	5.56%	6.37%	6.89%	0.31%
2005	3.93%	4.42%	4.43%	4.76%	**4.94%**	5.56%	5.69%	6.08%	6.74%	7.66%	8.10%	0.38%
2004	4.26%	4.61%	4.63%	**4.99%**	5.32%	5.76%	5.92%	6.37%	7.12%	7.86%	8.30%	0.37%
2003	5.69%	6.22%	**6.28%**	6.94%	7.25%	7.81%	8.08%	8.49%	9.13%	9.84%	10.34%	0.42%
2002	5.23%	**5.78%**	5.86%	6.34%	6.58%	7.24%	7.57%	7.92%	8.54%	9.25%	9.58%	0.40%
2001	**4.59%**	5.10%	5.26%	5.67%	5.90%	6.62%	6.89%	7.20%	7.78%	8.41%	8.79%	0.38%
												0.34%

Table 21 – Infant Mortality Productivity Growth and Inefficiency Path over the Years

Inefficiency - Measured in year t

OECD	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	Annual
2011	0.43	0.51	0.57	0.66	0.72	0.98	0.97	0.93	0.93	0.92	**1.04**	0.06
2010	0.47	0.61	0.65	0.68	0.74	1.06	1.03	1.02	1.02	**1.00**	1.26	0.07
2009	0.58	0.70	0.71	0.73	0.79	1.13	1.11	1.08	**1.06**	1.08	1.23	0.06
2008	0.49	0.62	0.63	0.65	0.68	0.89	0.92	**0.93**	0.99	0.97	1.07	0.05
2007	0.59	0.70	0.74	0.74	0.79	0.98	**1.00**	1.01	1.01	0.98	1.06	0.04
2006	0.54	0.71	0.72	0.71	0.78	**0.97**	0.97	1.04	1.02	1.00	1.06	0.05
2005	0.58	0.69	0.72	0.72	**0.85**	1.09	1.11	1.09	1.09	1.04	1.11	0.05
2004	0.60	0.71	0.73	**0.87**	1.03	1.25	1.26	1.22	1.17	1.12	1.17	0.05
2003	0.64	0.84	**0.86**	0.92	1.05	1.25	1.20	1.14	1.09	1.04	1.04	0.04
2002	0.71	**0.82**	0.90	0.95	1.08	1.22	1.19	1.15	1.10	1.05	1.04	0.03
2001	**0.78**	0.86	0.93	0.97	1.07	1.16	1.12	1.08	1.03	0.99	0.96	0.02
												0.05

Table 22 – Technical Change, Efficiency Change, and Productivity Growth by Country

	2001-2010	Tech	Eff	Prod
1	**Australia**	0.27%	0.66%	0.93%
2	**Austria**	4.10%	1.00%	5.14%
3	**Belgium**	3.34%	1.27%	4.66%
4	**Canada**	0.78%	-0.67%	0.10%
5	**Chile**	0.88%	-1.73%	-0.87%
6	**Czech Republic**	1.81%	-1.01%	0.78%
7	**Denmark**	3.50%	-2.22%	1.20%
8	**Estonia**	1.51%	2.21%	3.74%
9	**Finland**	4.56%	-3.62%	0.77%
10	**France**	1.12%	1.14%	2.27%
11	**Germany**	3.72%	0.56%	4.30%
12	**Greece**	0.51%	0.46%	0.97%
13	**Hungary**	0.01%	-0.18%	-0.17%
14	**Iceland**	1.57%	0.00%	1.57%
15	**Ireland**	0.54%	5.56%	6.12%
16	**Israel**	0.00%	1.46%	1.46%
17	**Italy**	1.13%	0.60%	1.73%
18	**Japan**	0.25%	-0.50%	-0.25%
19	**Korea**	1.04%	-1.12%	-0.09%
20	**Luxembourg**	4.03%	0.69%	4.75%
21	**Mexico**	2.32%	-3.38%	-1.14%
22	**Netherlands**	3.66%	1.32%	5.03%
23	**New Zealand**	3.16%	-2.05%	1.04%
24	**Norway**	3.03%	2.46%	5.57%
25	**Poland**	0.32%	-0.30%	0.03%
26	**Portugal**	2.37%	1.70%	4.11%
27	**Slovak R.**	0.75%	-8.00%	-7.30%
28	**Slovenia**	2.27%	1.12%	3.42%
29	**Spain**	0.03%	-0.07%	-0.03%
30	**Sweden**	0.51%	0.00%	0.51%
31	**Switzerland**	0.23%	0.06%	0.29%
32	**Turkey**	3.15%	-6.06%	-3.10%
33	**UK**	2.88%	0.77%	3.68%
34	**United States**	3.34%	-0.16%	3.17%
	OECD	1.84%	-0.28%	1.56%

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Different Types of Healthcare Inefficiencies and Outcome Losses:

A Multi-Stage Efficiency Analysis of OECD Healthcare Systems

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Abstract

This paper measures the multi-stage technical efficiency of healthcare systems, the impact of environmental variables, and the expenditure levels across OECD countries between 2000 and 2011, based on a 12 year, 34 country panel data. We adopt an output-oriented DEA (Data Envelopment Analysis) methodology to obtain the technical efficiencies in production and provision. We find 3.05% overall inefficiency across OECD countries, which translates into a loss of 1.38 years of life expectancy at birth and additional 0.75 infant deaths per 1000 live births. There are further outcome losses, however, from environmental variables (0.54%), and inadequate healthcare spending (1.94%), 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.

The inefficiency is split 21%-79% between production and provision. While provision is generally the main source of inefficiency, other countries like the US, suffer heavily from production inefficiency (61%). Although most countries are inefficient in one way or another, the type of inefficiencies they suffer and the solutions to those issues as well as the policy implications might be very different.

Keywords: Healthcare, Efficiency, Network DEA, OECD, Environmental Variables

1 Introduction

Governments in most developed countries allocate a significant share of public resources to healthcare [11]. This share has been steadily increasing to its current level of over 10% of global GDP [85, 109]. Although there are some signs of slowdown [81], the latest OECD data show a bounce back in expenditure growth [104].

Many studies [66, 67, 98] have tried to explain this trend by laying out the main culprits of the expenditure growth. "Proximity to death" [139] accounts for about 1/6 of the expenditure growth while the rise in medical service prices is found to be the main driver of rising expenditures, primarily due to wage increases in the medical sector exceeding productivity growth [118]. This is mainly a supply-side problem, as predicted by Baumol's unbalanced growth model [12], which identifies the medical sector as a high-skilled labor intensive non-progressive sector. However, these increases can be significantly curbed by monopsonistic payers, especially the public sector and large insurers [7, 88, 118].

Increased social expectations and use of medical services due to rising incomes, especially among less developed countries, are also major contributing factors. The high income-elasticity of healthcare [118, 49] implies that an increasing share of national income will be allocated to healthcare as nations get richer. Similarly, increasing use of technological equipment [46, 86, 103], investment in technology [7], and inefficiency of healthcare systems are other major reasons for increasing healthcare costs.

Technological advances in healthcare, notably hospital care, have been dramatic over the last four decades [43], but they have often been blamed for the mounting costs of hospital care, especially in the United States. Various analysts (Aaron, (1991) [1]; Newhouse, (1993) [100]; and Schwartz and Mendelson, (1994) [122]) have argued that technological change generates the underlying growth in expenditures, without providing in-depth empirical analysis.

On the other hand, many studies in the literature [18, 19, 52, 93, 112, 121] identify technical change as the main source of healthcare improvements. Fare et al. [40], for example, find widespread and rapid productivity growth for a sample of OECD countries from 1974 to 1989, especially for Denmark and the USA. Likewise, Moscone et al. [93] find a significant relationship between scientific research and the growth in healthcare productivity. Although technical change is found to

constitute about a quarter of the healthcare expenditure growth, it also constitutes a large portion of the outcome growth. Our working papers [13, 14], which include data for all OECD Countries between 2000 and 2011, finds a similar increase in technical change, and identify this as the main source of healthcare improvements.

Even though Europe and the US experience similar levels of technological improvement over the long haul [94], healthcare costs remain substantially different. The main reason for such a phenomenally high cost differential between the US and other OECD countries is the relative price levels [53, 60], due to very different market structure and medical systems. Average physician income in the US, for instance, is nearly three times the OECD average ($200,000 vs. $70,000) and the ratio of physician income / average income in the US is 5.5, but only 3.4 in Germany, 3.2 in Canada, 1.9 in France, and 1.4 in the UK [118]. Similarly Koechlin et al. [76] find US medical service prices to be 73% higher than in a selected group of OECD countries. The main reasons for such high prices in the US [81] can be summarized as,

a) more intense use of health-related technologies, [22, 126]
b) low productivity, [56, 58, 75]
c) decentralized price negotiations and fragmentation in the insurance market, [87, 90, 92]
d) high level of provider concentration and less monopsonist power than OECD [15, 133]
e) high administrative costs. [36, 118]

Therefore the reasons for the current high levels of healthcare costs in the US should not be confused with the reasons for the growth in costs, which can only partially be attributed to investment in technology.

Another possibility is that increasing inefficiency in the hospital industry is causing real expenditure growth; a World Bank Health, Nutrition and Population Paper by Wang, et al. [132] and a WHO study (2000) [136] made early attempts to measure global healthcare efficiency using different performance indicators, showing enormous variance in health outcomes, despite similar income and education levels. This generated considerable interest in the measurement of healthcare efficiency. Among the seminal healthcare studies at the system level are Hollingsworth and Wildman (2002) [63], Jamison et al. (2001) [69], Salomon et al. (2001) [120], and Evans et al. (2001) [37].

Schwartz and Mendelson [122] argue that almost a quarter of the real expenditure growth could be eliminated if inefficiency was curbed. Similarly recent studies suggest that if increases in healthcare

costs are inevitable, the focus should shift from cost reduction to improving healthcare quality [129]. It is then much more plausible to argue the system should try to maximize its output levels given the input it is provided, as the resources and expenditure levels used in healthcare production are usually determined externally. This is why we adopt an *output-oriented* efficiency measure in our study.

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. *Data Envelopment Analysis (DEA)* is a nonparametric approach which constructs a theoretical *best-practice* frontier from the observed data points to measure the efficiency of any observed point. The method can simultaneously handle multiple inputs and outputs, which are assumed to be homogeneous across units. The first application of DEA to health issues is an unpublished work from 1979 regarding family planning centers in Costa Rica and Guatemala (Ray 2004, p. xi) [114]. Nunamaker and Lewin (1983) [102] is the first published work applying DEA to healthcare, whereas Sherman (1984) [123] was the first author to use DEA to evaluate overall hospital efficiency.

The technique was first introduced by Charnes, Cooper, and Rhodes in 1978 [23] and further formalized by Banker, Charnes and Cooper in 1984 [9] based on Farrell's (1959) [45] simple measure of firm efficiency that accounted for multiple inputs. Today there is a very extensive DEA literature surveyed by O'Neill et al. (2008) [106], who emphasize national differences in hospital efficiency research, and Ozcan (2008) [109] who considers many aspects of healthcare delivery, as well as providing an overview of existing techniques. Hollingsworth (2008) [64] classifies 317 published papers into various subcategories, including parametric techniques such as *stochastic frontier analysis*, and offers comments as to their practical usefulness.

Recent healthcare studies that concentrate on OECD countries include Retzlaff-Roberts et al. (2004) [119], who find that countries with less stellar results can also be relatively efficient; Varabyova et al. (2013) [131], who use a panel data set and compare parametric and non parametric methods for a robustness check; and Cheng and Zervopoulos (2014) [48], 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) [121], 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. [108] also find a positive impact of doctors on infant mortality, applying a multilevel analysis. Davies et al. [34] evaluate three dimensions (efficiency, effectiveness,

equity) of hospital performance, while Gholami [51] and Nayar et al. [99] question if the tradeoff between efficiency and quality is really inevitable.

Many of the other studies focus on the relative performance of health status and the determinants of health and healthcare expenditures of the different OECD countries [4-7, 29, 50, 66, 82, 91, 105, 118, 119]. Lorenzoni [81] elaborates and presents an executive summary of the earlier studies to highlight the major differences between the US healthcare system and other OECD countries. Gerdtham et al [49] find the income elasticity of healthcare to be greater than 1, resulting in an increased share of medical expenditures with rising incomes.

2 Objectives

As stressed by Jacobs et al. (2006) [68], efficiency analysis should be based on outcomes of healthcare. However, researchers are often forced to study efficiency on the basis of measured services like patients treated or hospital discharges. Many of the published studies use health services as outputs [8, 35, 117] but some studies include health outcomes as outputs [20, 33, 74, 125], and a few include quality, either explicitly [57] or as an explanatory variable [138]. Either approach is problematic; since health services as intermediate goods do not tell us whether the patient's health has improved, while the outcomes are not the direct products of the inputs used but of intermediate goods in conjunction with other non-discretionary inputs. This critique was summarized in Newhouse (1994) [101] and fully discussed in Jacobs et al. (2006) [68], who conclude by suggesting the use of multivariate models and multi-stage models [59], where objectives may include quality.

Much of the literature finds diverse results with respect to healthcare efficiency. While there are studies that find countries like Turkey with relatively poor health outcomes to be efficient [34, 108] others find the opposite results [17, 127]. The problem obviously stems from the output choice (services vs. outcomes) and the lack of consistent and reliable quality measurements. Additionally, measuring the impact of the environmental factors is also the goal of a growing body of studies with diverse implications [16, 62, 84, 107], though they often fail to explain why those inefficiencies occur and how to cure them. Our study not only measures but also depicts how much environmental variables impact healthcare and shift the production frontier.

Most countries, regardless of their level of development, are inefficient in producing healthcare to some degree. However, the kinds of inefficiencies they suffer vary greatly by level of development and market structure. Pinpointing the precise type of such inefficiencies with composite effects has

important political implications. Also, the conflicting results due to the choice of outputs necessitates a more comprehensive multi-stage efficiency analysis, where both health services and health outcomes are included in separate stages, controlling for other factors.

Following the seminal model of Färe and Grosskopf (2000) [44], we devise a multi-stage healthcare system analysis where first-stage production uses resources to produce health services, which are, as intermediate goods, then transformed to 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 controlled for.

There is no study in the literature, to our knowledge, that 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. As part of this multi-stage analysis, this paper's main contribution will be *to pinpoint where exactly and what type of inefficiencies occur, what is the impact of environmental variables on health outcomes, and which policies might be used to improve efficiency and health outcomes*.

Using panel data has several advantages compared to 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 validity and data accuracy. For pooled analysis, such a comparison may allow for increased discrimination among efficient units and the inclusion of additional variables.

We are mainly using OECD data [104], which are, for the most part, standardized across fairly similar countries; so the quality of the variable measurements, although spotty at times, is relatively good. The only non-OECD data are the BMI figures acquired from the World Health Organization as an environmental variable. The inclusion of multiple (12) years also serves to give a better picture of each country, rather than a one-year snapshot.

Following the standard procedure, we are using additional variables to control for risk factors, outcome quality, and capital intensity, which will be further investigated in the following pages. In order to achieve our goal, we control for non-discretionary inputs, healthcare expenditures, and the quality of outputs; and aim to measure inefficiency levels, identify the sources of inefficiency, and measure the impacts of environmental variables and healthcare expenditures.

3 Methodology

3.1 Literature

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 treated 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 [30, 130]. It is often necessary to study the internal structure of a system to identify the cause of any inefficiency.

Another issue is that an overall system may be efficient, even when all of its stages are not [70]. Although a DMU which is efficient in all stages is also efficient overall, there are cases in which a DMU is less efficient in all stages than another DMU, and yet the former still has better system efficiency [71]. Similarly, in healthcare production, a DMU inefficient at production can still appear efficient in overall outcomes. This is because a) in the case of overuse of health resources, the inefficiency in production does not automatically lead to inefficiency in provision; b) constant returns in production is often linked with diminishing returns in provision, so a fairly large efficiency loss in production will not always result in similar losses in outcomes.

Measuring efficiency in healthcare directly from resources to outcomes does not capture the inefficiencies in production. We show in this study that the inefficiency in production remains underestimated or simply undetected without a multi-stage analysis, and a network DEA model is required to produce correct results when measuring efficiencies.

The first study using this approach is probably Charnes et al. (1986) [24], who observe two stages in army recruitment: creating awareness and creating contracts. *Separating large operations into multiple stages helps identify the real impact of input factors.* The simplest case is to separate the whole operation into two stages, as in Charnes et al. (1986) and Wang et al. (1997) [130].

Countless studies that discuss network DEA have been published since Charnes et al. (1986). Cook, Liang, and Zhu (2010) [28] reviewed a number of models for the basic two-stage systems, connected in series, where the second stage only consumes all the outputs from the first production. Castelli, Pesenti, and Ukovich (2010) [21] reviewed shared-flow, multilevel, and some network models. The network models they reviewed are of the general network DEA form developed by Färe and Grosskopf (2000) [44], leaving many others untouched.

Some examples of basic two stage structure include Yang (2006) [137] who used the CCR-concept model to measure the production and inventory efficiencies of 72 life and health insurance companies in Canada. Chen and Zhu (2004) [26] used a *process distance measure model* to find the input efficiency of process one and the output efficiency of process two, composing a system efficiency with the given weights. This idea is widely discussed in the literature. Chen, Cook, and Zhu (2010) [27] applied a system distance measure model to measure the system efficiency of a basic two-stage system. The paper is also able to project the efficient intermediate product, which is also what we do in the first stage of our analysis.

Kao and Hwang (2011) [72] use a BCC input model [9] to measure the scale efficiency of the first process and an output model to measure efficiency for the second process, decomposing the system efficiency into the product of the technical and scale efficiencies. Kao and Hwang (2013) [73], on the other hand, study the performance changes of a basic two-stage system by using the relational model. They show that the Malmquist productivity index [MPI, 83] of the system is the product of those two processes. Chen, Cook, Li, and Zhu (2009) [25] set weights for each of the processes in a two stage structure, resulting in an aggregate efficiency measure, which is called an *additive model* in the literature.

Our study is best described as a "*General two stage-structure*", which is an extended form of basic two stage models, allowing both stages to consume exogenous inputs supplied from outside and to produce final outputs. Examples include Simon, Simon, and Arias (2011) [124] who analysed the productivity growth of 34 Spanish university libraries using an MPI or Löthgren and Tambour (1999) [80], who included customer satisfaction in studying the performance of 31 Swedish pharmacies.

Färe and Whittaker (1995) [41] developed an output-oriented distance measure model to evaluate 137 US dairy farms, while. Färe and Grosskopf (1996) [42] proposed a similar model with the MPI also being calculated. Lozano, Gutierrez, and Moreno (2013) [79] used a directional distance function to study the performance of 39 Spanish airports.

Premachandra, Zhu, Watson, and Galagedera (2012) [110] extended the additive model of Chen, Cook, et al. (2009) for the basic two-stage system to allow for exogenous inputs for the second stage in studying the performance of 66 large mutual fund families in the US. Guan and Chen (2012) [54] used the same model to measure the innovation efficiency of 22 OECD countries, with the assumption of constant returns to scale.

There are more complicated cases with more than two stages and in different structural forms such as a series structure, a parallel structure, or a mixture of these, which are collectively called “network structures”. The DEA technique to measure the efficiency of systems with a network structure is called “network DEA” (Färe & Grosskopf, 2000) [44].

3.2 Output-oriented two-stage Model

As we are using panel data in this study, each yearly data point for each country is treated as a separate Decision Making Unit (DMU); e.g. the year 2000 data point for the US is an entirely different DMU than the US data point for 2001. We are assuming non-regressive technology, which implies that a currently available technology will also be available to all future DMUs, but was not available to the past ones. This assumption requires control for technological progress over time and can be done by the in/exclusion of the relevant firms.

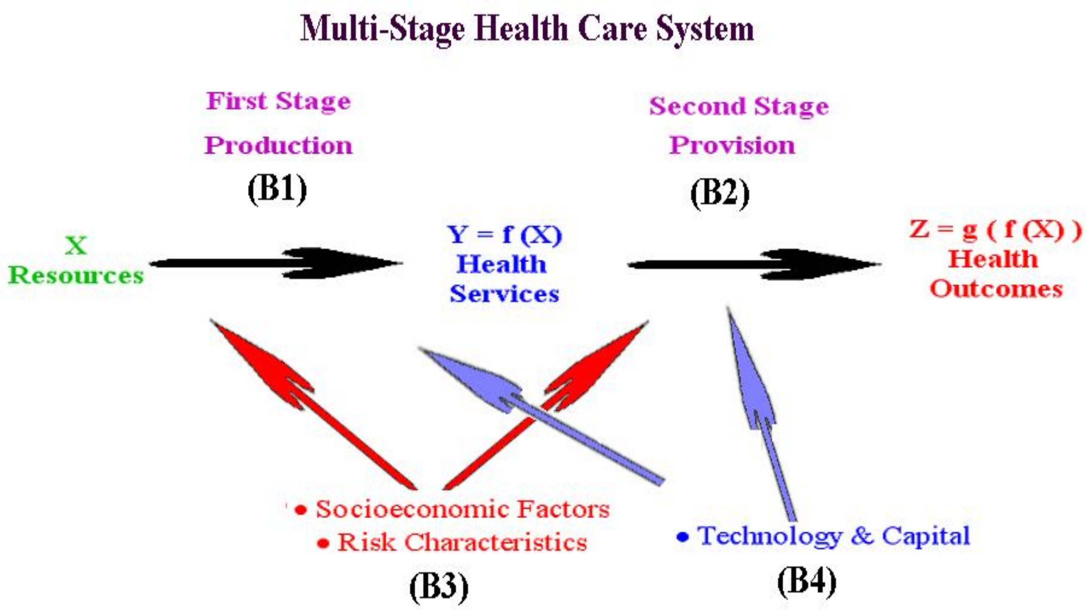
An important methodological decision in DEA is whether to apply constant or variable returns to scale. The first nonparametric models for efficiency estimation by Charnes et al. (1978) [23] assumed constant returns to scale (CRS). Later, Banker et al. (1984) [9] relaxed the CRS assumption to account for firms that do not operate at their optimal scale, allowing VRS.

Although it is generally accepted that the production stage exhibits CRS, the provision of health services demonstrates VRS, and most OECD countries operate at a sharply diminishing returns region. In other words, although doubling of all resources will lead to doubling of health services (CRS), this will not necessarily lead to a similar increase in health outcomes (VRS). Therefore, the OECD healthcare system exhibits CRS in production but VRS in the provision stage and as a whole.

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 should have been produced. The second stage, on the other hand, measures the *non-radial* efficiency levels of provision under VRS with desirable and undesirable health outcomes, due to countries improving asymmetrically in their health outcomes. This stage alternatively uses the actual (y) and efficient (y*) quantities of services as inputs to measure the second stage ($\boldsymbol{\beta_2}$) and overall ($\boldsymbol{\beta}$) inefficiency levels, respectively, which allows us to also derive the first stage inefficiency ($\boldsymbol{\beta_1}$).

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. For example, a 1% change in *life expectancy at birth* of an 80 year average is equivalent to a 4% change in *life expectancy at age 65* of a 20 year average, which requires a relative weight of 4 to 1 (80 to 20) respectively.

Graph 1 – Multi-Stage Healthcare System



3.3 Model Specification

DEA relies on a number of fairly weak assumptions to construct the production technology but avoids any explicit functional relationship between the inputs and outputs through a production function [32]. These assumptions are summarized below. Let Ψ be the feasible set:

a) all observed input-output combinations are possible; $(x_1, y_1) \in \Psi$.

b) the production possibility set is convex; Let $\alpha \in [0, 1]$; If $(x_1, y_1), (x_2, y_2) \in \Psi$, then $(x, y) = \alpha(x_1, y_1) + (1-\alpha)(x_2, y_2) \in \Psi$.

c) inputs and outputs are freely disposable; Let $x_2 \geq x_1$, and $y_2 \leq y_1$. If $(x_1, y_1) \in \Psi$ then $(x_2, y_1) \in \Psi$ and $(x_1, y_2) \in \Psi$

First Stage

Let (x_i, y_i) represent the input-output bundle of a firm i, assuming input-output bundle observed for N firms. Then given the aforementioned assumptions, the CRS production possibility set is

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

By measuring the radial (equiproportional) efficiency levels of production under constant returns to scale (CRS), we obtain the efficient services (y*) that should 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, and these controls are subject to VRS by definition, which further requires the condition $\sum_{i}^{N} \lambda_i = 1$ for controls, where q_{ik} is the control k for DMU i.

The output-oriented radial efficiency of a DMU s:

$$TE\,(x_s, y_s) = \left(\frac{1}{1+\theta_s}\right), \text{ where } \theta_s = \max(\theta) : (x_s, (1+\theta) y_s) \in T_c \qquad \{ii\}$$

The standard DEA LP problem solved to estimate the efficiency of DMU s, relative to contemporaneous CRS frontier is

Objective: Max **θ**, where **θ: Radial Output inefficiency**, subject to {iii}

- $\sum \lambda_i x_{ij} \leq x_{0j}$ 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)

In the maximization problem above (Max **θ**), constraints (1), (2), and (5) 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 producing **θ*** y_{0k} more outputs (services), where the **θ** is the radial inefficiency rate for all outputs. If θ equals 0, then the unit appears efficient in producing at least at one output, given the observed data. The inclusion of undesirable output (3) in the first stage, first popularized by FGLP89 [38] and FGLY93 [39], acts like a control variable and

ensures that the benchmark unit created from the convex combination of reference DMUs, which produce **θ*** y_{0k} more output, has at least the same quality of healthcare. However, the convexity and the scalability of the control variables need to be addressed, because the quality (or risk) does not scale up or down like the actual outputs, and these controls are subject to VRS by definition.

Among the various ways to incorporate environmental variables into the DEA framework, we use Ruggiero's 3-stage method [116] to consolidate multiple risk factors into one risk variable (4a), as it performed best in virtually all scenarios, being the only model robust to sample size and the number of nondiscretionary variables [96], when compared to the other common methods such as Ray (1991) [113], Muñiz (2002) [95] and Banker and Morey [10]. The original DEA model without the risk factors (4a) is solved and the second-stage regression on the risk factors is performed. Let $\hat{\theta}$ be the estimated inefficiency regressed on the risk factors:

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

After construction of q_{i2} (*the combined patient-risk control*) from estimating the first inefficiency, the model {iii} 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.

Second Stage

Let (y_i, z_i) represent the input-output bundle of a firm i, assuming input-output bundle observed for N firms. Then given the aforementioned assumptions, the VRS production possibility set is

$$T_v = \{(y, z); y \geq \sum_{i}^{N} \lambda_i y_i ; z_i \leq \sum_{i}^{N} \lambda_i z_i ; \sum_{i}^{N} \lambda_i = 1; \lambda_i \geq 0; (i = 1,2,3,\ldots, N)\} \qquad \{v\}$$

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

$$TE\,(y_s, z_s) = (\frac{1}{1+\beta_s}), \text{ where } \beta_s = \sum w_k \beta_{ks} = \max(\sum_{k=1}^{3} w_k \beta_k) : (y_{ks}, (1+\beta_k) z_{ks}) \in T_v \ \{vi\}$$

The standard DEA LP problem solved to estimate the efficiency of DMU s, relative to contemporaneous VRS frontier is,

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

subject to {iii}

- $\sum\lambda_i * y_{ij} \leq y_{0j}$ $j = 1\ldots3$ (Input constraint) (1)
- $\sum\lambda_i * z_{ik} \geq (1 + \boldsymbol{\beta_k}) * z_{sk}$ $k = 1, 2$ (Desirable Output constraint) (2a)
- $\sum\lambda_i * z_{ik} \leq (1 - \boldsymbol{\beta_k}) * z_{sk}$ $k = 3$ (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)
- $\lambda_i \geq 0$, $\sum\lambda_i = 1$ (Variable Returns to Scale) (5)

At the second stage, we measure the *non-radial* efficiency levels of provision under VRS (6) with desirable (2a), and undesirable (2b) outputs (health outcomes). In the maximization problem above (Max **β**), constraints (1), (2a), (2b), and (5) 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 $\boldsymbol{\beta_k} * z_{0k}$ more of desirable and less of undesirable outputs, where the $\boldsymbol{\beta_k}$ is the non-radial inefficiency rate for output k, and $\boldsymbol{\beta} = \sum \mathbf{w_k} * \boldsymbol{\beta_k}$ is *the weighted non-radial outcome inefficiency*. If $\boldsymbol{\beta_k}$ equals 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 $\boldsymbol{\beta} = \sum \mathbf{w_k} * \boldsymbol{\beta_k}$ may still be greater than zero, implying inefficiency in other outputs.

The inclusion of healthcare expenditures (3) ensures 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 (4a, 4b).

3.4 Decomposition of Inefficiencies and Impact of Environmental Variables

In the model, we initially decompose **β** (outcome inefficiency) into two parts. As in Chen, Cook, and Zhu (2010) [27], the overall efficiency is defined as the product of efficiencies in two consecutive stages. Let "$1 + \boldsymbol{\beta} = (1 + \boldsymbol{\beta_1}) * (1 + \boldsymbol{\beta_2})$" where,

$\boldsymbol{\beta_1}$: Outcome inefficiency of production, $\boldsymbol{\beta_2}$: Outcome inefficiency of provision

Using the actual health services as given in the model implicitly assumes the first stage production is fully efficient and will only yield $\boldsymbol{\beta_2}$, the outcome inefficiency of provision. Using the efficient health services obtained from the first stage as the inputs, on the other hand, implies no such assumption, and yields the total outcome inefficiency ($\boldsymbol{\beta}$), from which, $\boldsymbol{\beta_1}$ 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 not be precise due to the non-radial approach adopted in the second stage, compared to the radial approach in the first.

Further relaxing the controls in the model, equations (3), (4a), and (4b), and alternating between the actual (y) and efficient (y^*) levels of services as inputs allow us to gauge the separate and composite effects of the risk factors, inequality, and inadequate expenditure levels on the healthcare outcomes. Dropping constraint (3), for example, yields $\mathbf{(1 + \beta) * (1 + \beta_3)}$ with y^* as inputs, but $(1 + \beta)$ $\mathbf{* (1 + \beta_{3\text{-}2})}$ with y, from which $\boldsymbol{\beta_{3\text{-}1}}$ can easily be derived.

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

Φ: Total Outcome Loss,

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

$\boldsymbol{\beta_1}$: Loss from production inefficiency $\boldsymbol{\beta_2}$: Loss from provision inefficiency

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

$\boldsymbol{\beta_3}$: Loss from risk factors and inequality $\boldsymbol{\beta_4}$: Loss from inadequate expenditure

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

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

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

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

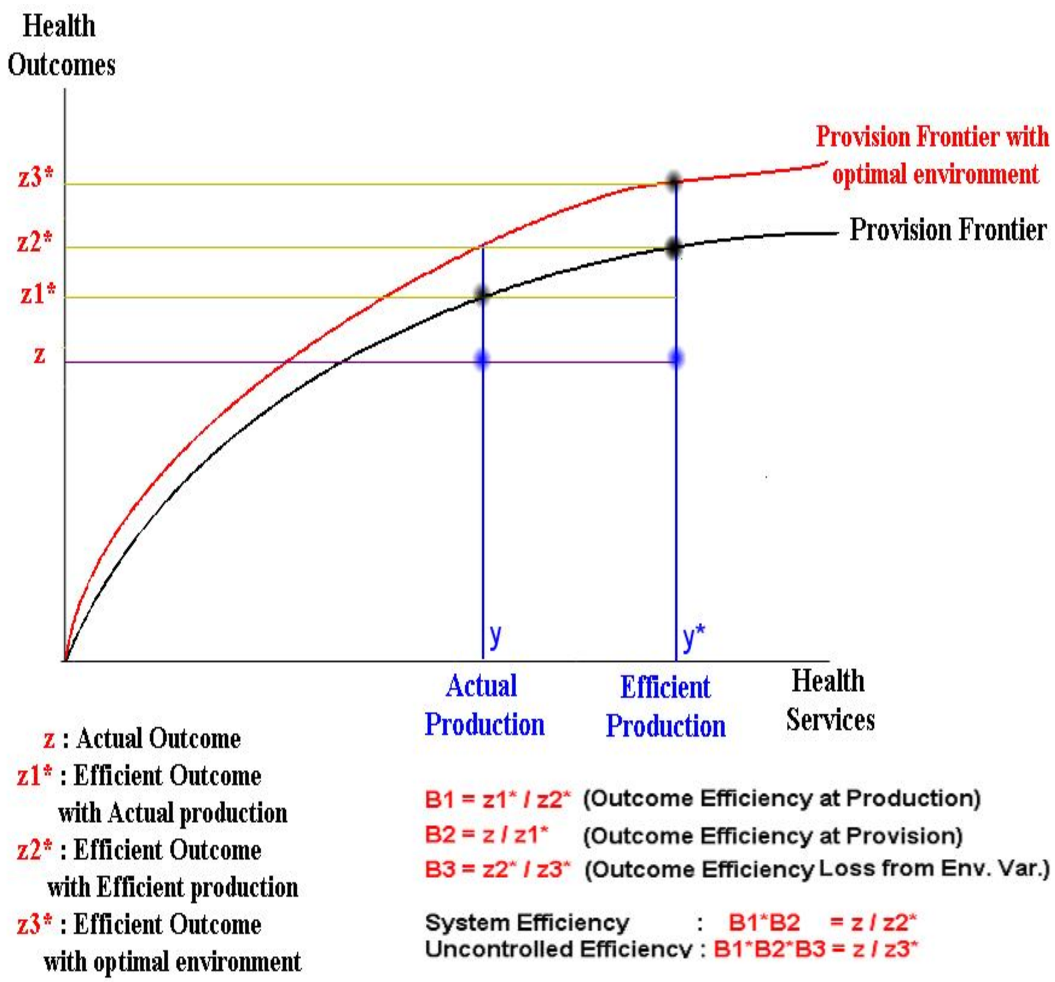
$\boldsymbol{\beta_{4\text{-}12}}$: on healthcare system, $\boldsymbol{\beta_{4\text{-}3}}$: on environmental variables

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	$\beta_{3\text{-}1}$	$\beta_{4\text{-}3}$	

We will further decompose the impact of inequality and risk factors when necessary. Such detailed decomposition will not only help us pinpoint where exactly the inefficiencies are, but also what type of inefficiencies and what policy implications each country faces.

3.5 Illustration of the Model

Graph 2 – Decomposition of Inefficiencies



4 Data

Data used in this study are obtained from the Organization for Economic Cooperation and Development (OECD) Health Data 2013 [141], which is the broadest source of comparable statistics on diverse health systems across OECD countries. The sources and methods of data collection are described in detail in the OECD documentation [60].

Because countries are not uniform in their reporting practices and not all variables are recorded each year, some adjustment of OECD data is unavoidable and common in OECD studies [106, 141]. Similarly, in this study, linear interpolation is applied to impute missing values in the time-series for particular countries, meaning some of the gaps are filled with average estimates (5-10% of the data points).

The dataset consists of 34 OECD countries and 12 years between 2000 and 2011 for a total of 408 DMUs. However, the number of included DMUs in the measurements varies by year for a minimum of 5 years (170 DMUs) and up to 11 years (378 DMUs) in order to control for technical change through time, with the assumption of *non-regressive technology*.

Variables

The variables used to determine efficiency include: *Resources, health Services, health outcomes, quality of outputs, healthcare expenditures per capita, patient risk characteristics, inequality of access to healthcare* (See the table 1).

4.1 Resources (First Stage Inputs): The inclusion of physicians, nurses and hospital beds is pretty much standard across most healthcare studies [64, 106, 108, 109] and there is significant homogeneity in the data as well.

4.2 Health Services (Intermediate Products): We use three of the most commonly used hospital services, namely *doctor consultations, hospital discharge rates, and patient days*, as the intermediate goods [64, 106, 109], or in other words, the outputs of the first stage, later to be used as inputs of the second stage. Because their homogeneity varies and effectiveness on health status depends on environmental variables, we control for per capita healthcare expenditure as a proxy for capital intensity, in addition to risk factors, and inequality.

4.3 Health Outcomes (Final Outputs): We use three of the most commonly used health outcomes as our outputs of the provision stage [64, 106, 109]. Life expectancy at birth is a good proxy for general

healthcare, and life expectancy at age 65 is a better proxy for senior and chronic healthcare, while infant mortality is particularly useful to measure more basic and youth healthcare efficiency.

4.4 Quality of Health Services (First Stage Control): We use Potential years of life lost (PYLL)[1] as a proxy for service quality at the first stage. It is defined as "a summary measure of premature mortality which provides an explicit way of weighting deaths occurring at younger ages, which are, a priori, preventable" [142].

4.5 Per capita Health Expenditures (Second Stage Control): We use healthcare expenditure per capita at the second stage, as a proxy for capital intensity and technology level. Both total and public health expenditures are employed for robustness checks.

4.6 Patient-risk Characteristics (General Control): There are three highly standardized and commonly used risk characteristics defined in the OECD data set, namely tobacco and alcohol consumption, and obesity. Data regarding tobacco and alcohol consumption have been obtained from the OECD web site while, the BMI figures, as a proxy for overweight population, were obtained from the WHO data set [140].

4.7 Inequality of Access to Healthcare (General Control): We use the Gini coefficient and alternatively poverty rates for each country as a proxy for inequality of access to healthcare. Although not a perfect match, the Gini is a sufficient indicator of healthcare inequality. There are various studies in the literature that show clear negative correlations between socioeconomic inequality and access to healthcare, both globally [135] and within a country [61]. We find that this correlation is stronger in privately oriented healthcare systems.

4.8 Variables not included in the study: In this study, we have only included the control variables that have direct effects on healthcare, in order to avoid diluting the results with too many control variables causing underestimation of inefficiency. However, there are other variables that are also commonly included in the literature, such as *education, income*, and to a lesser extent, *homicide and suicide rates*. For instance, we indeed find the *homicide and suicide rates* [65] to be statistically

[1] The calculations for PYLL involve adding up deaths occurring at each age and multiplying this with the number of remaining years to live up to a selected age limit. The limit of 70 years has been chosen for the calculations in OECD Health Data.

significant, but the inclusion of such controls, with the exception of Mexico, does not substantially affect the results, since the differences in the rates across OECD countries are small in absolute terms.

The existence of an "*education gradient*" on health outcomes is widely accepted in the literature [31], though it is not clear why this is the case. As Lochner (2011) [78] suggested, the literature has produced mixed results, and most studies fail to address the endogeneity of education and health behaviors in regressions. Basically we attempt to control for all channels, through which education can affect the data. Simply put, individuals with better education also tend to be richer (*poverty rates*), behave better and take better care of themselves (*risk factors*), and spend more money on healthcare (*per capita health expenditure*). Additionally, the education levels alone are usually not the primary factor in health outcomes. Eastern European countries, for example, often suffer from poor health outcomes though they are among the most educated nations. This anomaly is primarily seen as a "*development*" issue [2, 3, 111].

Table 1 - Variables

	#	Variables	Definition	Measurement
Resources	1	Physicians	Professionally active physicians, including practising physicians	density per 1 000 population
	2	Nurses	Professionally active nurses, including practising nurses	density per 1 000 population
	3	Hospital beds	Regularly maintained & staffed, immediately available for use	density per 1 000 population
Services	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	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	10	Tobacco Consumption	Tobacco consumption, % of all adult daily smokers	percentage of population
	11	Alcohol consumption	Alcohol consumption, litres per capita aged 15+	litres per capita aged 15+
	12	BMI	Overweight population, % of all population with a BMI>25 kg/m2	percentage of population
Ineq.	13a	Gini Coefficient	Measurement of Inequality in the population	between 0 and 1
	13b	Poverty	Percentage of population below poverty threshold	percentage of population
Exp.	14a	Total Health Expenditure	Total Healthcare Expenditures	per capita, US$ PPP
	14b	Public Health Expenditure	Public Healthcare Expenditures	per capita, US$ PPP
O	15	PYLL	Potential Years of Life Lost, All causes, 0-69 Years	per 100 000 population

5 Results

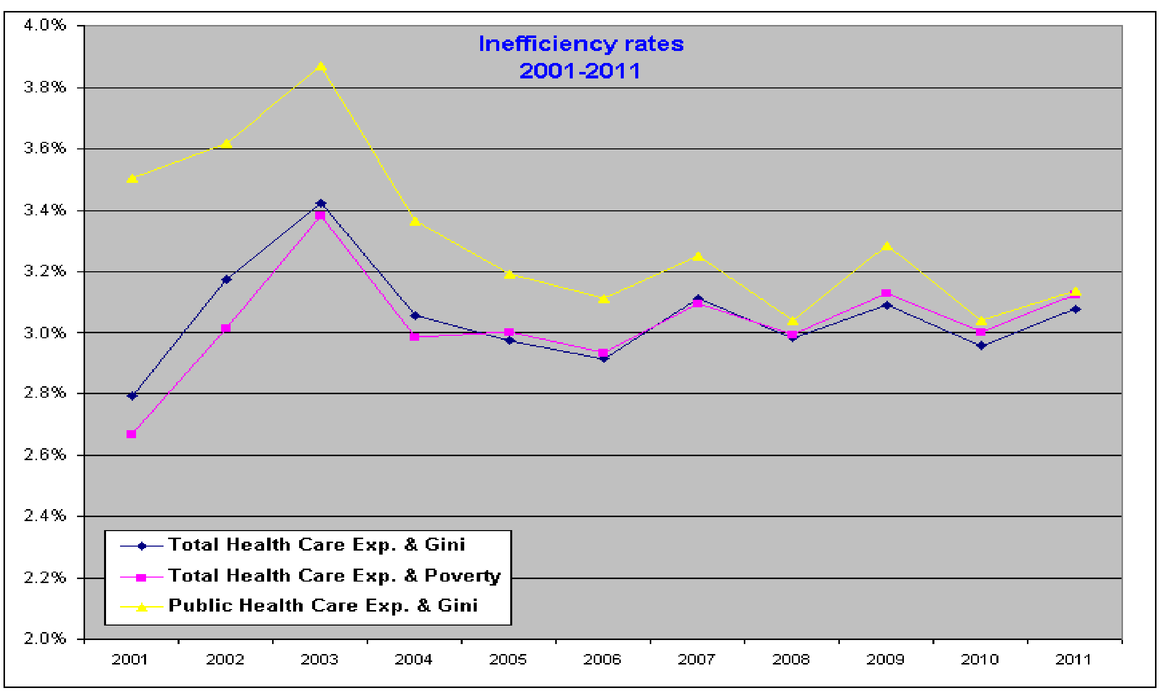
5.1 Inefficiency over time

Table 8 – OECD Health Outcome Inefficiency over Time

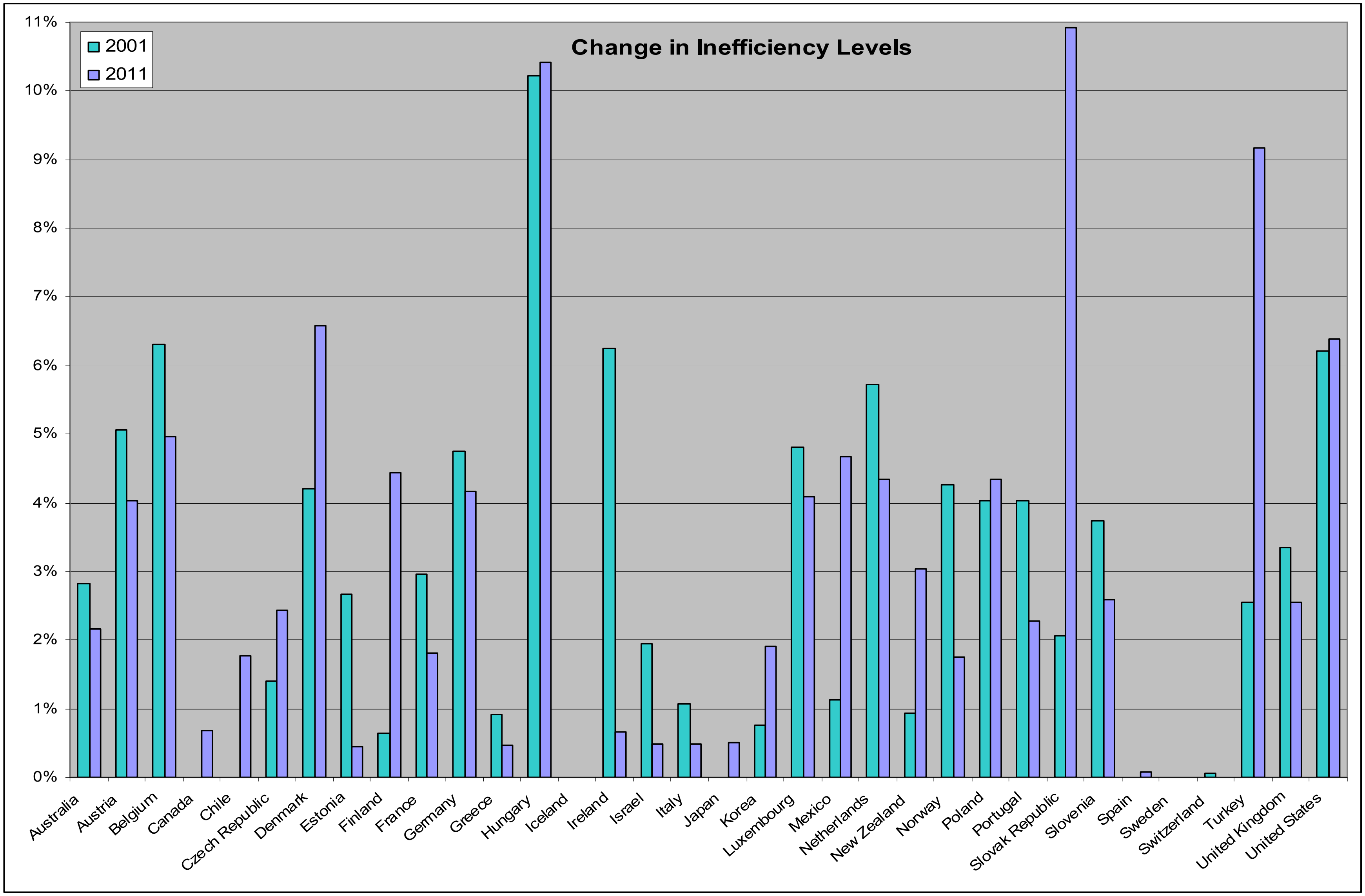
	Inefficiency over the years		
OECD	Total HC Exp. & Gini	Total HC Exp. & Poverty	Public HC Exp. & Gini
2011	3.08%	3.12%	3.14%
2010	2.96%	3.00%	3.04%
2009	3.09%	3.13%	3.28%
2008	2.98%	2.99%	3.04%
2007	3.11%	3.09%	3.25%
2006	2.91%	2.94%	3.11%
2005	2.97%	3.00%	3.19%
2004	3.06%	2.99%	3.36%
2003	3.42%	3.38%	3.87%
2002	3.17%	3.02%	3.62%
2001	2.79%	2.67%	3.50%
Average	3.05%	3.03%	3.31%

The results indicate that the OECD health outcome inefficiency is relatively stable, around 3% over time. Our baseline control with total per capita health expenditure and Gini for inequality indicates a slight increase in inefficiency by 0.28%. This analysis is replicated with the use of poverty rates instead, yielding a similar 0.44% increase in inefficiency and almost identical trend over the years. Using public healthcare expenditures, on the other hand, produced somewhat different results. The average inefficiency is slightly greater at around 3.3%, showing a decrease in inefficiency of 0.35% instead, although the general trend is virtually the same.

Graph 1 – OECD Inefficiency over the Years



Graph 2 – Change in Inefficiency Levels between 2001 and 2011



This result may reflect the increasing share of public expenditures in healthcare [60], as public expenditure is often found to be more efficient than private in the literature [49]. This is likely why the trend is reversed with the inclusion of the relatively less efficient private expenditures.

However, the change in inefficiency levels is not homogenous across the board. Some countries such as Estonia, Ireland, and Portugal have seen remarkable improvements in their healthcare efficiencies while some others such as Finland, Slovak Republic, and Turkey became less efficient, probably because these countries had a hard time adjusting to the drastic changes in the healthcare sector [17, 127].

5.2 Decomposition of Inefficiency

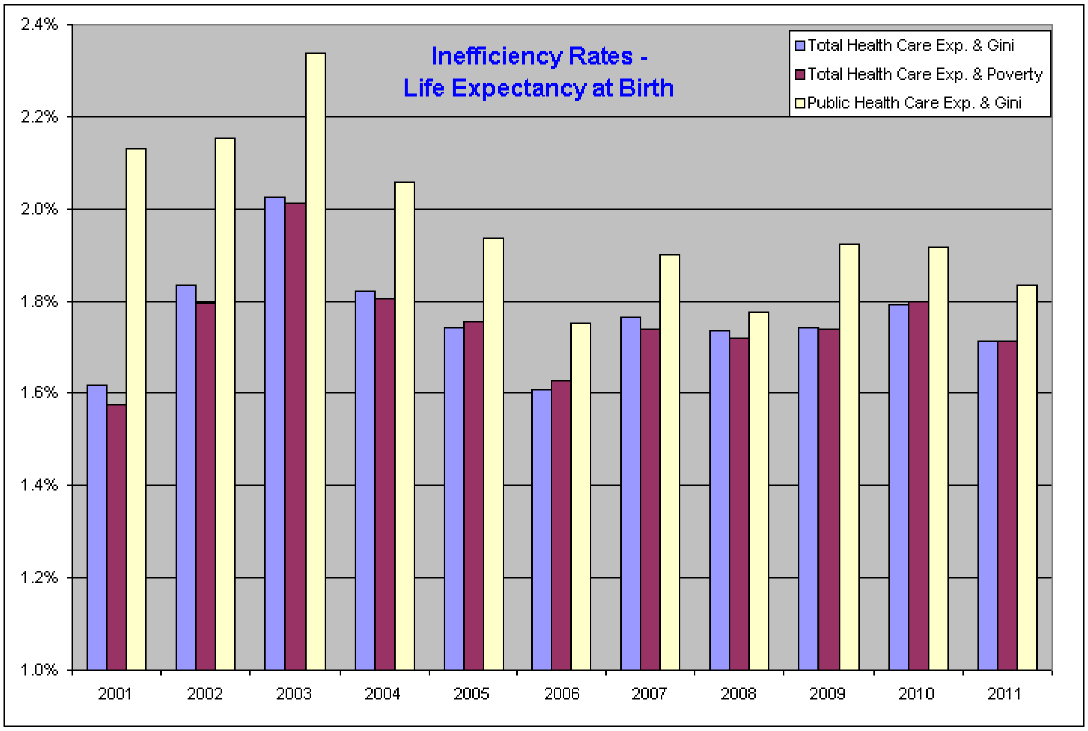
Both life expectancy at birth and at age 65 replicate the overall trend, albeit at different levels. Inefficiency levels for life expectancy at birth hover around 1.8%, regardless of whether the Gini or poverty rate is used as a control. Controlling for public expenditures, however, leads to a noticeable rise in average inefficiency, to around 2%. Life expectancy at age 65 yields around 5% inefficiency across the board, also resulting in a similar rise in inefficiency with the use of public expenditures for control. Overall, controlling for total expenditure shows a fairly stable trend while public expenditures show a slight decrease in inefficiency, with similar fluctuations in both cases.

Table 9 & 10 – OECD Inefficiency Life Expectancy at Birth & Age 65

Table 9	Inefficiency in Life Expectancy at Birth		
OECD	Total HC Exp. & Gini	Total HC Exp. & Poverty	Public HC Exp. & Gini
2011	1.71%	1.71%	1.84%
2010	1.79%	1.80%	1.92%
2009	1.74%	1.74%	1.92%
2008	1.74%	1.72%	1.78%
2007	1.77%	1.74%	1.90%
2006	1.61%	1.63%	1.75%
2005	1.74%	1.75%	1.94%
2004	1.82%	1.80%	2.06%
2003	2.02%	2.01%	2.34%
2002	1.83%	1.80%	2.15%
2001	1.62%	1.57%	2.13%
Average	1.76%	1.75%	1.97%

Table 10	Inefficiency in Life Expectancy at age 65		
OECD	Total HC Exp. & Gini	Total HC Exp. & Poverty	Public HC Exp. & Gini
2011	4.76%	4.72%	4.95%
2010	4.99%	5.00%	5.25%
2009	4.74%	4.70%	4.97%
2008	4.62%	4.59%	4.56%
2007	4.87%	4.83%	5.08%
2006	4.50%	4.56%	4.78%
2005	4.94%	4.97%	5.25%
2004	4.99%	4.90%	5.58%
2003	6.28%	6.15%	6.86%
2002	5.78%	5.61%	6.50%
2001	4.59%	4.37%	5.99%
Average	5.01%	4.95%	5.43%

Graph 3 – OECD Inefficiency Rates for Life Expectancy at Birth



Graph 4 – OECD Inefficiency Rates for Life Expectancy at aget 65

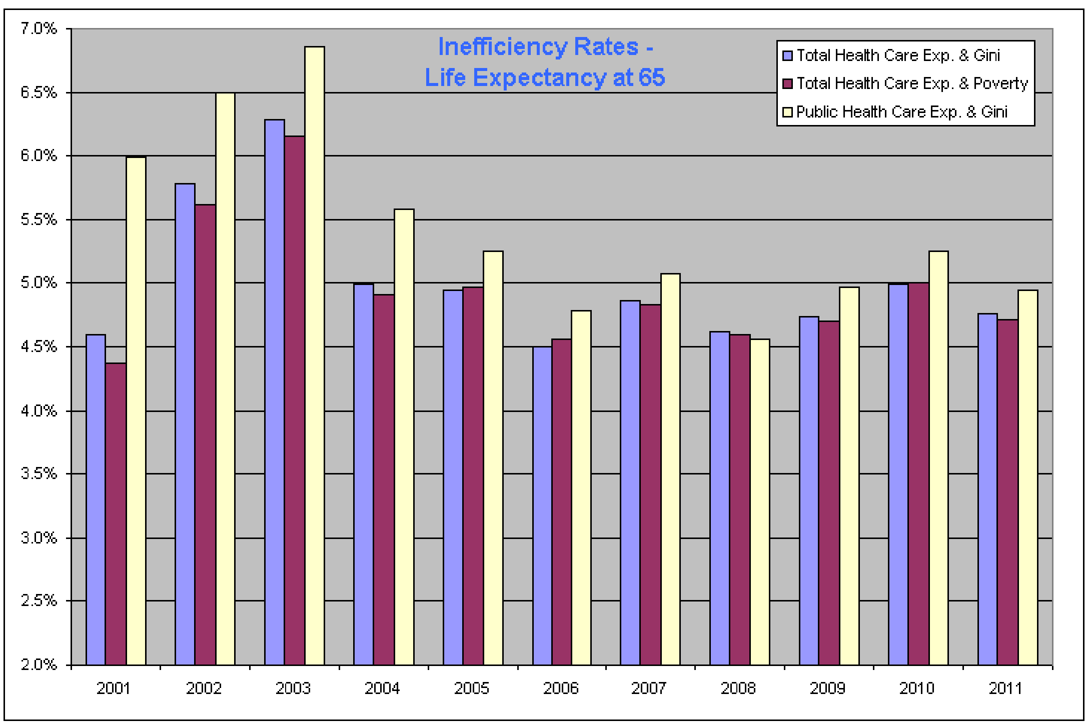
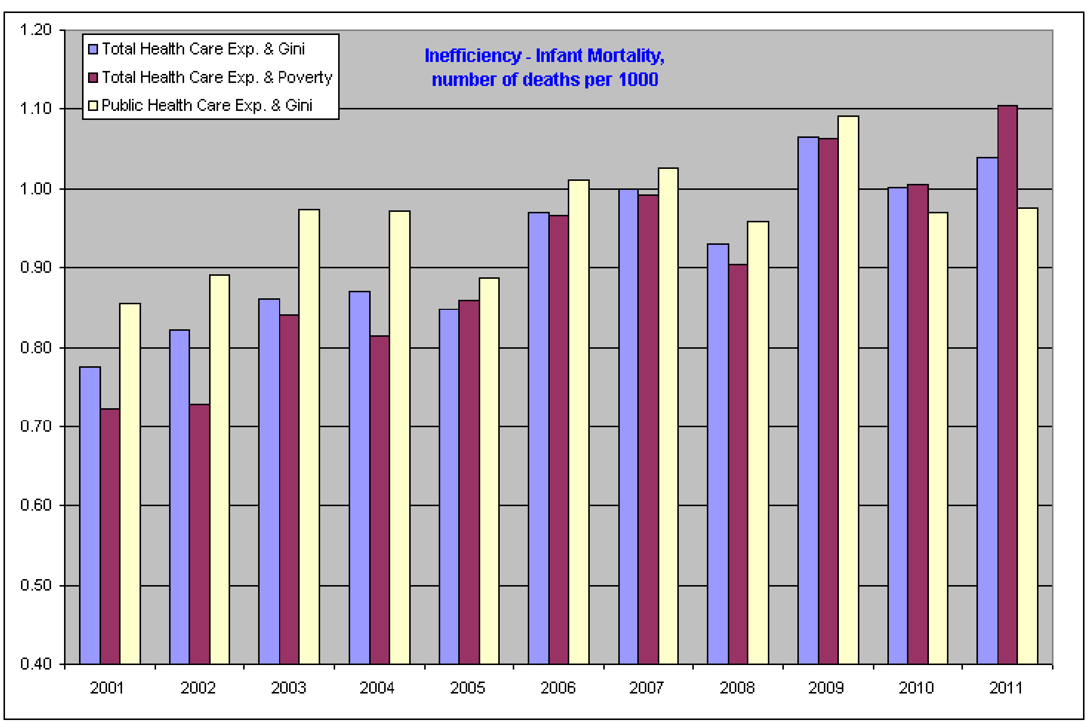


Table 11	Inefficiency in Infant Mortality (number of deaths)		
OECD	Total HC Exp. & Gini	Total HC Exp. & Poverty	Public HC Exp. & Gini
2001	0.78	0.72	0.85
2002	0.82	0.73	0.89
2003	0.86	0.84	0.97
2004	0.87	0.81	0.97
2005	0.85	0.86	0.89
2006	0.97	0.97	1.01
2007	1.00	0.99	1.03
2008	0.93	0.90	0.96
2009	1.06	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

The results show that it is infant mortality that has exhibited a rise in the overall inefficiency, with consistency across different controls. We are using the actual number of deaths here, rather than percentages to avoid distortion on the relative magnitudes.

Infant mortality inefficiency increases from around 0.8 to over 1 death (per 1000) between 2001 and 2011. The results show that although technology has rapidly increased, healthcare systems are still trying to catch up to the new frontiers, resulting in lower efficiency rates, which is expected given the rapid developments in this field. This is a classic example of rising productivity with diminishing efficiency.

Graph 5 – OECD Inefficiency Rates for Infant Mortality



5.3 Production vs. Provision Inefficiency

Table 12	Inefficiency over the years		
OECD	β1 + β2	β1	β2
2011	3.08%	0.69%	2.37%
2010	2.96%	0.76%	2.19%
2009	3.09%	0.76%	2.32%
2008	2.98%	0.62%	2.35%
2007	3.11%	0.63%	2.47%
2006	2.91%	0.52%	2.38%
2005	2.97%	0.47%	2.49%
2004	3.06%	0.56%	2.48%
2003	3.42%	0.63%	2.77%
2002	3.17%	0.72%	2.44%
2001	2.79%	0.69%	2.09%
Average	**3.05%**	**0.65%**	**2.39%**
Share of Inefficiency		**21.31%**	**78.69%**

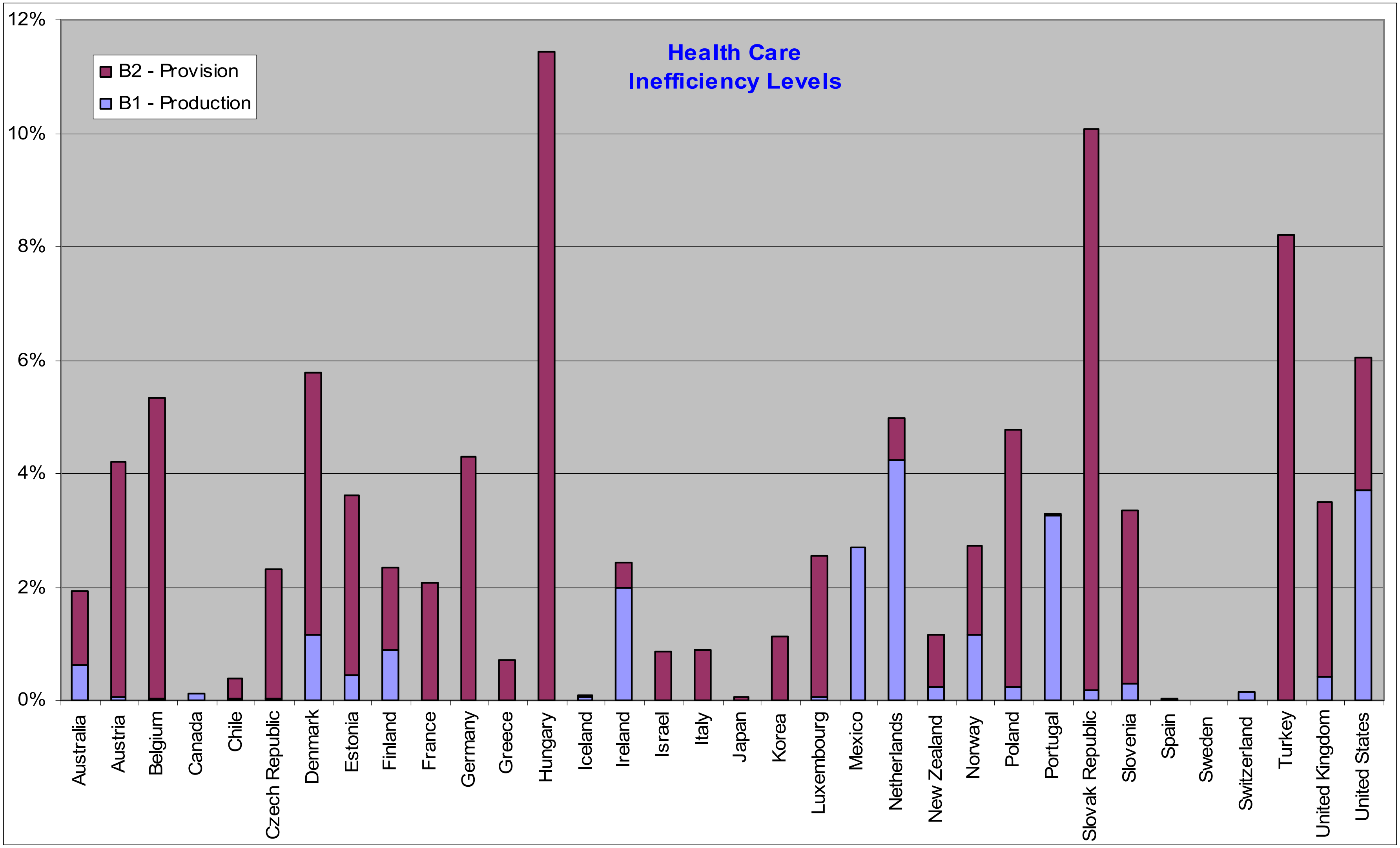
The major advantage of a multi-stage efficiency analysis is to be able to see the contribution of each stage to inefficiency. Our analysis reveals that the lion's share of inefficiency is in provision; about 79% of the efficiency loss occurs at the provision stage, leaving 21% for the production inefficiency. This would not be detected in a traditional single stage analysis, and would lead to a significant underestimation of the inefficiency. Production inefficiency, however, is a major issue for some countries. More than 60% of inefficiency in the U.S., for example, comes from production, in stark contrast to the OECD trend.

A notable result of the study is that the countries that suffer from production inefficiency are mostly Nordic or English speaking countries, where relative price levels tend to be higher [76], in addition to Mexico and Portugal.

Provision efficiency is similar to the term "*effectiveness*" in the literature [55, 97, 134], although it is defined in terms of health services, rather than resources. As mentioned earlier, a multi-stage analysis is required to distinguish whether the inefficiencies are a result of the production or provision of the services. That being said, provision efficiency depends primarily on:

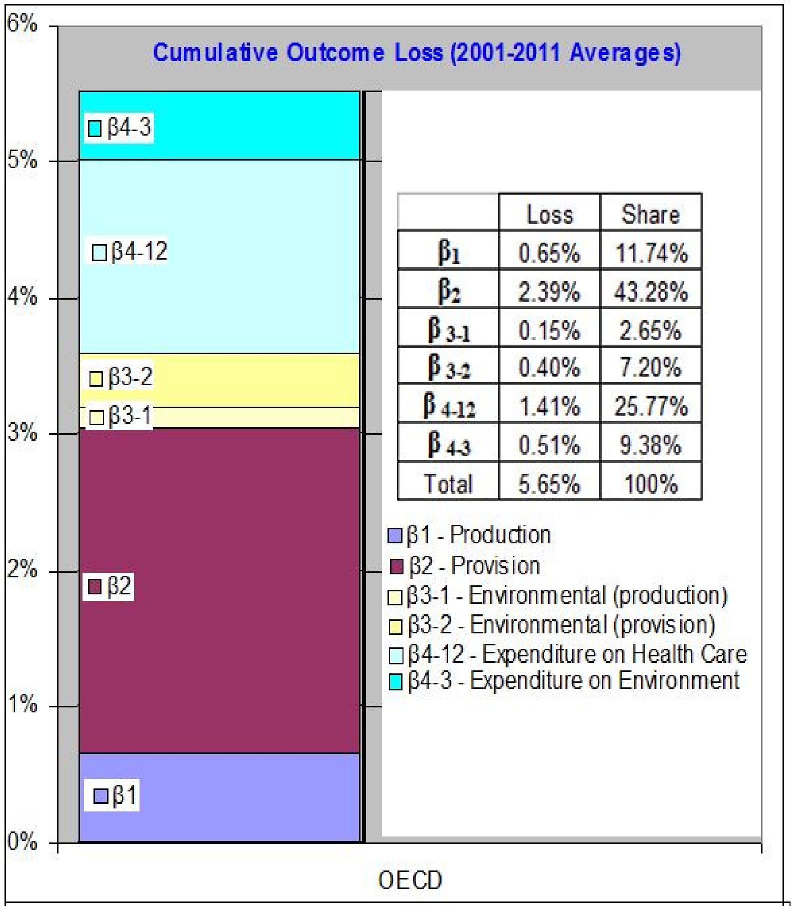
- *Quality of health services*: Although we control the benchmark unit to have equal or better quality, the evaluated country is still allowed to produce lower quality services, which will manifest itself as inefficiency in provision.
- *Social institutions and culture*: The greatest divide between countries is likely to be the social institutions [128] that interactively affect the collective behaviours of individuals. The notoriously low life expectancy for males in Eastern European countries is a major example of this kind of behavioural patterns.
- *Development level:* As Acemoglu argues [2, 3], better institutions lead to higher growth and development, which directly or indirectly affects the duration and quality of life as Preston showed [111].
- Other environmental variables that are not directly covered in this study, such as *education.*

Graph 6 - Health Care Inefficiency Levels (2001-2011 Averages)



5.4 Impact of Environmental Variables on Health Outcomes

Graph 7 – Outcome Losses



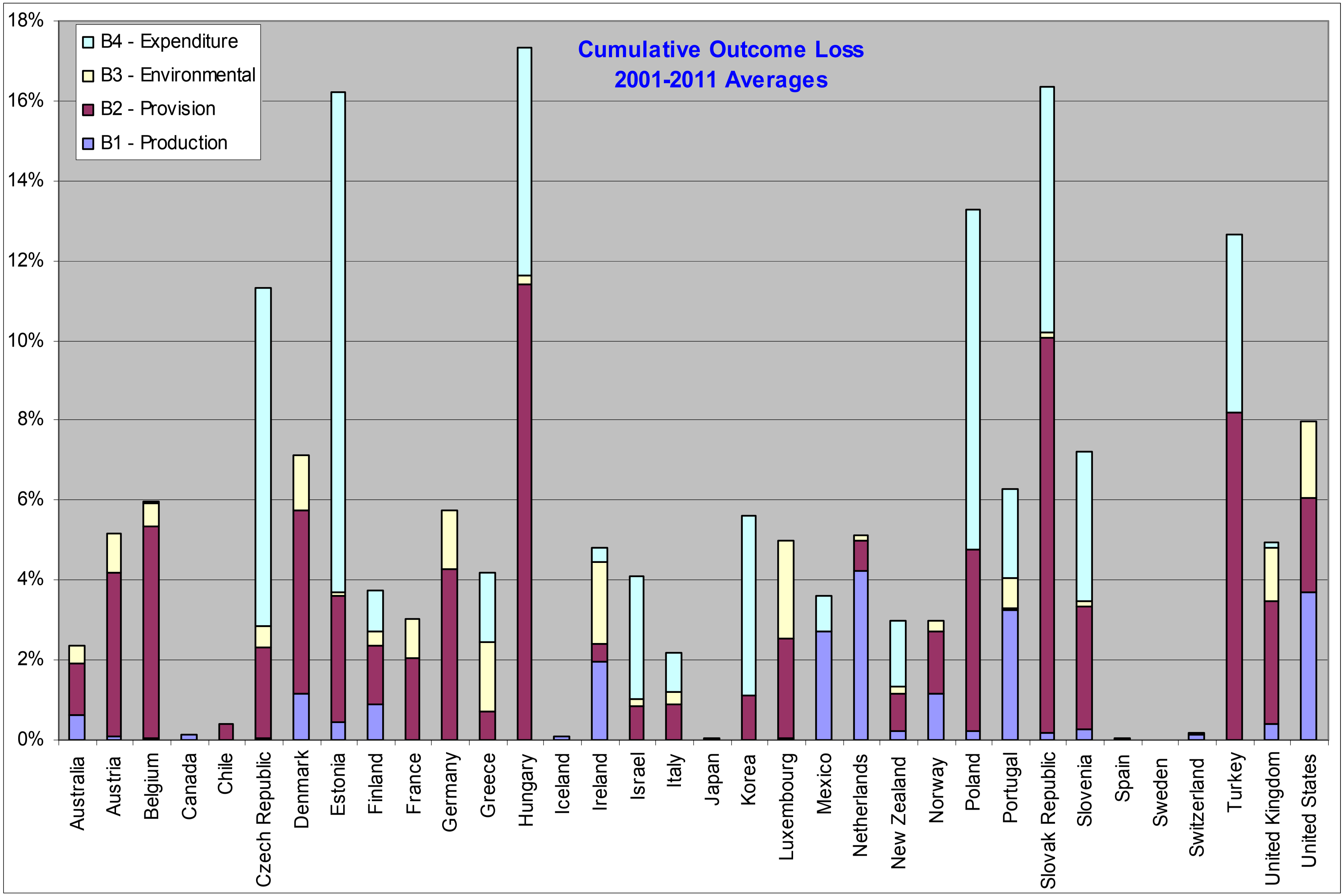
Production inefficiency (**β_1**) is responsible for 21% of the total inefficiency and about 12% of the total loss in health outcomes in OECD countries although it is much more significant for some countries than others.

Provision inefficiency (**β_2**) is responsible for 79% of the total inefficiency and over 43% of the total outcome loss, and is the single most important source of inefficiency, affecting most of the OECD countries.

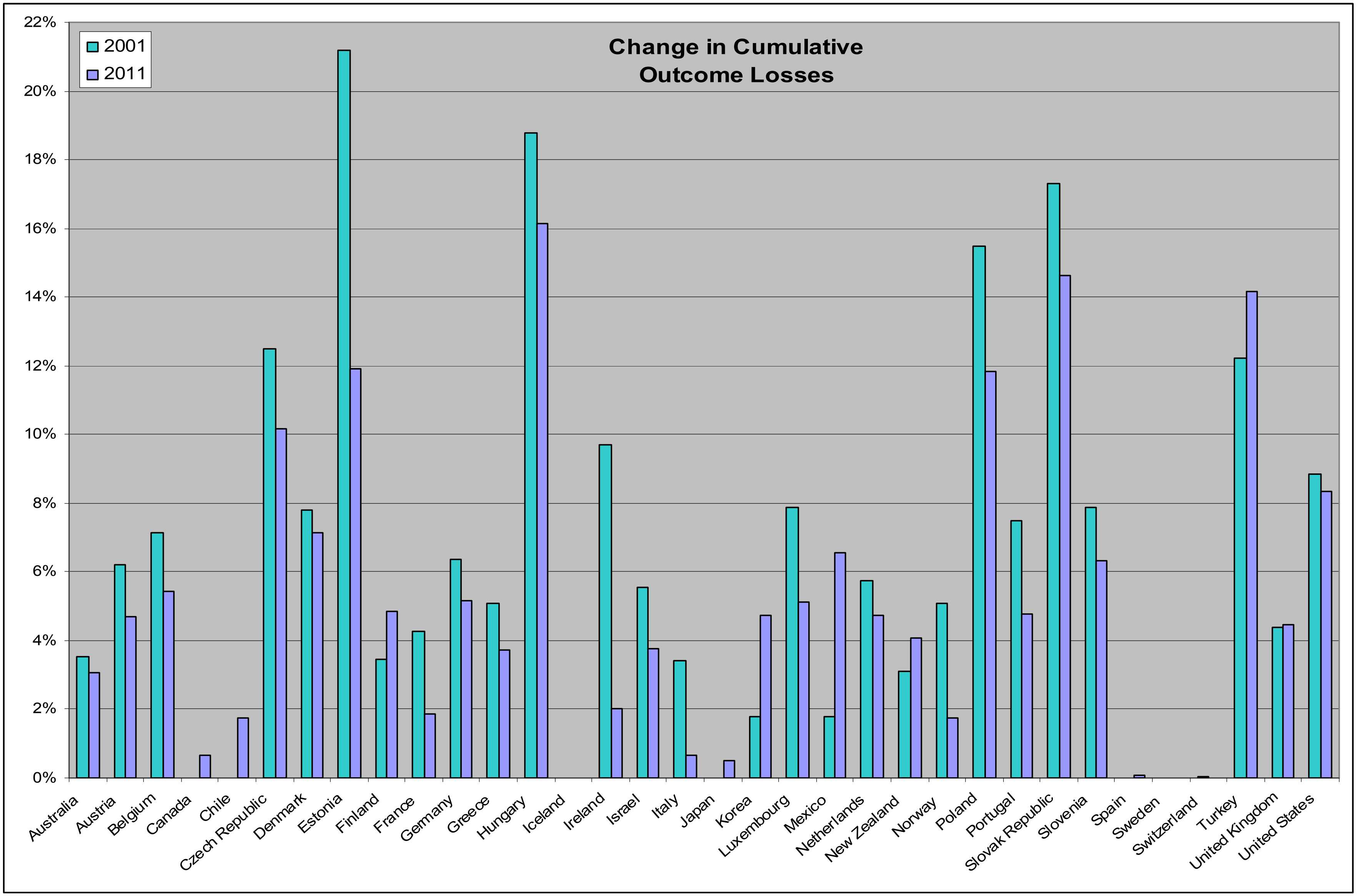
Risk factors and inequality also play a significant role in outcome losses. About 2.65% of outcome loss is due to environmental variables' impact on production (**$\beta_{3\text{-}1}$**), and a further 7.2% is due to provision (**$\beta_{3\text{-}2}$**). Together, these are responsible for about 10% of the total outcome loss (**β_3**).

Insufficient healthcare expenditure is an even more important factor in explaining the further outcome losses. Increasing expenditures on the healthcare system will reduce the outcome losses by 26%, (**$\beta_{4\text{-}12}$**) while allocating more resources to improve the environment will reduce the losses by over 9%, totalling up to a staggering 35% (**β_4**). This is especially true for poorer countries like Estonia, Hungary, Poland, and Turkey, as well as, for Greece, Israel and Korea.

Graph 8 – Total Outcome Losses (2001 – 2011 Averages)



Graph 9 – Change in Cumulative Losses



Although we see a slight increase in the average inefficiency levels (from 2.8% to 3.1%) between 2001 and 2011, the outcome losses are offset by the gains from the improvement of the environmental factors, staying flat at around 3.5%. This is most likely a result of reduction in the smoking rates and better healthcare coverage. Moreover, inclusion of the impact of insufficient healthcare expenditures shows a substantial decrease in outcome losses from 6.3% to 5.1%.

Rising expenditures, especially in the less developed countries, led to huge outcome gains. This is particularly true for some Eastern European countries like Estonia, which not only considerably improved its inefficiency levels 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% point though the increasing healthcare expenditures keep the outcome losses at only 1.9% point. The recent healthcare reform in Turkey [17, 127] clearly needs time to take hold and deliver improvements.

5.5 Impact of the inequality and poverty

We see a small but statistically significant impact of inequality on overall OECD health outcomes. However, a closer look at the individual countries reveals a very different picture (Table 11). 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%).

This impact can also be decomposed into separate outcomes. The impact is replicated in *life expectancy* at birth and especially in *infant mortality*, with similar characteristics, although the US seems to be the only country that is negatively affected in terms of *life expectancy at age 65*. This implies that the systems in those countries create some barriers in access to healthcare, rather than the systems themselves being lower quality. Private systems are inherently more susceptible to inequality, with relatively higher medical prices, and our results here confirm the higher inequality leads to overall worse results.

Table 13 - Countries Ordered by the Impact of Inequality on Health Outcomes

	Inefficiency %			LE0 - years			LE65 - years			IM - deaths	
1	US	2.37%	1	US	0.76	1	US	0.35	1	US	2.10
2	UK	1.18%	2	UK	0.15	2	Australia	0.00	2	UK	1.67
3	Australia	0.68%	3	Australia	0.13	3	Austria	0.00	3	Australia	0.91
4	Portugal	0.39%	4	New	0.07	4	Belgium	0.00	4	New	0.61
5	New	0.36%	5	Greece	0.04	5	Canada	0.00	5	Chile	0.57
6	Italy	0.27%	6	Israel	0.01	6	Chile	0.00	6	Netherla	0.47
7	Netherla	0.20%	7	Austria	0.00	7	Czech	0.00	7	Portugal	0.40
8	Japan	0.19%	8	Belgium	0.00	8	Denmark	0.00	8	Japan	0.16
9	France	0.05%	9	Canada	0.00	9	Estonia	0.00	9	Italy	0.12
10	Finland	0.04%	10	Chile	0.00	10	Finland	0.00	10	France	0.11
11	Chile	0.02%	11	Czech	0.00	11	France	0.00	11	Finland	0.04
12	Israel	0.01%	12	Denmark	0.00	12	Germany	0.00	12	Israel	0.04
13	Czech R.	0.00%	13	Estonia	0.00	13	Greece	0.00	13	Austria	0.00

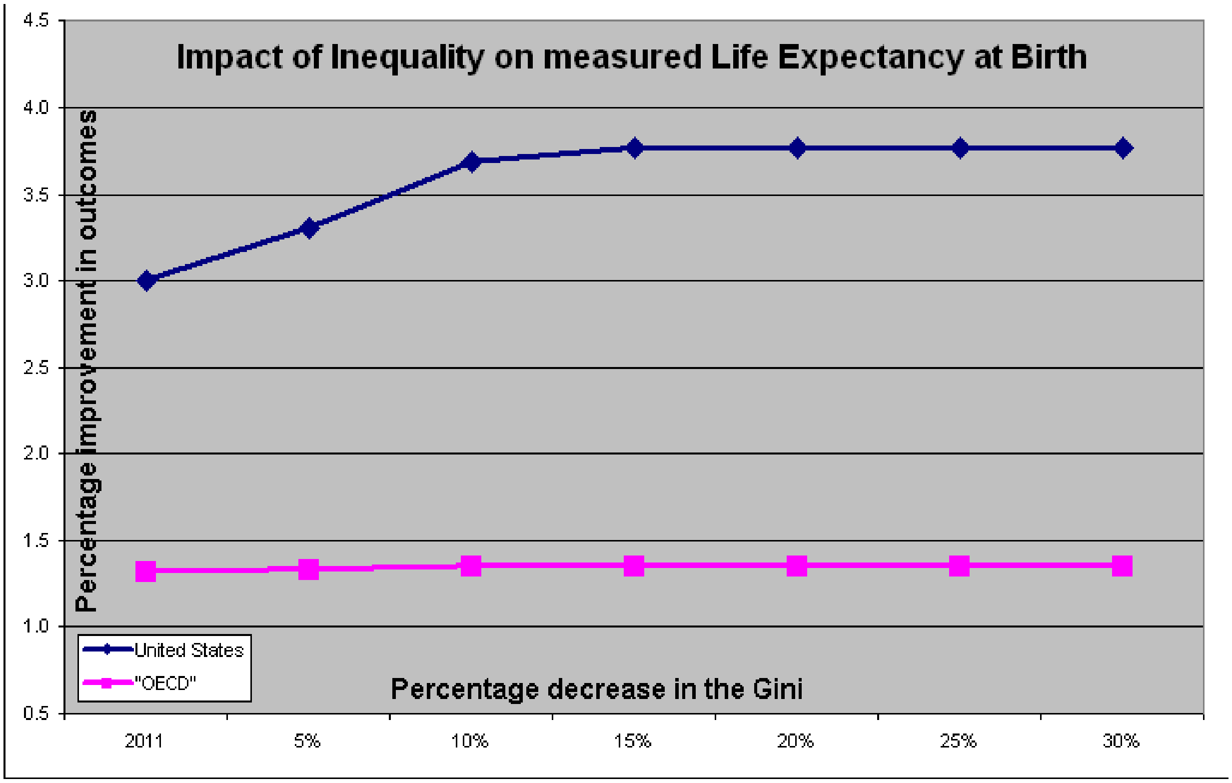
As shown on graph 6, the impact of inequality is far from homogeneous. Considering the US as our prime example, about a 15% reduction in Gini (to 0.32, upper end of the EU spectrum) would be sufficient to prevent most of the losses. Life expectancy at age 65 would tolerate even a higher inequality around 0.34. Infant mortality, however, is the main source of outcome losses and very susceptible to inequality. It would benefit until the Gini drops down to 0.28, near the most egalitarian European nations. Using the poverty rates instead of the Gini after necessary scale adjustments yields very similar results. It should be noted that about a one-third reduction in Gini halves the expected poverty rates[2].

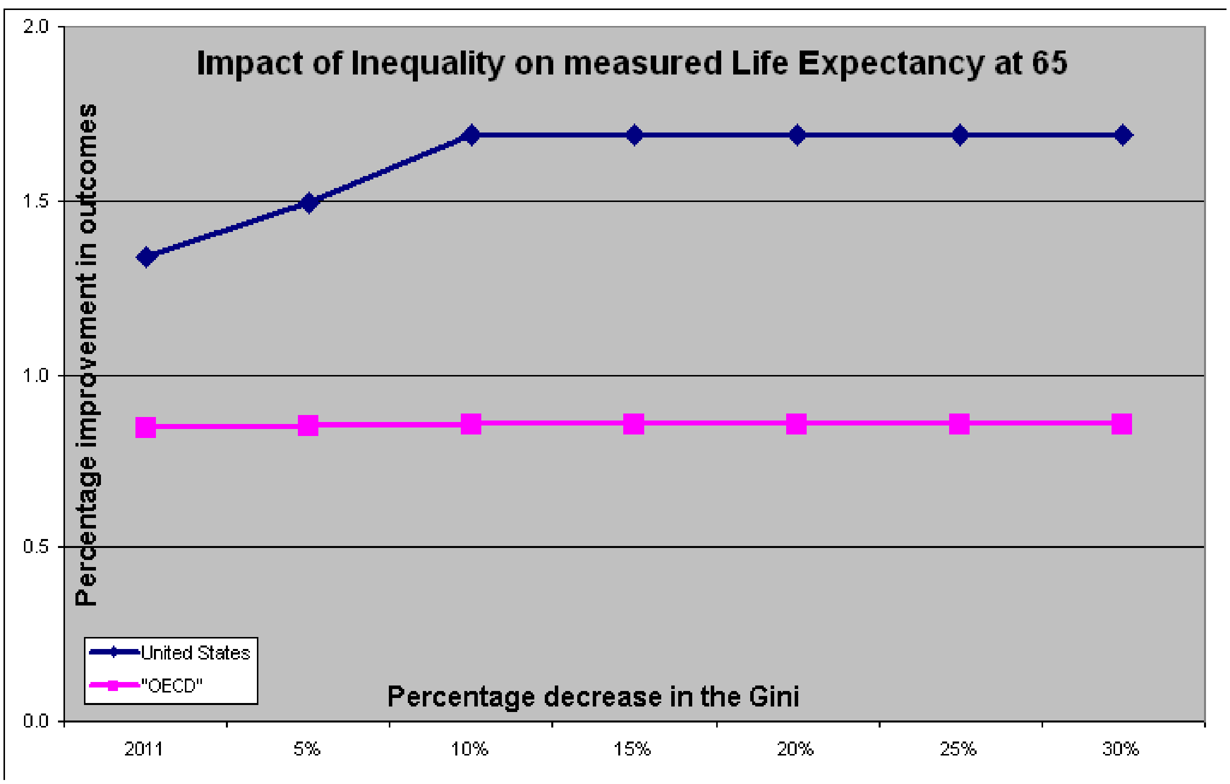
Market structure is the main factor in the US, with phenomenally high prices and the lack of universal coverage. However, a diverse immigrant population, as in other English speaking nations, also seems to play a role in these outcomes. In other countries, on the other hand, universal healthcare and a greater share of public resources seem to cushion the impact of social inequality.

Chile is a curious example, given its track record of the highest Gini in OECD. The country does not seem to be affected by the high degree of inequality, or we simply cannot show an impact within this study. Either way, the impact, if it exists, cannot be substantial, considering the country's results are comparable with those of the US, although they operate with far fewer resources, under much worse environmental conditions.

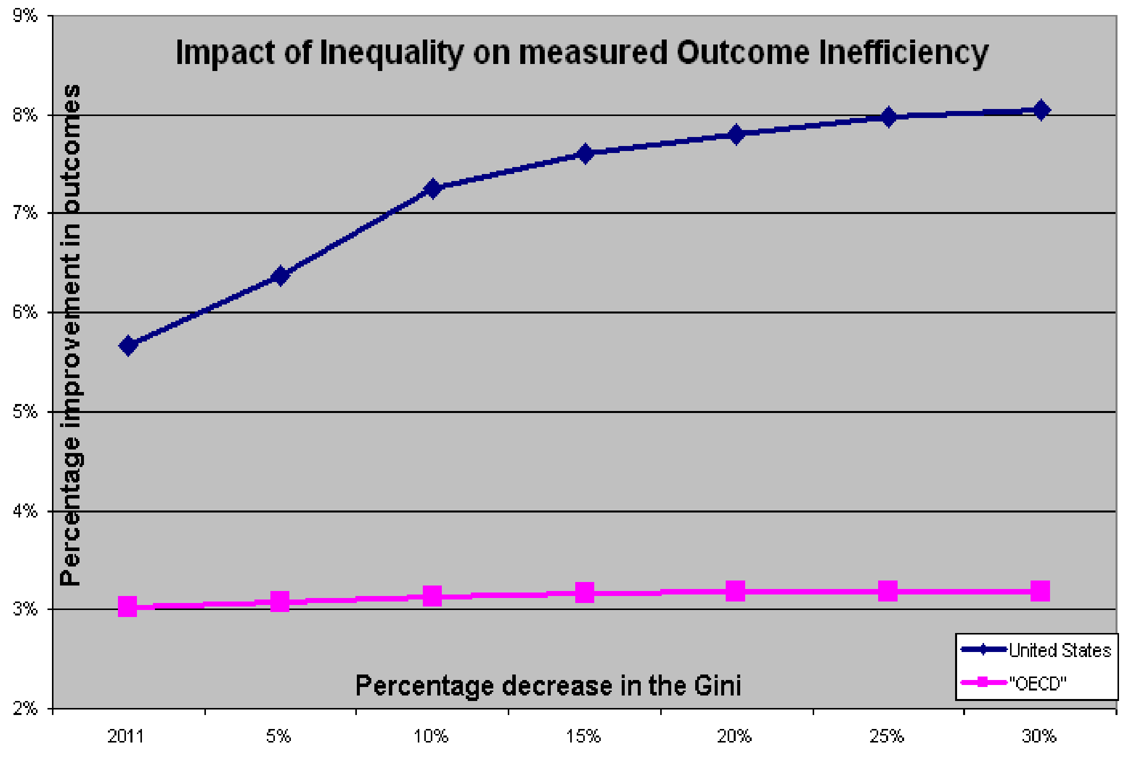
2 OLS: Slope : 0.61, R2 : 0.777, significant at 99.9%

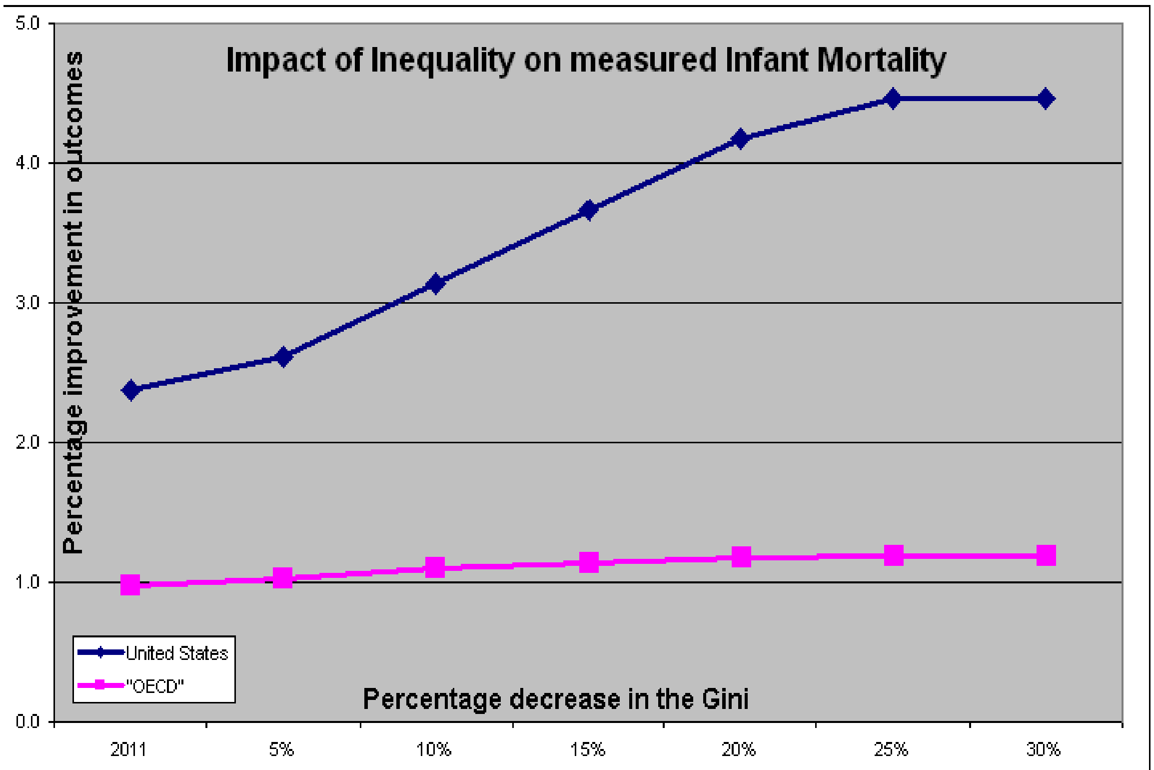
Graph 10 – Impact of Inequality on Life Expectancy at Birth and 65





Graph 11 – Impact of Inequality on Overall Efficiency and Infant Mortality





5.6 A closer look at the healthcare expenditures

The PPP-adjusted average health expenditure in OECD between 2000 and 2011 was $2669 per capita, while the efficient unit spends only $2425 on average, or 90.9% of the actual figure. This is not, however, a measure of cost efficiency, as we do not have the price data for each country-year and implicitly assume equal prices across the board. However, it is still a helpful figure as countries are only contrasted against similar countries, and the figures do not seem to be unreasonable.

The analysis suggests that Australia, for instance, should cut their spending by a mere 3.5% to be considered efficient along with a 1.94% increase in outcomes. However, lower spenders like the Czech Republic and Hungary, as well as Greece and Korea, should maintain their expenditure levels and focus on improving their outcomes. The largest anomaly is the US, which should decrease its expenditure levels from an average of $6812 to merely $2871, which is very unlikely given the price levels. An earlier study [89] suggests that the US is actually spending less than Germany with the normalized medical prices. So it is not that the US is too cost inefficient, it is just that the US market produces too high a level of prices resulting in under-production of services.

Table 14 – Summarized Impact of OECD Inefficiency and Environmental Variables

OECD 2000-2011 Averages	Actual Outcome	Efficient Outcomes				
		b1	b1b2	b1b2b3	b1b2b4	b1b2b3b4
Life Exp. at Birth	78.61	78.92	79.98	80.17	80.67	81.02
Years of Loss		0.32	1.38	1.56	2.06	2.42
Life Exp. at 65	18.29	18.48	19.18	19.29	19.61	19.80
Years of Loss		0.19	0.89	1.01	1.32	1.52
Infant Mortality	5.22	5.01	4.47	4.24	4.13	3.72
Number of Deaths		0.21	0.75	0.98	1.10	1.50
Expenditure	2,669	2,425		2,442	2,814	2,917
Percent of Actual	100.0%	90.9%		91.5%	105.4%	109.3%

Table 15 – Summarized Impact of US Inefficiency and Environmental Variables

US 2000-2011 Averages	Actual Outcome	Efficient Outcomes				
		b1	b1b2	b1b2b3	b1b2b4	b1b2b3b4
Life Exp. at Birth	77.66	79.89	80.79	81.38	80.79	81.38
Years of Loss		2.23	3.13	3.72	3.13	3.72
Life Exp. at 65	18.29	19.72	19.77	19.96	19.77	19.96
Years of Loss		1.43	1.48	1.67	1.48	1.67
Infant Mortality	6.68	6.20	4.59	2.71	4.59	2.71
Number of Deaths		0.47	2.09	3.96	2.09	3.96
Expenditure	6,812	2,781		3,221	2,781	3,221
Percent of Actual	100.0%	40.8%		47.3%	40.8%	47.3%

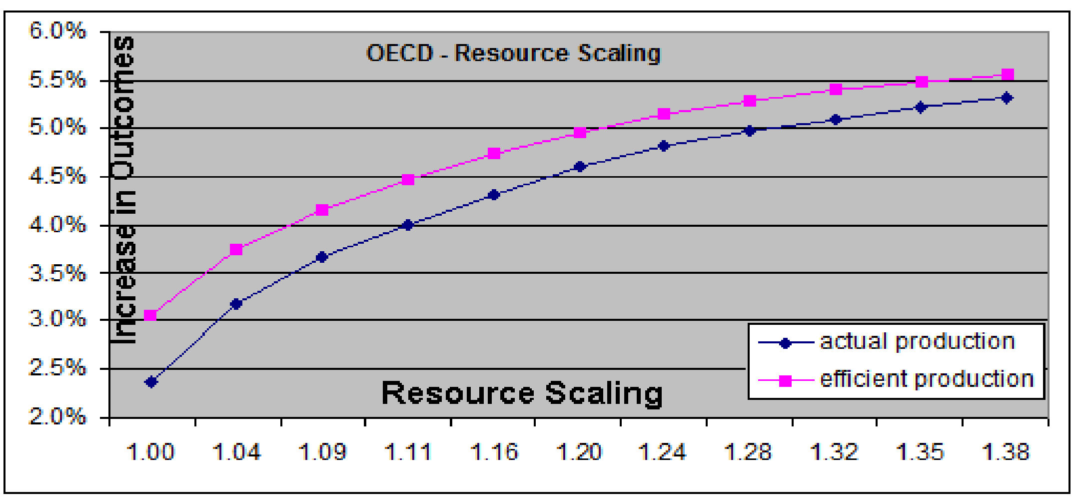
Removing the expenditure constraint overall raises the suggested average expenditure to $2814, or 105.4% of the actual number. Improving the environmental variables requires additional funds, arriving further at $2917, or 109.3% of the actual. This implies potential room for higher expenditures, even if the systems were efficient, especially for the low spenders like Turkey, which is suggested to more than double its expenditures from $722 to $1871. This figure rises to $2161 when the environmental development is also taken into account.

Table 14 summarizes the impact of inefficiency and environmental variables as well as the efficient expenditure levels at price parity across the OECD, while Table 15 is US specific for comparison. For a detailed report for all other countries, please see the appendix.

5.7 Scaling up the Resources and Health Services

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.

Graph 12 –Scaling up the Resources and Services - OECD

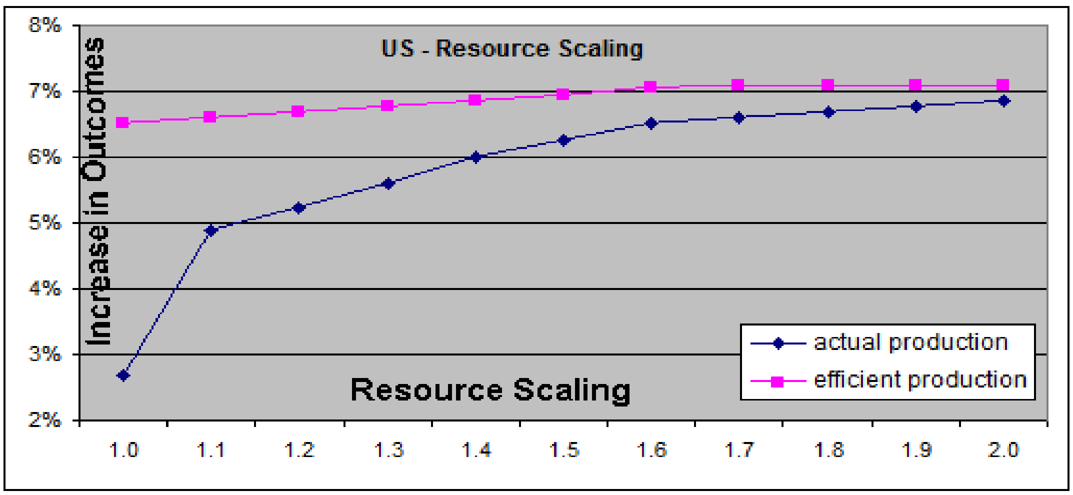


Allowing for 10% increase intervals under Variable Returns to Scale (VRS) in the provision does not necessitate such an increase if such observations are not in the data set. As a result, allowing a cumulative 100% increase only required a 38% radial increase in resources. A closer look at the resource use shows us that *doctor consultations* is the binding constraint here, and OECD countries

would especially benefit from a greater number of consultations, along with an 18% in *patient days,* while *number of discharges* was mostly not a binding factor.

The efficient frontier results in a 2.49 percentage point increase in health outcomes, rising from 3.07% to 5.56% while the actual frontier brings in a 2.95 percentage point improvement, from 2.37% to 5.32%. Additional resource use seems to reduce the gap, as the efficient and actual production frontiers converge due to diminishing returns in provision.

Graph 13 –Scaling up the Resources and Services - US



The 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. There is a substantial difference between the actual and efficient frontiers of the US (see Graph 8). The large inefficiency in US production (close to 44% under-supply in 2011) leads to huge outcome losses. US healthcare production is so highly supply-constrained that even a 10% boost in US resources and health services would eliminate half the outcome inefficiency from production, or 1/3 of total inefficiency, benefiting from every drop of extra services. At further levels, the efficient and the actual frontiers seem to converge due to sharply diminishing returns to scale.

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Table 16 – Maximum Production Scale

1	Australia	1.70	18	Japan	1.04
2	Austria	1.00	19	Korea	1.00
3	Belgium	1.00	20	Luxembourg	1.03
4	Canada	2.00	21	Mexico	2.00
5	Chile	2.00	22	Netherlands	2.00
6	Czech R.	1.17	23	N. Zealand	2.00
7	Denmark	1.37	24	Norway	1.17
8	Estonia	1.00	25	Poland	1.46
9	Finland	1.49	26	Portugal	2.00
10	France	2.00	27	Slovak Republic	1.44
11	Germany	1.00	28	Slovenia	1.00
12	Greece	1.81	29	Spain	2.00
13	Hungary	1.78	30	Sweden	2.00
14	Iceland	1.00	31	Switzerland	2.00
15	Ireland	1.65	32	Turkey	2.00
16	Israel	1.97	33	UK	1.77
17	Italy	2.00	34	US	2.00

Table 16 shows the maximum production scaling of the individual OECD Countries for 2011. Countries with a “1.00” scaling have abundant services produced and would not benefit from additional services under VRS. Most resource-scarce countries with a “2.00” scaling, on the other hand, would significantly benefit from increasing the amount of services at least at one category. Other countries, with a scaling between 1 and 2, would benefit to various degrees, albeit at rapidly diminishing returns to scale.

Inefficiency is also not directly related to scaling of the production. 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.

5.8 Inefficiency Trends

OLS analysis shows that all health outcome inefficiencies are highly correlated and statistically significant in explaining one another. The inefficiencies in life expectancy at birth explain 89% of the variation of the inefficiency at age 65. Likewise, inefficiencies in infant mortality alone explain 22% of the inefficiencies at life expectancy at birth[3]. These relationships between outcome losses only get stronger with the inclusion of environmental variables and healthcare spending, reaching to 94% and 34% respectively[4].

A closer look at the correlations, however, reveals some potentially important insights. The US, for instance, has a better inefficiency rate for life expectancy at age 65, but a much worse infant mortality inefficiency, given the inefficiency levels for life expectancy at birth. The relationship gets stronger for infant mortality with the inclusion of income inequality. This implies that although US healthcare is relatively better than the numbers would suggest, but the lack of a universal healthcare system and insurance coverage largely contributes to the outcome losses in the US.

One interesting trend to note here is between two seemingly similar groups of countries: Eastern Europeans countries, which heavily suffer from short life expectancies but excel in infant mortality, and relatively less educated but otherwise similarly developed countries like Turkey and Mexico, which tend to do a better job with life expectancies but suffer from poor infant mortality. Although Eastern European countries benefit from higher education early in life, the lack of strong social institutions and the accompanying lifestyles seem to have an adverse affect [47, 77, 115]. While half of the gains of Turkey and Mexico in life expectancy at birth come from the improvements in infant mortality, those countries also severely lag in life expectancy at age 65, implying an overall deficit in healthcare quality (see graph 14).

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. English speaking countries, particularly those with diverse immigrant populations, tend to be negatively affected by inequality, but the overall impact is rather small. Additionally, Eastern European countries are distinctly different in terms of outcome inefficiency, most likely as a result of weak social institutions and different cultural values and habits.

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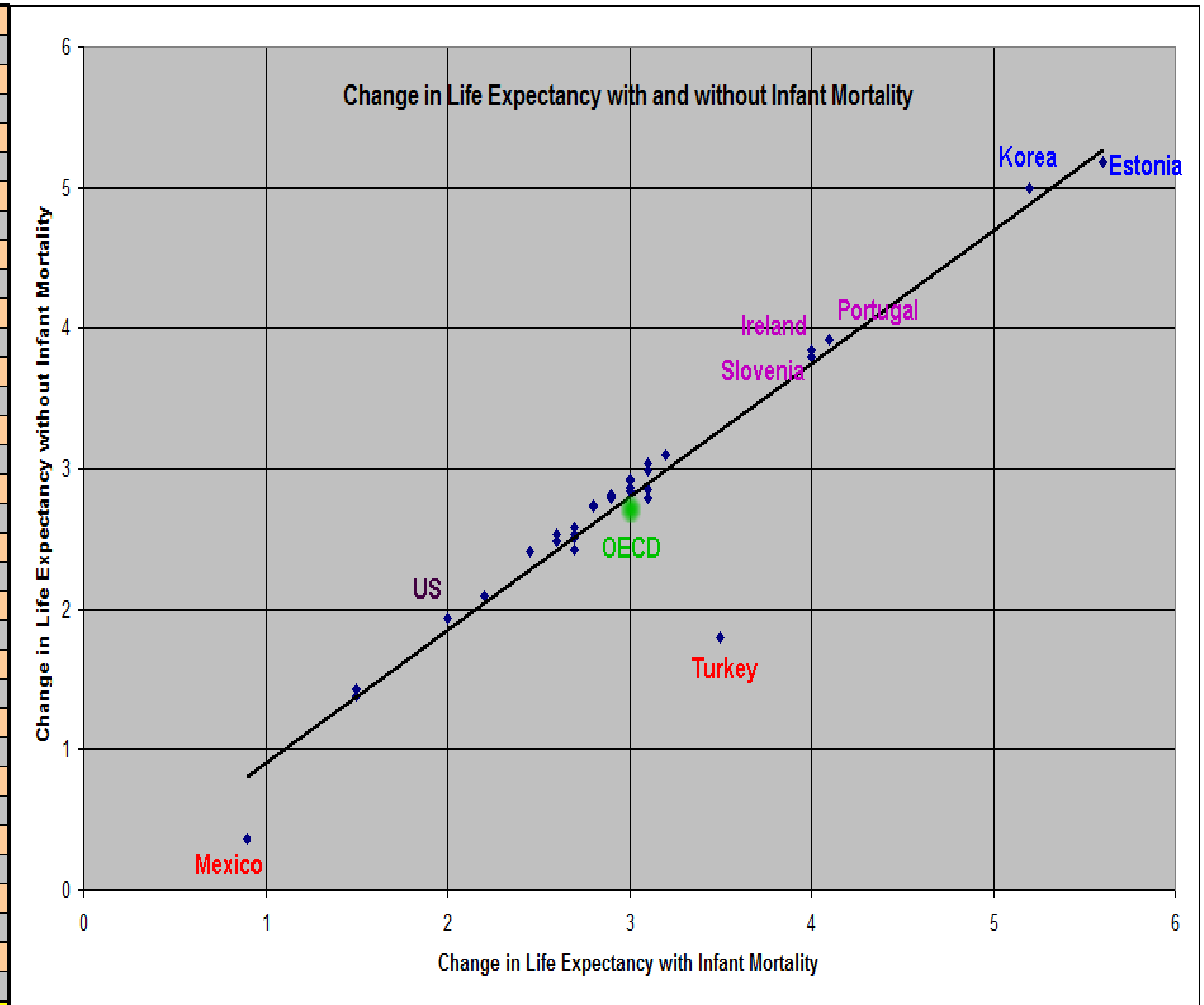
[3] OLS_1: Slope : 0.63, R^2 : 0.886, significant at 99.9%, OLS_2: Slope : 0.23, R^2 : 0.217, significant at 99.9%,

[4] OLS_3: Slope : 0.63, R^2 : 0.943, significant at 99.9%, OLS_4: Slope : 0.25, R^2 : 0.338, significant at 99.9%,

Graph 14 – Life Expectancy at Birth with and without Infant Mortality

	Country	Change in Life Exp. At birth with Infant Mortality	w/o Infant Mortality
1	Estonia	5.60	5.18
2	Korea	5.20	4.99
3	Portugal	4.10	3.92
4	Ireland	4.00	3.79
5	Slovenia	4.00	3.85
6	Turkey	3.50	1.80
7	United Kingdom	3.20	3.10
8	Poland	3.10	2.85
9	Hungary	3.10	2.79
10	Luxembourg	3.10	3.04
11	Netherlands	3.10	2.98
12	Denmark	3.00	2.87
13	France	3.00	2.92
14	Israel	3.00	2.84
15	Spain	3.00	2.91
16	Czech Republic	2.90	2.79
17	Austria	2.90	2.81
18	Finland	2.90	2.79
19	Switzerland	2.90	2.81
20	Italy	2.80	2.73
21	New Zealand	2.80	2.74
22	Greece	2.70	2.50
23	Iceland	2.70	2.53
24	Belgium	2.70	2.58
25	Australia	2.70	2.59
26	Slovak Republic	2.70	2.43
27	Norway	2.60	2.49
28	Germany	2.60	2.54
29	Canada	2.45	2.41
30	Sweden	2.20	2.10
31	United States	2.00	1.94
32	Chile	1.50	1.38
33	Japan	1.50	1.43
34	Mexico	0.90	0.37
	Average	2.95	2.76

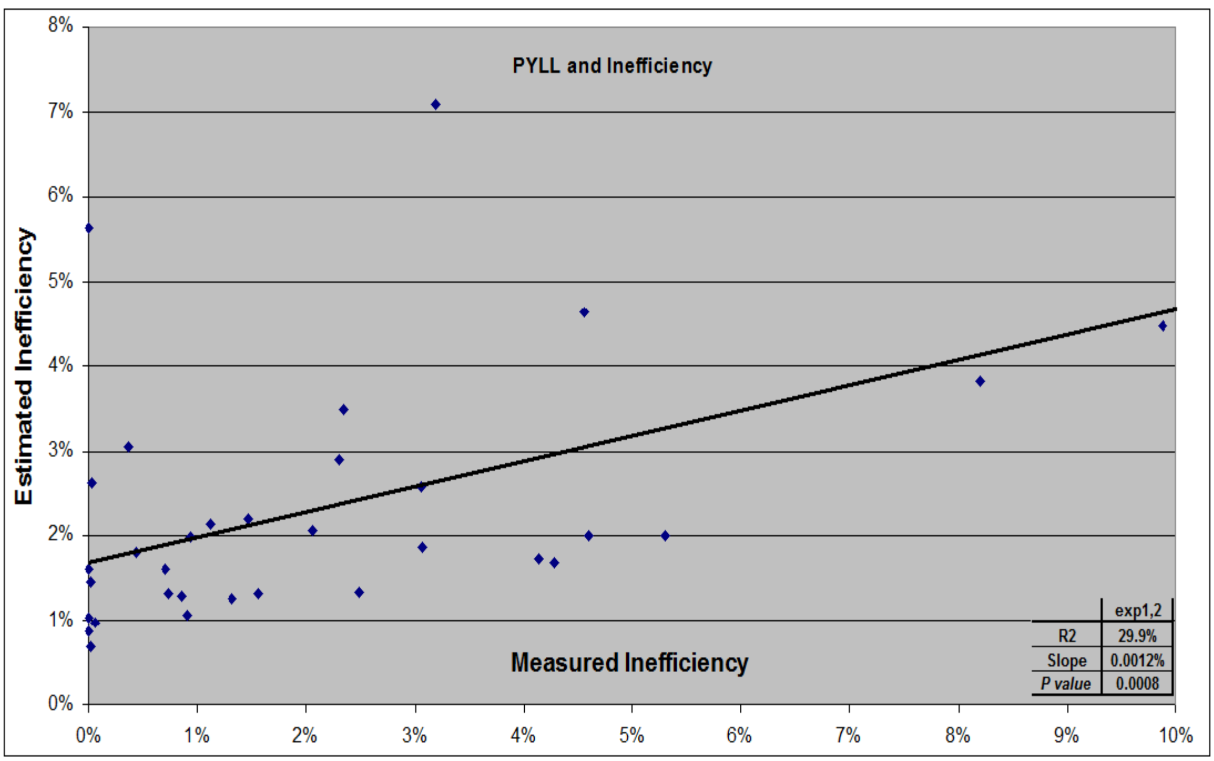


5.9 Quality of Services vs. Outcome Inefficiency

Distinguishing between production and provision inefficiencies inevitably raises the question, "*Does producing more, but lower quality services lead to better health outcomes?*". Along with other studies in the literature [35, 51, 99], our study shows that there are no advantages whatsoever to skimping on quality to produce more services.

Most developing countries have no problem producing the efficient amount of services, but the provision efficiency suffers terribly with resulting results. There is a statistically significant and substantial correlation between lower quality (higher PYLL) and higher provision inefficiency numbers. Likewise, although not statistically significant, lower quality values are also associated with higher production inefficiency.

Graph 15 – Low Quality vs. Provision Inefficiency



An increase in service quality may have a complex role in determining the production inefficiency. Higher quality in services, which may impose a short run trade off between quality and quantity, actually ends up decreasing the demand for services, resulting in better utilization and better provision inefficiency. Patients who get a proper treatment in hospitals are less likely to have another hospital visit and more likely to have better results in provision.

5.10 Limitations of the Study

Main limitations of the study are;

a) *Nonparametric frontier analyses tend to underestimate the inefficiency levels*. Due to its general construction, the firms on the frontier are assumed to be efficient in the analysis. Additionally, the assumption of variable returns to scale in life expectancy may conceal some of the potential gains from increasing resources.

b) The definition of the objective function and the composition of the non-radial inefficiency analysis are inherently subjective (see *section 3.2* Output-oriented two-stage Model). Changing the given weights or adding / dropping one of the health outcomes will affect the measured efficiencies.

c) Country-level aggregate data are far from precise but can still present profound insights, especially when applied at multiple stages and with different controls for robustness check. A single-stage efficiency analysis based on only health services or health outcomes is inherently inferior to a multi-stage analysis that combines both in addition to various controls.

d) Provision inefficiency is composed of multiple factors that need to be further decomposed. Unfortunately the lack of a standard measurement makes this a very difficult task. Concentrating on a small subset of more similar countries may provide better precision and judgment but has limited appeal.

e) Decomposition of inequality and risk factors may be imprecise and future data updates and possible improvements in the analysis should improve precision and accuracy.

f) In this study, impacts of risk factors are considered as relative shifts in the production and provision functions that constitute some form of disadvantage to countries, which need to be considered. However, the "common" characteristics that all countries show will not be captured. If, for example, all countries are composed of at least 10% smokers, only the impact of smoking rates in excess of 10% will be detected.

6 Conclusion

6.1 Concluding Remarks

In this study, we have found around 3% inefficiency in healthcare, with a relatively stable 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 comes from infant mortality, and is highly related to the poorer segments of OECD.

We find that 79% of the inefficiency in OECD countries comes from the provision stage, leaving only 21% to the production stage, although production inefficiency is a major issue for some countries. More than 60% of the US's inefficiency, for example, comes from production. This sort of production inefficiency is apparent in Nordic or English speaking countries with relatively high medical prices, in addition to Mexico and Portugal.

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. The drastic changes in recent healthcare technologies as well as substantial reforms in those countries seem to have played a role in this setback.

Production and provision inefficiencies are jointly responsible for 55% of the total outcome loss. 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%. Even though we see a slight increase in the average inefficiency levels (from 2.8% to 3.1%) between 2001 and 2011, the outcome losses are offset by gains from the improvement of environmental factors, relatively stable at around 3.5%. Moreover, inclusion of the impact of insufficient healthcare expenditures shows a substantial decrease in outcome losses from 6.3% to 5.1%.

Rising expenditures, especially in the less developed countries, led to huge outcome gains. This is particularly true for Ireland and most Eastern European countries. Not all OECD countries share the same kind of success stories though. Mexico suffers both from higher inefficiency and even worse expenditure losses, while Turkey experiences mixed results with an increasing overall inefficiency level but increasing expenditures that curbed the outcome losses.

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. The US, for instance, suffered an additional 2.37% outcome loss, solely from inequality, followed by the UK

(1.18%) and Australia (0.68%). The systems in those countries seem to create some barriers in access to healthcare, and are inherently more susceptible to inequality, with overall worse results.

Our study does not measure cost efficiency due to the lack of medical price data at the country level, but it may still be helpful to compare the calculated expenditure levels at price parity for the efficient outcomes, as each country is only compared with other similar ones. Our analysis suggests a 9% average reduction in healthcare expenditures along with a 3.1% increase in outcomes. One interesting example here is the US, which would enjoy a 60% decrease in healthcare expenditure if the price levels were on par with the OECD average.

Interestingly, there is still room for higher expenditures even with the current technology, especially for the low spenders such as the Eastern European countries, as well as Turkey, Mexico, Greece, and Korea. Our findings suggest a 14% increase in average spending on healthcare systems, and an additional 4% to improve the environmental factors, although the amounts greatly vary by country. Turkey, for instance, is suggested to increase its expenditures on the healthcare system by 159% and another 40% on environmental factors.

We find significant gains from scaling up the production of health services, especially for the countries that employ low quantities of resources or simply underutilize them. A 38% increase in health service production, especially *doctor consultations* would lead to a 2.6% increase in health outcomes, which is substantial considering that the total outcome loss is 5.2% in 2011 and the loss from inefficiency is 3.1%. This brings the potential total outcome gains up to 7.8% in 2011. These gains only partially depend on the production inefficiency of a country, and even the relatively efficient but resource scarce countries like Canada would tremendously benefit from it.

Correlations between different health outcome efficiencies shed more light on the weaknesses of each country. Eastern European countries benefit from higher education early in life, but the lack of strong social institutions and the accompanying lifestyles seem to have an adverse affect on health outcomes. Other similarly developed but less educated countries suffer more from infant mortality, though they fare better in life expectancies. The US, a curious example, particularly suffers from high infant mortality, similar to some less developed countries, but has relatively better results for life expectancy at age 65. This suggests that the actual problem is with the market structure and the healthcare system rather than the quality of care itself.

Finally our study shows that there are no advantages whatsoever to skimping on quality to produce a greater amount of services. Lower quality services lead to higher inefficiencies both in production and

provision in the long run. 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.

6.2 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.

Countries with low capital intensity and low 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 higher education. However, we also find that foregoing quality for quantity of services does not pay off, and such countries should focus on producing higher quality of services first, rather than quantity.

Additionally, relatively less developed countries will 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. Education, used in conjunction

with strong social policies can be an indispensable tool to lower the risk factors and the outcome losses as a result, as well as other losses that appear in provision inefficiency.

Correlations between different outcome inefficiencies, with or without the impact of environmental factors, shed light on where the problems lie in healthcare. The US, for instance, offers a relatively good healthcare for those who have access and can afford it, but not for those who cannot. So it is not a matter of "quality" in the US, but rather the access to and supply of healthcare. 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.

With the exception of the English speaking nations, the bulk of the 10% environmental loss comes from risk factors. As we noted in the *limitations of the study*, this figure is an underestimation by definition, and measures only the impact arising from the differences across countries. 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. Especially countries with high alcohol consumption should work to decrease binge drinking and the associated fatalities. 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, especially countries with high alcohol consumption should work to decrease binge drinking and the associated fatalities.

7 Appendix

Table 17 – Non-Radial Inefficiency Levels between 2001 and 2011

	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	Average
Australia	2.16%	2.04%	2.19%	1.31%	2.30%	1.80%	1.25%	1.72%	1.36%	2.36%	2.83%	1.94%
Austria	4.03%	3.85%	3.91%	3.48%	3.66%	3.80%	4.59%	4.35%	5.17%	4.44%	5.07%	4.21%
Belgium	4.97%	4.35%	4.49%	4.99%	4.64%	5.65%	5.43%	4.88%	6.43%	6.51%	6.30%	5.33%
Canada	0.68%	0.40%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.31%	0.00%	0.13%
Chile	1.76%	0.00%	0.25%	0.33%	1.42%	0.00%	0.00%	0.20%	0.25%	0.00%	0.00%	0.38%
Czech R.	2.44%	1.29%	3.22%	1.31%	1.35%	1.45%	1.73%	2.79%	5.15%	3.43%	1.40%	2.32%
Denmark	6.58%	6.26%	6.58%	6.56%	6.89%	6.37%	5.24%	5.40%	4.54%	5.40%	4.21%	5.82%
Estonia	0.45%	0.80%	1.55%	8.22%	6.39%	1.03%	3.47%	6.71%	7.60%	1.13%	2.67%	3.64%
Finland	4.43%	3.19%	3.76%	3.62%	2.19%	2.57%	1.81%	1.72%	1.35%	0.69%	0.65%	2.36%
France	1.80%	1.90%	1.46%	1.33%	1.34%	1.35%	1.71%	1.64%	3.67%	2.83%	2.96%	2.00%
Germany	4.17%	4.10%	4.11%	3.84%	4.02%	4.00%	4.17%	3.99%	5.10%	4.89%	4.76%	4.29%
Greece	0.46%	0.48%	1.01%	0.41%	0.68%	0.63%	0.73%	0.67%	0.73%	1.01%	0.92%	0.70%
Hungary	10.42%	10.98%	10.34%	10.76%	11.35%	11.90%	12.75%	12.02%	13.37%	11.60%	10.21%	11.43%
Iceland	0.00%	0.00%	0.01%	0.18%	0.27%	0.00%	0.00%	0.52%	0.00%	0.00%	0.00%	0.09%
Ireland	0.65%	0.29%	0.39%	0.83%	1.48%	1.83%	2.30%	3.25%	4.40%	5.00%	6.25%	2.42%
Israel	0.48%	0.50%	0.47%	0.44%	0.57%	0.28%	0.51%	0.85%	1.09%	2.16%	1.95%	0.85%
Italy	0.48%	0.21%	1.44%	0.30%	0.71%	0.82%	1.32%	1.34%	1.32%	0.88%	1.08%	0.90%
Japan	0.50%	0.00%	0.00%	0.00%	0.00%	0.00%	0.17%	0.00%	0.00%	0.00%	0.00%	0.06%
Korea	1.91%	2.33%	0.68%	1.55%	1.53%	1.11%	0.84%	0.50%	0.62%	0.47%	0.77%	1.12%
Luxembourg	4.09%	3.14%	1.67%	0.52%	1.96%	2.02%	1.37%	0.91%	4.08%	3.47%	4.81%	2.55%
Mexico	4.67%	4.85%	4.70%	4.01%	2.24%	1.83%	1.62%	2.10%	1.48%	1.17%	1.13%	2.71%
Netherlands	4.35%	3.95%	4.08%	4.35%	4.85%	5.38%	5.55%	4.82%	5.94%	6.04%	5.72%	5.00%
N. Zealand	3.05%	2.80%	0.86%	0.79%	0.50%	0.82%	0.32%	0.69%	0.78%	1.35%	0.93%	1.17%
Norway	1.76%	2.25%	2.85%	0.48%	3.54%	3.62%	1.28%	2.52%	3.58%	4.05%	4.26%	2.74%
Poland	4.35%	5.09%	6.41%	5.60%	4.88%	3.73%	4.03%	4.51%	4.63%	5.45%	4.03%	4.79%
Portugal	2.28%	2.90%	4.37%	3.48%	3.30%	2.70%	2.88%	2.45%	3.11%	4.56%	4.02%	3.28%
Slovak R.	10.93%	13.34%	13.15%	13.32%	12.38%	10.96%	9.99%	8.99%	8.28%	7.54%	2.06%	10.09%
Slovenia	2.58%	0.84%	1.74%	1.23%	1.22%	3.27%	5.47%	4.50%	6.72%	5.55%	3.73%	3.35%
Spain	0.07%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.21%	0.00%	0.03%
Sweden	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Switzerland	0.00%	0.00%	0.09%	0.00%	0.00%	0.00%	0.00%	0.43%	1.12%	0.07%	0.06%	0.16%
Turkey	9.17%	9.24%	10.23%	8.92%	10.32%	10.40%	10.74%	9.25%	4.55%	4.90%	2.55%	8.21%
UK	2.56%	2.88%	3.06%	3.56%	3.69%	3.89%	3.72%	3.63%	4.07%	4.05%	3.35%	3.50%
USA	6.38%	6.31%	5.97%	5.68%	6.19%	5.88%	6.00%	6.56%	5.85%	6.40%	6.21%	6.13%
Average	3.08%	2.96%	3.09%	2.98%	3.11%	2.91%	2.97%	3.06%	3.42%	3.17%	2.79%	3.05%

Table 18 – Life Expectancy at Birth Inefficiency Levels (in Years of Life Lost)

	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	Average
Australia	0.37	0.56	0.31	0.10	0.05	0.00	0.22	0.22	0.22	0.23	0.56	0.26
Austria	1.30	1.54	1.31	0.70	1.00	1.08	1.53	1.51	1.98	1.83	1.89	1.42
Belgium	1.90	2.18	1.55	1.69	1.44	1.96	2.27	2.15	2.73	2.58	2.66	2.10
Canada	0.25	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.04
Chile	0.77	0.00	0.01	0.34	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.15
Czech R.	1.01	0.68	1.74	0.72	0.75	0.80	0.90	1.46	2.71	1.79	0.70	1.21
Denmark	2.67	2.63	2.64	2.44	2.64	2.51	2.20	2.54	2.30	2.71	2.10	2.49
Estonia	0.30	0.50	1.04	5.29	4.27	0.70	2.40	4.52	4.85	0.82	1.72	2.40
Finland	1.80	2.03	2.06	1.60	1.16	1.46	1.41	1.28	1.01	0.46	0.44	1.34
France	0.12	0.26	0.23	0.15	0.13	0.19	0.65	0.77	1.55	1.12	1.15	0.57
Germany	1.73	2.01	1.94	1.18	1.20	1.40	1.39	1.64	2.05	1.99	1.95	1.68
Greece	0.11	0.20	0.43	0.19	0.33	0.13	0.27	0.19	0.25	0.26	0.28	0.24
Hungary	5.49	5.68	5.70	5.77	6.13	6.36	6.65	6.34	6.69	6.23	5.48	6.05
Iceland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ireland	0.36	0.03	0.15	0.19	0.73	0.31	0.65	1.17	1.79	2.14	2.59	0.92
Israel	0.04	0.02	0.00	0.02	0.05	0.04	0.09	0.06	0.15	0.49	0.48	0.13
Italy	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.36	0.00	0.02	0.04
Japan	0.20	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.03
Korea	0.88	1.17	0.30	0.82	0.79	0.50	0.41	0.25	0.32	0.21	0.28	0.54
Luxembourg	1.33	1.36	0.43	0.15	1.13	1.12	0.88	0.36	1.64	1.70	2.04	1.10
Mexico	2.86	2.91	2.80	2.24	1.20	0.99	0.85	1.04	0.70	0.56	0.53	1.52
Netherlands	1.18	1.45	0.83	0.97	1.07	1.41	1.75	1.70	2.06	2.04	1.97	1.49
N. Zealand	0.79	0.75	0.22	0.19	0.17	0.16	0.06	0.14	0.11	0.19	0.25	0.27
Norway	0.39	0.58	0.44	0.00	0.74	0.74	0.40	0.91	1.40	1.68	1.75	0.82
Poland	2.87	3.25	3.82	3.56	3.15	2.55	2.59	2.78	2.71	3.10	2.38	2.98
Portugal	1.31	1.81	1.86	2.01	1.80	1.73	1.68	1.50	1.85	2.54	2.43	1.87
Slovak R.	5.12	6.06	6.04	6.12	5.89	5.23	4.78	4.52	4.08	3.89	1.16	4.81
Slovenia	1.57	0.55	1.06	0.80	0.80	1.95	2.77	2.64	3.66	3.30	2.02	1.92
Spain	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sweden	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Switzerland	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.00
Turkey	4.28	4.38	4.41	3.59	4.06	3.96	3.63	2.76	0.56	0.81	0.63	3.01
UK	1.04	1.35	1.37	1.49	1.41	1.45	1.39	1.36	1.60	1.65	1.35	1.41
USA	3.31	3.14	2.98	2.79	3.19	3.13	3.14	3.22	2.88	3.11	3.09	3.09
Average	1.33	1.39	1.34	1.33	1.35	1.23	1.33	1.38	1.54	1.40	1.23	1.35

Table 19 – Life Expectancy at 65 Inefficiency Levels (in Years of Life Lost)

	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	Average
Australia	0.10	0.32	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.18	0.06
Austria	0.57	0.88	0.72	0.31	0.45	0.56	0.68	0.78	1.21	1.20	1.08	0.77
Belgium	1.06	1.34	0.82	0.82	0.52	0.84	1.22	1.36	1.59	1.65	1.54	1.16
Canada	0.09	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.02
Chile	0.89	0.00	0.00	0.00	0.58	0.00	0.00	0.15	0.08	0.00	0.00	0.15
Czech R.	1.36	1.07	1.78	0.96	1.30	1.37	1.61	1.21	2.14	1.45	0.63	1.35
Denmark	2.25	1.65	1.70	1.46	1.69	1.62	1.37	1.35	1.48	1.86	1.41	1.62
Estonia	0.14	0.26	0.44	2.58	1.76	0.26	0.84	1.69	2.10	0.21	0.54	0.98
Finland	0.82	1.18	1.26	0.25	0.09	0.27	0.13	0.24	0.38	0.25	0.23	0.46
France	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.04	0.00	0.03
Germany	1.28	1.61	1.55	0.75	0.72	0.95	0.87	0.98	1.40	1.33	1.27	1.15
Greece	0.04	0.08	0.12	0.10	0.19	0.13	0.16	0.19	0.35	0.32	0.22	0.17
Hungary	3.23	3.30	3.18	3.21	3.31	3.43	3.72	3.46	3.81	3.40	2.97	3.36
Iceland	0.00	0.00	0.01	0.20	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Ireland	0.33	0.01	0.07	0.30	0.63	0.41	0.80	1.19	1.66	1.93	2.11	0.86
Israel	0.00	0.01	0.00	0.01	0.23	0.02	0.05	0.03	0.33	0.43	0.63	0.16
Italy	0.00	0.00	0.25	0.00	0.00	0.00	0.10	0.00	0.55	0.21	0.12	0.11
Japan	0.06	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.01
Korea	0.99	1.05	0.58	0.79	0.81	0.66	0.46	0.25	0.31	0.25	0.31	0.59
Luxembourg	1.11	0.88	0.02	0.10	0.90	0.51	0.57	0.14	1.38	0.98	1.16	0.70
Mexico	0.75	0.72	0.67	0.50	0.30	0.21	0.21	0.25	0.18	0.08	0.00	0.35
Netherlands	1.08	1.38	0.78	0.81	0.91	1.28	1.40	1.28	1.63	1.83	1.67	1.28
N. Zealand	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Norway	0.29	0.47	0.10	0.03	0.43	0.29	0.10	0.50	0.68	1.30	1.25	0.50
Poland	1.46	1.80	2.16	1.95	1.62	1.08	1.30	1.56	1.71	2.08	1.45	1.65
Portugal	0.39	1.15	1.08	1.27	1.12	1.05	1.25	1.01	1.29	1.55	1.38	1.14
Slovak R.	3.64	4.25	4.09	4.09	4.08	3.90	3.60	3.44	3.09	2.97	0.74	3.44
Slovenia	1.04	0.32	0.71	0.46	0.45	1.19	1.83	1.66	2.52	2.19	1.66	1.28
Spain	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00
Sweden	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Switzerland	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00
Turkey	3.60	3.60	3.55	3.37	3.43	3.23	3.03	2.77	2.15	1.98	1.08	2.89
UK	0.55	0.78	0.81	1.04	0.87	0.91	1.13	1.03	1.33	1.30	1.04	0.98
USA	1.50	1.50	1.24	1.18	1.39	1.50	1.34	1.54	1.41	1.59	1.49	1.42
Average	0.84	0.87	0.82	0.78	0.82	0.75	0.82	0.83	1.03	0.96	0.77	0.84

Table 20 – Infant Mortality (in Number of preventable deaths)

	2011	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	Average
Australia	1.33	1.31	1.48	1.02	1.56	1.34	0.90	1.17	1.01	1.70	1.75	1.33
Austria	2.00	2.21	2.01	2.04	1.63	1.48	1.80	1.73	1.71	0.98	1.65	1.75
Belgium	1.97	2.18	2.03	2.23	2.17	2.35	1.42	1.53	1.70	1.79	1.59	1.91
Canada	0.42	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.08
Chile	0.38	0.00	0.36	0.00	0.68	0.00	0.00	0.07	0.21	0.00	0.00	0.15
Czech R.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Denmark	2.28	2.00	1.60	2.29	2.23	1.63	1.32	1.13	0.56	0.56	0.52	1.46
Estonia	0.00	0.00	0.00	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.06
Finland	1.23	0.90	1.20	1.12	0.54	0.58	0.17	0.16	0.00	0.00	0.00	0.54
France	1.02	1.11	0.91	0.82	0.82	0.81	0.79	0.60	1.53	1.27	1.32	1.00
Germany	1.68	1.87	1.42	1.43	1.69	1.35	1.38	1.33	1.37	1.27	1.10	1.44
Greece	0.24	0.25	0.32	0.08	0.24	0.25	0.21	0.20	0.18	0.35	0.35	0.24
Hungary	1.23	1.55	1.12	1.45	1.34	1.48	1.61	1.56	2.23	1.31	1.33	1.47
Iceland	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.24	0.00	0.00	0.00	0.03
Ireland	0.00	0.22	0.13	0.34	0.47	0.75	0.91	0.76	0.94	0.84	1.34	0.61
Israel	0.30	0.29	0.28	0.26	0.35	0.16	0.35	0.61	0.50	1.11	0.72	0.45
Italy	0.30	0.15	1.03	0.20	0.48	0.54	0.79	0.82	0.29	0.51	0.65	0.52
Japan	0.16	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01
Korea	0.15	0.21	0.05	0.02	0.00	0.01	0.18	0.00	0.06	0.06	0.14	0.08
Luxembourg	2.22	1.77	0.76	0.10	0.10	0.39	0.05	0.28	0.89	0.73	1.55	0.80
Mexico	3.19	3.77	3.93	3.81	2.28	1.77	1.76	2.33	1.92	1.56	1.80	2.56
Netherlands	2.08	2.08	2.36	2.15	2.31	2.26	2.14	1.42	1.82	1.83	1.82	2.02
N. Zealand	2.98	2.52	0.73	0.63	0.32	0.63	0.23	0.53	0.65	1.15	0.60	1.00
Norway	0.63	1.23	1.55	0.25	1.52	1.68	0.43	0.88	0.99	0.69	0.84	0.97
Poland	1.80	0.42	0.41	0.14	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.25
Portugal	0.51	0.02	1.19	0.40	0.32	0.00	0.00	0.00	0.00	0.41	0.20	0.28
Slovak R.	1.60	2.53	2.47	2.50	2.02	1.26	1.12	0.44	0.63	0.12	0.00	1.33
Slovenia	0.25	0.00	0.00	0.00	0.00	0.17	0.63	0.13	0.27	0.16	0.00	0.15
Spain	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.01
Sweden	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Switzerland	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.55	0.75	0.04	0.04	0.13
Turkey	1.16	0.62	2.80	2.78	5.25	7.49	11.55	12.54	6.38	8.23	2.61	5.58
UK	1.07	1.11	1.84	1.79	2.06	1.50	1.36	1.11	1.05	0.96	0.87	1.34
USA	2.62	2.71	2.94	2.98	2.24	1.67	1.94	2.14	1.86	1.95	1.81	2.26
Average	1.02	0.98	1.03	0.92	0.96	0.93	0.97	1.01	0.87	0.88	0.73	0.94

Table 21 – Low Quality in Services vs. Outcome Inefficiency

2001-2011 Averages	PYLL	Inefficiency	
		Actual	Estimated
Australia	3,109	1.31%	1.25%
Austria	3,507	4.14%	1.72%
Belgium	3,743	5.31%	1.99%
Canada	3,415	0.00%	1.61%
Chile	4,635	0.36%	3.04%
Czech Rep	4,509	2.30%	2.89%
Denmark	3,750	4.60%	2.00%
Estonia	8,079	3.19%	7.09%
Finland	3,914	1.47%	2.19%
France	3,807	2.06%	2.07%
Germany	3,477	4.28%	1.68%
Greece	3,412	0.70%	1.60%
Hungary	7,117	11.43%	5.96%
Iceland	2,636	0.02%	0.69%
Ireland	3,573	0.43%	1.79%
Israel	3,141	0.85%	1.29%
Italy	2,944	0.90%	1.06%
Japan	2,865	0.05%	0.96%
Korea	3,870	1.12%	2.14%
Luxembourg	3,180	2.49%	1.33%
Mexico	6,839	0.00%	5.63%
Netherlands	3,164	0.74%	1.31%
N. Zealand	3,734	0.93%	1.98%
Norway	3,160	1.56%	1.31%
Poland	5,997	4.56%	4.64%
Portugal	4,269	0.02%	2.61%
Slovak Rep.	5,855	9.88%	4.47%
Slovenia	4,235	3.06%	2.57%
Spain	3,275	0.02%	1.44%
Sweden	2,782	0.00%	0.86%
Switzerland	2,917	0.01%	1.02%
Turkey	5,301	8.21%	3.82%
UK	3,633	3.07%	1.86%
US	5,011	2.34%	3.48%

R2	**29.9%**
Slope	**0.0012%**
P value	**0.0008**

Table 22 – Production Scaling by Country

		Consultations	Discharges	Patient Days
1	Australia	1.45	0.93	1.70
2	Austria	1.00	1.00	1.00
3	Belgium	1.00	1.00	1.00
4	Canada	1.25	1.46	2.00
5	Chile	1.51	1.39	2.00
6	Czech Rep.	1.17	0.72	0.71
7	Denmark	1.37	1.01	1.04
8	Estonia	0.96	0.87	0.76
9	Finland	1.49	0.84	0.81
10	France	1.82	0.68	2.00
11	Germany	1.00	1.00	1.00
12	Greece	1.81	0.52	0.54
13	Hungary	1.78	0.65	0.97
14	Iceland	1.00	1.00	1.00
15	Ireland	1.65	1.00	1.14
16	Israel	1.97	0.57	1.72
17	Italy	1.51	0.97	2.00
18	Japan	0.93	1.04	0.92
19	Korea	0.82	0.96	0.78
20	Luxembourg	1.03	0.98	0.99
21	Mexico	1.47	1.44	2.00
22	Netherlands	1.43	0.96	2.00
23	New Zealand	2.00	0.82	1.32
24	Norway	1.17	1.05	1.05
25	Poland	1.46	0.65	0.95
26	Portugal	2.00	1.10	2.00
27	Slovak Rep.	1.44	0.59	1.00
28	Slovenia	1.00	0.74	0.63
29	Spain	1.33	1.20	2.00
30	Sweden	2.00	0.90	0.88
31	Switzerland	2.00	0.82	1.05
32	Turkey	0.96	0.82	2.00
33	UK	1.77	0.81	1.16
34	US	2.00	1.26	1.96

Table 23 – Inefficiency and Other Outcome losses by Source – 2001 – 2011 Averages

	Values						Shares					
	B1	B2	B3-1	B3-2	B4-b1b2	B4-b3	B1	B2	B3-1	B3-2	B4-b1b2	B4-b3
Australia	0.62%	1.31%	0.25%	0.19%	0.00%	0.01%	25.95%	55.30%	10.61%	7.82%	0.07%	0.26%
Austria	0.07%	4.14%	0.00%	0.99%	0.00%	0.00%	1.35%	79.95%	0.00%	18.69%	0.00%	0.00%
Belgium	0.02%	5.31%	0.28%	0.32%	0.03%	0.00%	0.38%	89.22%	4.79%	5.36%	0.43%	0.00%
Canada	0.13%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Chile	0.02%	0.36%	0.00%	0.00%	0.00%	0.00%	5.65%	94.35%	0.00%	0.00%	0.00%	0.00%
Czech Rep.	0.03%	2.30%	0.02%	0.49%	6.17%	2.16%	0.23%	20.32%	0.20%	4.33%	55.49%	19.43%
Denmark	1.17%	4.60%	0.14%	1.21%	0.00%	0.00%	16.45%	64.62%	1.97%	16.97%	0.00%	0.00%
Estonia	0.43%	3.19%	0.01%	0.06%	10.47%	1.84%	2.66%	19.72%	0.07%	0.35%	65.64%	11.56%
Finland	0.88%	1.47%	0.00%	0.43%	0.52%	0.48%	23.59%	39.40%	0.00%	9.95%	14.02%	13.04%
France	0.00%	2.06%	0.29%	0.68%	0.00%	0.00%	0.00%	67.92%	9.74%	22.34%	0.00%	0.00%
Germany	0.01%	4.28%	0.18%	1.26%	0.00%	0.00%	0.09%	74.75%	3.15%	22.00%	0.00%	0.00%
Greece	0.00%	0.70%	0.00%	1.75%	0.43%	1.27%	0.00%	16.86%	0.00%	42.09%	10.39%	30.66%
Hungary	0.00%	11.43%	0.01%	0.18%	3.14%	2.52%	0.00%	65.86%	0.03%	1.02%	18.38%	14.71%
Iceland	0.07%	0.02%	0.00%	0.01%	0.00%	0.00%	73.53%	16.77%	0.00%	9.70%	0.00%	0.00%
Ireland	1.98%	0.43%	0.44%	1.60%	0.02%	0.33%	41.12%	9.02%	9.25%	33.30%	0.49%	6.81%
Israel	0.00%	0.85%	0.00%	0.19%	0.66%	2.37%	0.00%	20.73%	0.00%	4.60%	16.33%	58.35%
Italy	0.00%	0.90%	0.00%	0.29%	0.35%	0.64%	0.00%	41.06%	0.00%	13.42%	16.03%	29.49%
Japan	0.01%	0.05%	0.00%	0.00%	0.00%	0.00%	21.06%	78.94%	0.00%	0.00%	0.00%	0.00%
Korea	0.00%	1.12%	0.00%	0.00%	4.31%	0.19%	0.00%	19.93%	0.00%	0.00%	76.76%	3.30%
Luxembourg	0.06%	2.49%	0.00%	2.45%	0.00%	0.00%	1.15%	49.91%	0.00%	48.93%	0.00%	0.00%
Mexico	2.71%	0.00%	0.00%	0.00%	0.81%	0.11%	74.72%	0.00%	0.00%	0.00%	22.23%	3.05%
Netherlands	4.24%	0.74%	0.13%	0.00%	0.00%	0.00%	83.03%	14.41%	2.54%	0.03%	0.00%	0.00%
New Zealand	0.24%	0.93%	0.02%	0.13%	1.34%	0.30%	7.97%	31.33%	0.82%	4.53%	45.27%	10.09%
Norway	1.16%	1.56%	0.05%	0.19%	0.00%	0.00%	39.22%	52.66%	1.56%	6.57%	0.00%	0.00%
Poland	0.23%	4.56%	0.00%	0.02%	7.29%	1.14%	1.70%	34.26%	0.00%	0.02%	55.39%	8.63%
Portugal	3.26%	0.02%	0.77%	0.00%	0.24%	1.97%	52.00%	0.33%	12.31%	0.00%	3.89%	31.47%
Slovak Rep.	0.18%	9.88%	0.04%	0.10%	4.95%	1.12%	1.12%	60.53%	0.26%	0.61%	30.57%	6.91%
Slovenia	0.29%	3.06%	0.01%	0.13%	2.93%	0.80%	3.94%	42.24%	0.13%	1.75%	40.80%	11.13%
Spain	0.01%	0.02%	0.00%	0.00%	0.00%	0.00%	24.70%	75.30%	0.00%	0.00%	0.00%	0.00%
Sweden	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	30.06%	9.66%	29.21%	31.07%	0.00%	0.00%
Switzerland	0.15%	0.01%	0.00%	0.00%	0.00%	0.00%	96.59%	3.41%	0.00%	0.00%	0.00%	0.00%
Turkey	0.00%	8.21%	0.00%	0.00%	4.20%	0.22%	0.00%	64.93%	0.00%	0.00%	33.32%	1.75%
UK	0.42%	3.07%	0.40%	0.94%	0.12%	0.00%	8.44%	62.09%	8.18%	19.14%	2.49%	0.00%
USA	3.70%	2.34%	1.95%	0.00%	0.00%	0.00%	46.31%	29.32%	24.37%	0.00%	0.00%	0.00%
OECD	0.65%	2.39%	0.15%	0.40%	1.41%	0.51%	11.74%	43.28%	2.65%	7.20%	25.77%	9.38%

Table 24 – Inefficiency and Other Outcome losses by Source – 2001

	Values						Shares					
	B1	B2	B3-1	B3-2	B4-b1b2	B4-b3	B1	B2	B3-1	B3-2	B4-b1b2	B4-b3
Australia	0.00%	2.83%	0.00%	0.70%	0.00%	0.00%	0.00%	80.24%	0.00%	19.76%	0.00%	0.00%
Austria	0.10%	4.96%	0.00%	1.16%	0.00%	0.00%	1.65%	80.79%	0.00%	17.56%	0.00%	0.00%
Belgium	0.20%	6.09%	0.67%	0.05%	0.17%	0.00%	2.82%	86.28%	9.50%	0.72%	2.43%	0.00%
Canada	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	53.43%	46.57%	0.00%	0.00%	0.00%
Chile	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	34.30%	65.70%	0.00%	0.00%
Czech Rep.	0.00%	1.40%	0.00%	0.00%	8.58%	2.15%	0.02%	11.38%	0.00%	0.00%	70.86%	17.74%
Denmark	0.33%	3.87%	0.00%	3.47%	0.00%	0.00%	4.29%	50.66%	0.00%	45.05%	0.00%	0.00%
Estonia	0.00%	2.67%	0.00%	0.00%	15.96%	1.80%	0.00%	12.90%	0.00%	0.00%	78.29%	8.82%
Finland	0.00%	0.65%	0.00%	0.00%	1.14%	1.64%	0.00%	18.87%	0.00%	0.00%	33.20%	47.93%
France	0.00%	2.96%	0.00%	1.25%	0.00%	0.00%	0.00%	70.25%	0.00%	29.75%	0.00%	0.00%
Germany	0.00%	4.76%	0.18%	1.37%	0.00%	0.00%	0.00%	75.44%	2.83%	21.73%	0.00%	0.00%
Greece	0.00%	0.92%	0.00%	1.32%	0.80%	1.93%	0.00%	18.52%	0.00%	26.50%	16.16%	38.83%
Hungary	0.00%	10.21%	0.00%	0.03%	5.16%	2.45%	0.00%	56.78%	0.00%	0.19%	29.18%	13.85%
Iceland	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Ireland	5.20%	1.00%	0.00%	3.42%	0.13%	1.58%	55.15%	10.59%	0.00%	16.14%	1.38%	16.74%
Israel	0.00%	1.95%	0.00%	1.04%	0.11%	2.34%	0.00%	35.84%	0.00%	19.13%	1.99%	43.05%
Italy	0.00%	1.08%	0.00%	0.88%	0.03%	1.38%	0.00%	32.05%	0.00%	26.10%	0.75%	41.10%
Japan	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Korea	0.00%	0.77%	0.00%	0.00%	1.00%	0.00%	0.00%	43.51%	0.00%	0.00%	56.49%	0.00%
Luxembourg	0.16%	4.64%	0.00%	3.07%	0.00%	0.00%	2.05%	60.08%	0.00%	37.87%	0.00%	0.00%
Mexico	1.13%	0.00%	0.00%	0.00%	0.64%	0.00%	63.97%	0.00%	0.00%	0.00%	36.03%	0.00%
Netherlands	5.72%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
New Zealand	0.00%	0.93%	0.00%	0.41%	1.44%	0.28%	0.00%	30.30%	0.00%	13.27%	47.21%	9.22%
Norway	2.02%	2.20%	0.29%	0.48%	0.00%	0.00%	40.52%	43.96%	5.80%	9.71%	0.00%	0.00%
Poland	0.00%	4.03%	0.00%	0.00%	9.04%	1.80%	0.00%	26.82%	0.00%	0.00%	61.00%	12.18%
Portugal	4.02%	0.00%	1.05%	0.00%	0.27%	1.99%	54.81%	0.00%	14.31%	0.00%	3.70%	27.18%
Slovak Rep.	0.00%	2.06%	0.00%	0.29%	13.31%	1.15%	0.00%	12.14%	0.00%	1.71%	79.28%	6.87%
Slovenia	0.00%	3.73%	0.00%	0.00%	3.76%	0.24%	0.00%	48.19%	0.00%	0.00%	48.76%	3.05%
Spain	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%
Sweden	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Switzerland	0.06%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Turkey	0.00%	2.55%	0.00%	0.00%	9.42%	0.00%	0.00%	21.33%	0.00%	0.00%	78.67%	0.00%
UK	0.15%	3.19%	0.18%	0.81%	0.48%	0.00%	3.46%	73.19%	4.03%	18.59%	10.38%	0.00%
USA	4.53%	1.60%	2.47%	0.00%	0.00%	0.00%	52.69%	18.65%	28.66%	0.00%	0.00%	0.00%
OECD	0.70%	2.09%	0.66%	2.72%	0.14%	0.58%	11.27%	33.89%	2.10%	8.60%	34.43%	9.99%

Table 25 – Inefficiency and Other Outcome losses by Source – 2011

	Values						Shares					
	B1	B2	B3-1	B3-2	B4-b1b2	B4-b3	B1	B2	B3-1	B3-2	B4-b1b2	B4-b3
Australia	0.63%	1.52%	0.16%	0.73%	0.00%	0.00%	20.81%	50.05%	5.18%	23.96%	0.00%	0.00%
Austria	0.00%	4.03%	0.00%	0.65%	0.00%	0.00%	0.00%	86.17%	0.00%	13.83%	0.00%	0.00%
Belgium	0.00%	4.97%	0.00%	0.44%	0.00%	0.00%	0.00%	91.94%	0.00%	8.06%	0.00%	0.00%
Canada	0.68%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Chile	0.20%	1.56%	0.00%	0.00%	0.00%	0.00%	11.60%	88.40%	0.00%	0.00%	0.00%	0.00%
Czech Rep.	0.00%	2.44%	0.00%	1.61%	4.77%	1.01%	0.00%	24.71%	0.00%	16.26%	48.72%	10.30%
Denmark	1.98%	4.51%	0.41%	0.10%	0.00%	0.00%	28.29%	64.40%	5.81%	1.50%	0.00%	0.00%
Estonia	0.02%	0.44%	0.00%	0.00%	9.04%	2.18%	0.16%	3.67%	0.00%	0.00%	77.51%	18.66%
Finland	2.15%	2.23%	0.04%	0.36%	0.00%	0.00%	44.92%	46.75%	0.83%	7.50%	0.00%	0.00%
France	0.00%	1.88%	0.04%	0.02%	0.00%	0.00%	0.00%	97.21%	1.85%	0.94%	0.00%	0.00%
Germany	0.00%	4.17%	0.00%	0.97%	0.00%	0.00%	0.00%	81.18%	0.00%	18.82%	0.00%	0.00%
Greece	0.00%	0.46%	0.00%	0.01%	0.45%	2.79%	0.00%	12.43%	0.00%	0.14%	12.12%	75.31%
Hungary	0.00%	10.42%	0.02%	0.07%	3.74%	1.29%	0.00%	66.84%	0.11%	0.47%	24.21%	8.37%
Iceland	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%
Ireland	0.17%	0.49%	0.02%	1.35%	0.00%	0.00%	8.25%	24.09%	0.95%	66.70%	0.00%	0.00%
Israel	0.00%	0.48%	0.00%	0.00%	0.76%	2.47%	0.00%	12.92%	0.00%	0.00%	20.56%	66.52%
Italy	0.00%	0.48%	0.00%	0.18%	0.00%	0.00%	0.00%	72.69%	0.00%	27.31%	0.00%	0.00%
Japan	0.14%	0.36%	0.00%	0.00%	0.00%	0.00%	28.03%	71.97%	0.00%	0.00%	0.00%	0.00%
Korea	0.00%	1.91%	0.00%	0.00%	2.54%	0.22%	0.00%	40.94%	0.00%	0.00%	54.40%	4.66%
Luxembourg	0.12%	3.97%	0.00%	1.07%	0.00%	0.00%	2.41%	78.29%	0.00%	19.30%	0.00%	0.00%
Mexico	4.67%	0.00%	0.00%	0.00%	1.24%	0.54%	72.34%	0.00%	0.00%	0.00%	19.20%	8.46%
Netherlands	4.35%	0.00%	0.38%	0.00%	0.00%	0.00%	92.06%	0.00%	7.94%	0.00%	0.00%	0.00%
New Zealand	0.69%	2.33%	0.16%	0.15%	0.48%	0.20%	17.28%	58.12%	3.92%	3.70%	12.04%	4.92%
Norway	0.00%	1.76%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%
Poland	0.82%	3.50%	0.00%	0.05%	6.20%	0.93%	7.13%	30.39%	0.00%	0.00%	54.31%	8.16%
Portugal	2.28%	0.00%	0.47%	0.00%	0.10%	1.85%	48.43%	0.00%	10.08%	0.00%	2.18%	39.32%
Slovak Rep.	0.75%	10.10%	0.00%	0.13%	2.51%	0.80%	5.31%	71.25%	0.00%	0.00%	17.80%	5.65%
Slovenia	0.00%	2.58%	0.00%	0.69%	2.71%	0.21%	0.00%	41.65%	0.00%	11.11%	43.90%	3.34%
Spain	0.07%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sweden	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	44.30%	0.00%	0.00%	0.50%	297.80%	0.00%
Switzerland	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	38.53%	0.00%	61.47%	0.00%	0.00%
Turkey	0.00%	9.17%	0.00%	0.00%	3.81%	0.72%	0.00%	66.79%	0.00%	0.00%	27.95%	5.26%
UK	0.34%	2.21%	0.86%	0.99%	0.14%	0.00%	7.75%	50.01%	19.65%	22.59%	0.00%	0.00%
USA	3.60%	2.68%	1.84%	0.00%	0.00%	0.00%	44.32%	33.03%	22.65%	0.00%	0.00%	0.00%
OECD	0.70%	2.37%	0.40%	1.59%	0.13%	0.28%	13.76%	46.89%	2.50%	5.45%	22.57%	8.91%

Table 26 – Changes in Inefficiency Levels and Outcome Losses between 2001 and 2011

	Inefficiency B1-B2			with Environmental Variables. B1-B2-B3			with Expenditures B1-B2-B3-B4		
	2001	2011	Delta	2001	2011	Delta	2001	2011	Delta
Australia	2.83%	2.16%	-0.67%	3.54%	3.06%	-0.48%	3.54%	3.06%	-0.48%
Austria	5.07%	4.03%	-1.04%	6.20%	4.70%	-1.50%	6.20%	4.70%	-1.50%
Belgium	6.30%	4.97%	-1.34%	7.07%	5.43%	-1.65%	7.12%	5.43%	-1.70%
Canada	0.00%	0.68%	0.68%	0.00%	0.68%	0.68%	0.00%	0.68%	0.68%
Chile	0.00%	1.76%	1.76%	0.00%	1.76%	1.76%	0.00%	1.76%	1.76%
Czech Rep.	1.40%	2.44%	1.04%	1.40%	4.09%	2.68%	12.47%	10.15%	-2.32%
Denmark	4.21%	6.58%	2.37%	7.80%	7.13%	-0.67%	7.80%	7.13%	-0.67%
Estonia	2.67%	0.45%	-2.22%	2.67%	0.45%	-2.22%	21.19%	11.92%	-9.27%
Finland	0.65%	4.43%	3.78%	0.65%	4.85%	4.19%	3.47%	4.85%	1.38%
France	2.96%	1.80%	-1.16%	4.25%	1.86%	-2.39%	4.25%	1.86%	-2.39%
Germany	4.76%	4.17%	-0.59%	6.38%	5.18%	-1.20%	6.38%	5.18%	-1.20%
Greece	0.92%	0.46%	-0.46%	2.26%	0.47%	-1.79%	5.07%	3.73%	-1.33%
Hungary	10.21%	10.42%	0.20%	10.25%	10.52%	0.27%	18.78%	16.13%	-2.66%
Iceland	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Ireland	6.25%	0.65%	-5.60%	7.87%	2.03%	-5.84%	9.71%	2.03%	-7.68%
Israel	1.95%	0.48%	-1.47%	3.01%	0.48%	-2.53%	5.54%	3.75%	-1.79%
Italy	1.08%	0.48%	-0.60%	1.97%	0.66%	-1.31%	3.41%	0.66%	-2.75%
Japan	0.00%	0.50%	0.50%	0.00%	0.50%	0.50%	0.00%	0.50%	0.50%
Korea	0.77%	1.91%	1.14%	0.77%	1.91%	1.14%	1.77%	4.72%	2.95%
Luxembourg	4.81%	4.09%	-0.72%	7.88%	5.11%	-2.77%	7.88%	5.11%	-2.77%
Mexico	1.13%	4.67%	3.54%	1.13%	4.67%	3.54%	1.78%	6.54%	4.76%
Netherlands	5.72%	4.35%	-1.37%	5.72%	4.74%	-0.98%	5.72%	4.74%	-0.98%
New Zealand	0.93%	3.05%	2.12%	1.34%	3.36%	2.02%	3.09%	4.07%	0.98%
Norway	4.26%	1.76%	-2.51%	5.07%	1.76%	-3.31%	5.07%	1.76%	-3.31%
Poland	4.03%	4.35%	0.31%	4.03%	4.35%	0.31%	15.48%	11.85%	-3.64%
Portugal	4.02%	2.28%	-1.74%	5.11%	2.76%	-2.35%	7.50%	4.77%	-2.72%
Slovak Rep.	2.06%	10.93%	8.87%	2.36%	10.93%	8.57%	17.32%	14.62%	-2.70%
Slovenia	3.73%	2.58%	-1.15%	3.73%	3.29%	-0.44%	7.89%	6.31%	-1.58%
Spain	0.00%	0.07%	0.07%	0.00%	0.07%	0.07%	0.00%	0.07%	0.07%
Sweden	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Switzerland	0.06%	0.00%	-0.06%	0.06%	0.00%	-0.06%	0.06%	0.00%	-0.06%
Turkey	2.55%	9.17%	6.62%	2.55%	9.17%	6.62%	12.21%	14.15%	1.94%
UK	3.35%	2.56%	-0.79%	4.37%	4.47%	0.10%	4.40%	4.47%	0.07%
USA	6.21%	6.38%	0.17%	8.83%	8.34%	-0.49%	8.83%	8.34%	-0.49%
OECD	2.79%	3.08%	0.29%	3.48%	3.49%	0.01%	6.29%	5.15%	-1.14%

Table 27 – Inefficiency Level for Life Expectancy at Birth between 2001 and 2011

	LE0 Inefficiency in years				
	b1	b1b2	b1b2b3	b1b2b4	b1b2b3b4
Australia	0.12	0.26	0.35	0.26	0.35
Austria	0.05	1.45	1.88	1.45	1.88
Belgium	0.05	2.13	2.42	2.13	2.42
Canada	0.04	0.04	0.04	0.04	0.04
Chile	0.01	0.15	0.15	0.15	0.15
Czech Rep.	0.01	1.23	1.55	4.59	5.72
Denmark	0.45	2.54	3.02	2.54	3.02
Estonia	0.36	2.52	2.57	8.30	8.96
Finland	0.34	1.35	1.49	1.60	1.95
France	0.16	0.59	0.81	0.59	0.81
Germany	0.02	1.71	2.21	1.71	2.21
Greece	0.00	0.24	0.85	0.54	1.53
Hungary	0.00	6.17	6.42	7.64	8.88
Iceland	0.00	0.00	0.00	0.00	0.00
Ireland	0.81	0.95	1.56	0.95	1.69
Israel	0.00	0.13	0.15	0.30	0.98
Italy	0.00	0.04	0.08	0.10	0.28
Japan	0.00	0.03	0.03	0.03	0.03
Korea	0.00	0.55	0.55	2.55	2.65
Luxembourg	0.03	1.13	1.96	1.13	1.96
Mexico	1.52	1.52	1.52	1.86	1.91
Netherlands	1.49	1.53	1.61	1.53	1.61
N. Zealand	0.09	0.28	0.31	0.80	0.84
Norway	0.48	0.84	0.95	0.84	0.95
Poland	0.11	3.04	3.04	6.15	6.60
Portugal	1.91	1.92	2.15	2.09	2.84
Slovak Rep.	0.06	4.90	5.03	7.20	7.75
Slovenia	0.18	1.98	2.10	3.09	3.43
Spain	0.00	0.00	0.00	0.00	0.00
Sweden	0.00	0.00	0.00	0.00	0.00
Switzerland	0.00	0.00	0.00	0.00	0.00
Turkey	0.00	3.04	3.04	5.13	5.24
UK	0.23	1.44	1.66	1.59	1.75
US	2.23	3.13	3.72	3.13	3.72
OECD	0.32	1.38	1.56	2.06	2.42

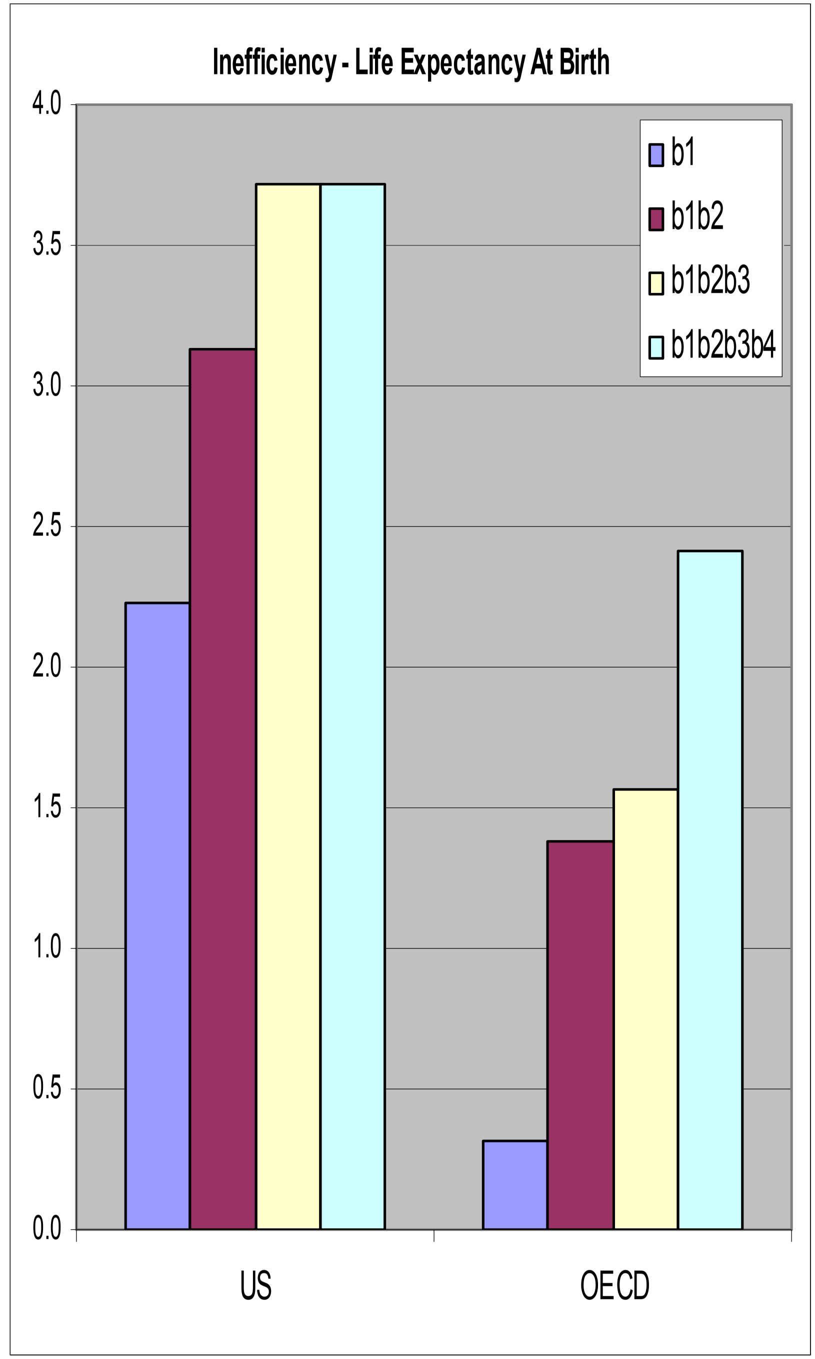


Table 28 – Inefficiency Level for Life Expectancy at 65 between 2001 and 2011

	LE65 Inefficiency in years				
	b1	b1b2	b1b2b3	b1b2b4	b1b2b3b4
Australia	0.04	0.06	0.07	0.06	0.07
Austria	0.08	0.82	1.02	0.82	1.02
Belgium	0.11	1.23	1.54	1.23	1.54
Canada	0.02	0.02	0.02	0.02	0.02
Chile	0.00	0.16	0.16	0.16	0.16
Czech Rep.	0.02	1.44	1.61	3.51	4.55
Denmark	0.32	1.70	2.02	1.70	2.02
Estonia	0.09	1.09	1.11	4.43	4.66
Finland	0.35	0.48	0.57	0.68	0.83
France	0.00	0.03	0.16	0.03	0.16
Germany	0.03	1.22	1.64	1.22	1.64
Greece	0.00	0.19	0.63	0.46	1.03
Hungary	0.00	3.52	3.85	4.39	5.42
Iceland	0.01	0.03	0.03	0.03	0.03
Ireland	0.71	0.94	1.27	0.96	1.34
Israel	0.00	0.17	0.17	0.40	0.53
Italy	0.00	0.12	0.12	0.18	0.20
Japan	0.00	0.01	0.01	0.01	0.01
Korea	0.00	0.62	0.62	2.24	2.33
Luxembourg	0.01	0.76	1.22	0.76	1.22
Mexico	0.35	0.35	0.35	0.52	0.55
Netherlands	1.00	1.37	1.43	1.37	1.43
N. Zealand	0.01	0.01	0.01	0.32	0.16
Norway	0.30	0.53	0.61	0.53	0.61
Poland	0.10	1.76	1.76	3.84	3.92
Portugal	1.25	1.26	1.33	1.40	1.57
Slovak Rep.	0.05	3.64	3.70	5.08	5.51
Slovenia	0.09	1.40	1.47	1.95	2.14
Spain	0.00	0.01	0.01	0.01	0.01
Sweden	0.00	0.00	0.00	0.00	0.00
Switzerland	0.00	0.00	0.00	0.00	0.00
Turkey	0.00	2.95	2.95	4.03	4.11
UK	0.14	1.06	1.08	1.21	1.10
US	1.43	1.48	1.67	1.48	1.67
OECD	0.19	0.89	1.01	1.32	1.52

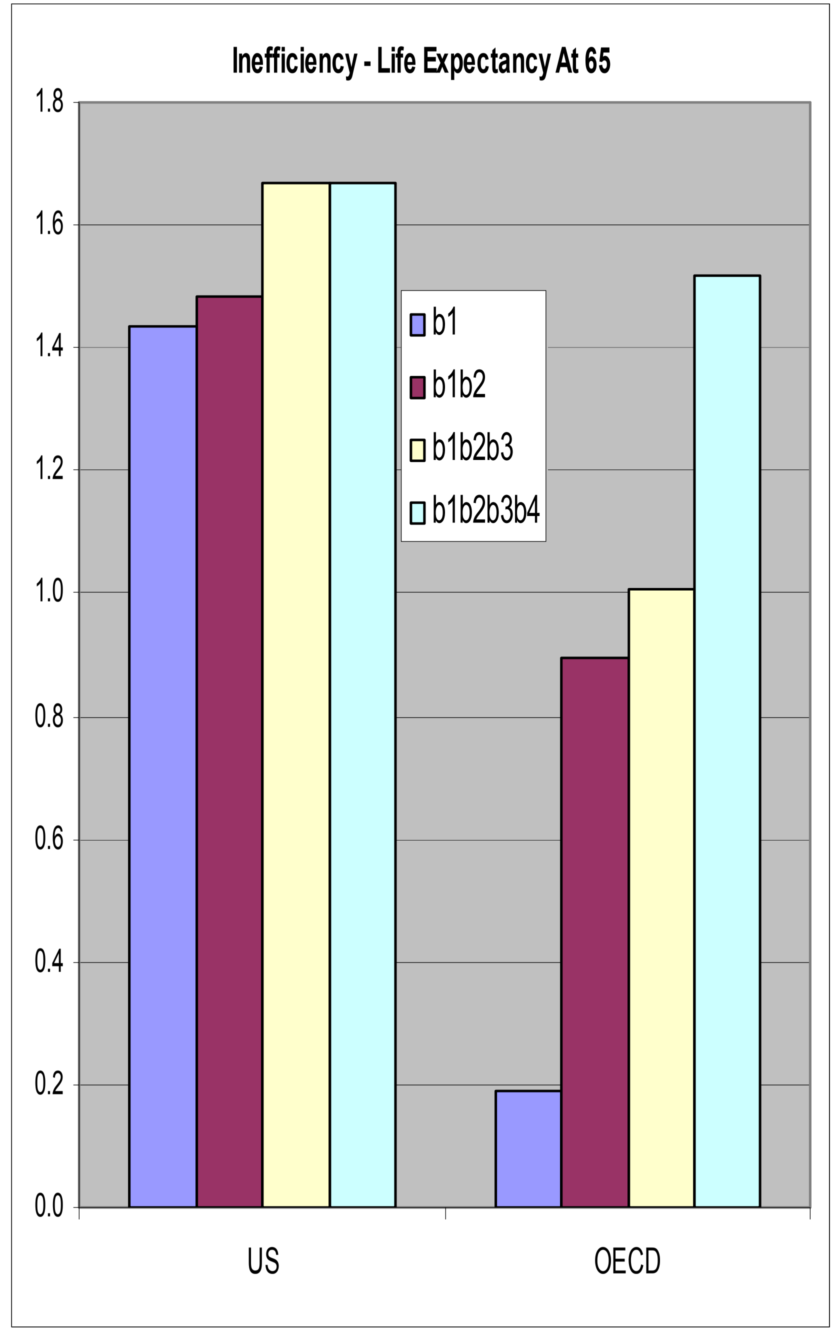


Table 29 – Inefficiency Level for Infant Mortality between 2001 and 2011

	IM Inefficiency in Infants / 1000				
	b1	b1b2	b1b2b3	b1b2b4	b1b2b3b4
Australia	0.33	1.12	1.44	1.12	1.44
Austria	0.00	1.58	1.95	1.58	1.95
Belgium	0.04	1.63	1.69	1.67	1.70
Canada	0.07	0.07	0.07	0.07	0.07
Chile	0.02	0.14	0.20	0.14	0.20
Czech Rep.	0.00	0.00	0.00	0.74	0.72
Denmark	0.48	1.39	1.85	1.39	1.85
Estonia	0.02	0.02	0.02	0.86	1.49
Finland	0.30	0.50	0.57	0.57	0.72
France	0.00	0.89	1.26	0.89	1.26
Germany	0.00	1.37	1.66	1.37	1.66
Greece	0.00	0.21	0.73	0.23	1.30
Hungary	0.00	1.18	1.21	2.49	2.83
Iceland	0.01	0.01	0.01	0.01	0.01
Ireland	0.39	0.48	1.23	0.49	1.38
Israel	0.00	0.35	0.48	0.64	1.93
Italy	0.00	0.47	0.61	0.68	1.10
Japan	0.01	0.01	0.01	0.01	0.01
Korea	0.00	0.06	0.06	0.72	0.75
Luxembourg	0.04	0.89	1.86	0.89	1.86
Mexico	2.21	2.21	2.21	2.85	2.97
Netherlands	1.48	1.71	1.78	1.71	1.78
N. Zealand	0.18	1.00	1.15	1.73	2.26
Norway	0.28	0.75	0.83	0.75	0.83
Poland	0.09	0.24	0.26	2.35	2.99
Portugal	0.23	0.24	0.59	0.29	1.47
Slovak Rep.	0.01	1.10	1.12	2.83	2.95
Slovenia	0.02	0.12	0.13	1.02	1.28
Spain	0.00	0.01	0.01	0.01	0.01
Sweden	0.00	0.00	0.00	0.00	0.00
Switzerland	0.12	0.12	0.12	0.12	0.12
Turkey	0.00	2.21	2.21	3.71	3.83
UK	0.19	1.20	2.12	1.20	2.14
US	0.47	2.09	3.96	2.09	3.96
OECD	0.21	0.75	0.98	1.10	1.50

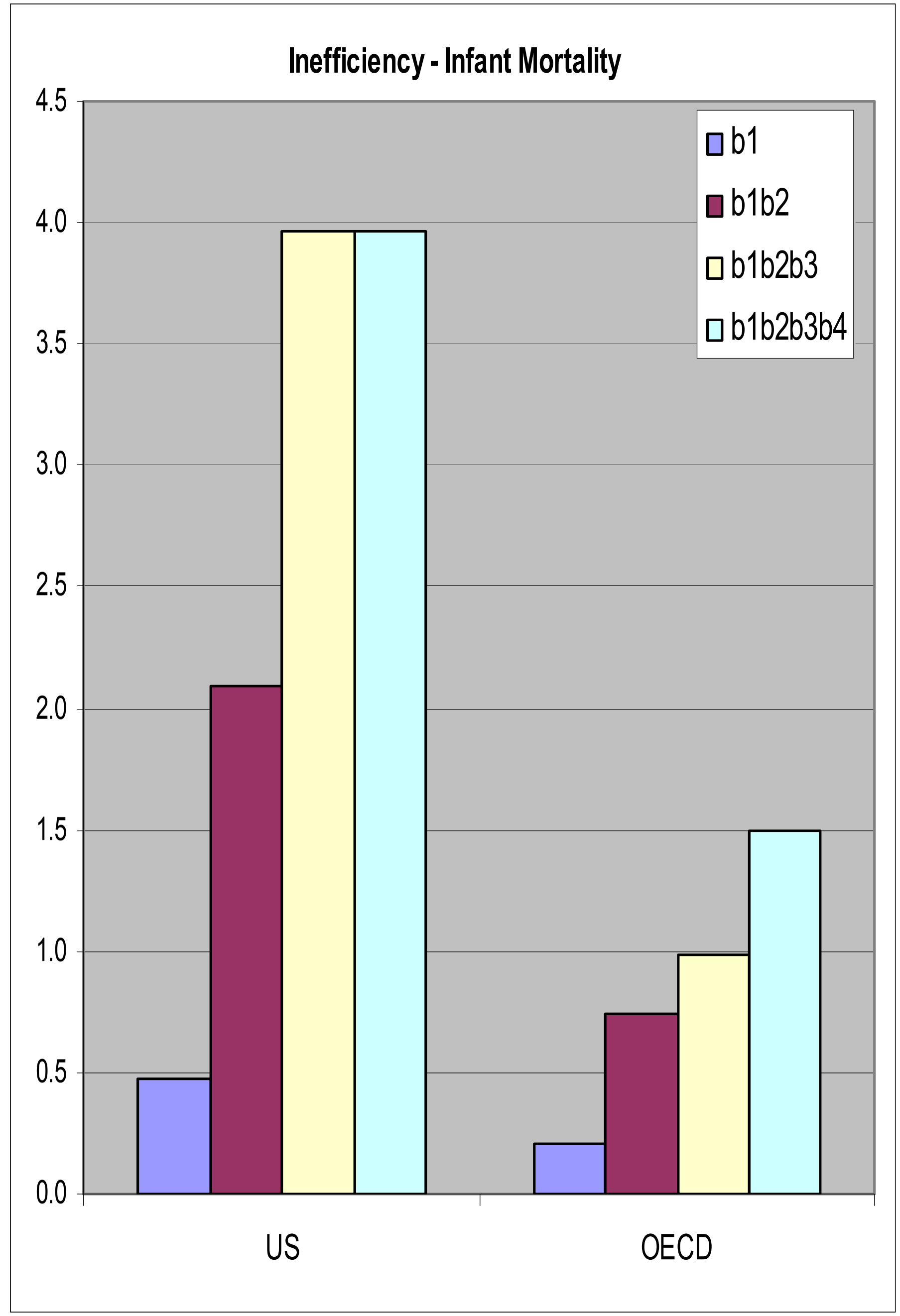


Table 30 – Actual vs. Efficient Outcomes, compared at each stage, 2000-2011 Averages (1)

	Life Exp. at Birth	Actual	Efficient Outcomes				
	2000-2011 Averages	Outcome	b1	b1b2	b1b2b3	b1b2b4	b1b2b3b4
1	Australia	80.85	80.97	81.11	81.20	81.11	81.20
2	Austria	79.63	79.69	81.08	81.51	81.08	81.51
3	Belgium	79.21	79.25	81.34	81.63	81.34	81.63
4	Canada	80.26	80.30	80.30	80.30	80.30	80.30
5	Chile	77.82	77.82	77.96	77.96	77.96	77.96
6	Czech Rep.	76.44	76.46	77.67	78.00	81.03	82.17
7	Denmark	78.18	78.63	80.72	81.20	80.72	81.20
8	Estonia	72.99	73.35	75.51	75.56	81.29	81.95
9	Finland	79.21	79.55	80.56	80.70	80.81	81.16
10	France	80.55	80.71	81.14	81.36	81.14	81.36
11	Germany	79.49	79.51	81.20	81.70	81.20	81.70
12	Greece	79.43	79.43	79.68	80.29	79.98	80.96
13	Hungary	73.41	73.41	79.58	79.83	81.05	82.29
14	Iceland	81.28	81.28	81.28	81.28	81.28	81.28
15	Ireland	79.13	79.95	80.08	80.69	80.09	80.83
16	Israel	80.41	80.41	80.54	80.56	80.71	81.39
17	Italy	81.15	81.15	81.19	81.23	81.25	81.43
18	Japan	82.23	82.22	82.25	82.25	82.25	82.25
19	Korea	78.62	78.62	79.17	79.17	81.16	81.27
20	Luxembourg	79.37	79.40	80.50	81.32	80.50	81.32
21	Mexico	73.90	75.42	75.42	75.42	75.76	75.81
22	Netherlands	79.68	81.16	81.20	81.28	81.20	81.28
23	N. Zealand	79.87	79.96	80.14	80.18	80.66	80.71
24	Norway	80.19	80.67	81.03	81.14	81.03	81.14
25	Poland	75.23	75.34	78.27	78.27	81.38	81.84
26	Portugal	78.52	80.43	80.44	80.67	80.61	81.35
27	Slovak Rep.	74.48	74.54	79.37	79.50	81.67	82.23
28	Slovenia	77.92	78.09	79.90	80.01	81.00	81.35
29	Spain	80.85	80.85	80.85	80.85	80.85	80.85
30	Sweden	80.79	80.79	80.79	80.79	80.79	80.79
31	Switzerland	81.48	81.48	81.48	81.48	81.48	81.48
32	Turkey	73.05	73.05	76.09	76.09	78.18	78.29
33	UK	79.36	79.59	80.79	81.02	80.95	81.10
34	US	77.66	79.89	80.79	81.38	80.79	81.38
	Averages	78.61	78.92	79.98	80.17	80.67	81.02

	Life Exp. at 65	Actual	Efficient Outcomes				
	2000-2011 Averages	Outcome	b1	b1b2	b1b2b3	b1b2b4	b1b2b3b4
1	Australia	19.70	19.74	19.76	19.77	19.76	19.77
2	Austria	18.82	18.90	19.64	19.84	19.64	19.84
3	Belgium	18.60	18.71	19.84	20.14	19.84	20.14
4	Canada	19.40	19.42	19.42	19.42	19.42	19.42
5	Chile	18.08	18.09	18.24	18.24	18.24	18.24
6	Czech Rep.	16.36	16.38	17.80	17.97	19.87	20.90
7	Denmark	17.59	17.90	19.29	19.61	19.29	19.61
8	Estonia	15.77	15.86	16.86	16.88	20.20	20.43
9	Finland	18.73	19.08	19.21	19.31	19.41	19.56
10	France	20.16	20.16	20.19	20.32	20.19	20.32
11	Germany	18.63	18.66	19.85	20.27	19.85	20.27
12	Greece	18.34	18.34	18.53	18.97	18.80	19.37
13	Hungary	15.55	15.55	19.07	19.39	19.94	20.97
14	Iceland	19.54	19.54	19.56	19.56	19.56	19.56
15	Ireland	18.11	18.82	19.06	19.38	19.07	19.45
16	Israel	19.17	19.17	19.34	19.34	19.56	19.69
17	Italy	19.62	19.62	19.74	19.74	19.80	19.82
18	Japan	20.80	20.80	20.82	20.82	20.82	20.82
19	Korea	17.96	17.96	18.59	18.59	20.20	20.29
20	Luxembourg	18.55	18.56	19.31	19.77	19.31	19.77
21	Mexico	17.51	17.86	17.86	17.86	18.03	18.06
22	Netherlands	18.43	19.42	19.79	19.86	19.79	19.86
23	N. Zealand	19.17	19.18	19.18	19.18	19.49	19.33
24	Norway	18.93	19.22	19.46	19.54	19.46	19.54
25	Poland	16.50	16.61	18.26	18.26	20.35	20.42
26	Portugal	18.18	19.44	19.44	19.51	19.58	19.76
27	Slovak Rep.	15.45	15.49	19.08	19.15	20.53	20.95
28	Slovenia	17.64	17.73	19.04	19.11	19.59	19.78
29	Spain	19.67	19.67	19.68	19.68	19.68	19.68
30	Sweden	19.15	19.15	19.15	19.15	19.15	19.15
31	Switzerland	20.03	20.03	20.04	20.04	20.04	20.04
32	Turkey	14.71	14.71	17.66	17.66	18.74	18.82
33	UK	18.55	18.69	19.61	19.63	19.76	19.65
34	US	18.29	19.72	19.77	19.96	19.77	19.96
	Averages	18.29	18.48	19.18	19.29	19.61	19.80

Table 31 – Actual vs. Efficient Outcomes, compared at each stage, 2000-2011 Averages (2)

	Infant Mortality	Actual	Efficient Outcomes				
	2000-2011 Averages	Outcome	b1	b1b2	b1b2b3	b1b2b4	b1b2b3b4
1	**Australia**	4.60	4.27	3.48	3.16	3.48	3.16
2	**Austria**	4.10	4.10	2.52	2.15	2.52	2.15
3	**Belgium**	3.98	3.94	2.34	2.29	2.31	2.28
4	**Canada**	5.14	5.06	5.06	5.06	5.06	5.06
5	**Chile**	7.96	7.94	7.81	7.76	7.81	7.76
6	**Czech Republic**	3.39	3.39	3.39	3.39	2.65	2.67
7	**Denmark**	4.12	3.64	2.73	2.27	2.73	2.27
8	**Estonia**	5.46	5.44	5.43	5.43	4.60	3.97
9	**Finland**	2.90	2.60	2.40	2.33	2.33	2.18
10	**France**	3.98	3.98	3.09	2.71	3.09	2.71
11	**Germany**	3.90	3.90	2.53	2.24	2.53	2.24
12	**Greece**	4.02	4.02	3.80	3.29	3.78	2.72
13	**Hungary**	6.43	6.42	5.24	5.21	3.94	3.60
14	**Iceland**	2.18	2.17	2.17	2.17	2.17	2.17
15	**Ireland**	4.32	3.93	3.83	3.08	3.82	2.94
16	**Israel**	4.38	4.38	4.03	3.90	3.74	2.45
17	**Italy**	3.79	3.79	3.33	3.18	3.11	2.69
18	**Japan**	2.73	2.71	2.71	2.71	2.71	2.71
19	**Korea**	4.32	4.32	4.26	4.26	3.60	3.57
20	**Luxembourg**	3.65	3.61	2.76	1.79	2.76	1.79
21	**Mexico**	16.84	14.63	14.63	14.63	14.00	13.87
22	**Netherlands**	4.43	2.94	2.71	2.64	2.71	2.64
23	**New Zealand**	5.46	5.28	4.46	4.31	3.73	3.20
24	**Norway**	3.18	2.89	2.43	2.35	2.43	2.35
25	**Poland**	6.37	6.27	6.12	6.11	4.01	3.38
26	**Portugal**	3.84	3.61	3.61	3.25	3.55	2.37
27	**Slovak Rep**	6.60	6.59	5.50	5.48	3.77	3.65
28	**Slovenia**	3.43	3.40	3.31	3.30	2.41	2.15
29	**Spain**	3.64	3.64	3.63	3.63	3.63	3.63
30	**Sweden**	2.83	2.82	2.82	2.82	2.82	2.82
31	**Switzerland**	4.28	4.16	4.16	4.15	4.16	4.15
32	**Turkey**	19.67	19.67	17.45	17.45	15.95	15.83
33	**UK**	4.94	4.75	3.75	2.82	3.75	2.80
34	**United States**	6.68	6.20	4.59	2.71	4.59	2.71
	Averages	5.22	5.01	4.47	4.24	4.13	3.72
	Expenditure	2,669	2,425		2,442	2,814	2,917

	Expenditure	Actual	Efficient Outcomes			
	2000-2011 Averages	Expend.	b1b2	b1b2b3	b1b2b4	b1b2b3b4
1	**Australia**	3,106	2,999	3,130	3,004	3,163
2	**Austria**	3,686	3,002	3,214	3,002	3,214
3	**Belgium**	3,226	3,037	2,991	3,088	3,006
4	**Canada**	3,554	3,500	3,500	3,500	3,500
5	**Chile**	986	965	965	965	965
6	**Czech Republic**	1,527	1,603	1,603	2,860	2,655
7	**Denmark**	3,504	3,113	3,128	3,117	3,137
8	**Estonia**	936	983	983	2,541	3,087
9	**Finland**	2,664	2,760	2,733	3,110	3,047
10	**France**	3,364	3,196	3,228	3,196	3,228
11	**Germany**	3,529	2,902	2,934	2,902	2,934
12	**Greece**	2,327	2,437	2,444	3,014	3,249
13	**Hungary**	1,368	1,436	1,436	2,407	2,684
14	**Iceland**	3,252	3,239	3,239	3,239	3,239
15	**Ireland**	3,042	3,005	2,883	3,090	3,093
16	**Israel**	1,915	2,010	2,010	2,425	3,263
17	**Italy**	2,576	2,680	2,680	2,889	3,058
18	**Japan**	2,592	2,557	2,557	2,557	2,557
19	**Korea**	1,427	1,495	1,495	2,543	2,531
20	**Luxembourg**	4,075	3,252	3,134	3,252	3,134
21	**Mexico**	765	803	803	1,223	1,281
22	**Netherlands**	3,845	2,864	2,852	2,864	2,852
23	**New Zealand**	2,321	2,437	2,437	3,435	3,155
24	**Norway**	4,439	3,106	3,131	3,106	3,131
25	**Poland**	984	1,033	1,033	2,760	2,993
26	**Portugal**	2,216	2,294	2,327	2,422	3,029
27	**Slovak Rep**	1,324	1,390	1,390	2,555	2,694
28	**Slovenia**	2,020	2,121	2,121	3,038	3,069
29	**Spain**	2,398	2,389	2,389	2,389	2,389
30	**Sweden**	3,155	3,155	3,155	3,155	3,155
31	**Switzerland**	4,325	4,256	4,247	4,256	4,247
32	**Turkey**	722	758	758	1,871	2,161
33	**UK**	2,779	2,903	2,882	3,117	3,061
34	**United States**	6,812	2,781	3,221	2,781	3,221
	Averages	2,669	2,425	2,442	2,814	2,917
	Percent of Actual	100.0%	90.9%	91.5%	105.4%	109.3%

Table 32 – Inefficiency and Outcome Loss Trends (1)

	Inefficiency Trend	2000-2011 Averages - Efficient					Outcome Loss with Environmental	2000-2011 Averages - Efficient			
		LE0	LE65	IM	Exp			LE0	LE65	IM	Exp
1	**Australia**	0.26	0.06	1.12	-3.4%	1	**Australia**	0.35	0.07	1.44	0.8%
2	**Austria**	1.45	0.82	1.58	-18.5%	2	**Austria**	1.88	1.02	1.95	-12.8%
3	**Belgium**	2.13	1.23	1.63	-5.8%	3	**Belgium**	2.42	1.54	1.69	-7.3%
4	**Canada**	0.04	0.02	0.07	-1.5%	4	**Canada**	0.04	0.02	0.07	-1.5%
5	**Chile**	0.15	0.16	0.14	-2.1%	5	**Chile**	0.15	0.16	0.20	-2.1%
6	**Czech Rep.**	1.23	1.44	0.00	5.0%	6	**Czech Rep.**	1.55	1.61	0.00	5.0%
7	**Denmark**	2.54	1.70	1.39	-11.1%	7	**Denmark**	3.02	2.02	1.85	-10.7%
8	**Estonia**	2.52	1.09	0.02	5.0%	8	**Estonia**	2.57	1.11	0.02	5.0%
9	**Finland**	1.35	0.48	0.50	3.6%	9	**Finland**	1.49	0.57	0.57	2.6%
10	**France**	0.59	0.03	0.89	-5.0%	10	**France**	0.81	0.16	1.26	-4.1%
11	**Germany**	1.71	1.22	1.37	-17.8%	11	**Germany**	2.21	1.64	1.66	-16.9%
12	**Greece**	0.24	0.19	0.21	4.7%	12	**Greece**	0.85	0.63	0.73	5.0%
13	**Hungary**	6.17	3.52	1.18	5.0%	13	**Hungary**	6.42	3.85	1.21	5.0%
14	**Iceland**	0.00	0.03	0.01	-0.4%	14	**Iceland**	0.00	0.03	0.01	-0.4%
15	**Ireland**	0.95	0.94	0.48	-1.2%	15	**Ireland**	1.56	1.27	1.23	-5.2%
16	**Israel**	0.13	0.17	0.35	5.0%	16	**Israel**	0.15	0.17	0.48	5.0%
17	**Italy**	0.04	0.12	0.47	4.0%	17	**Italy**	0.08	0.12	0.61	4.0%
18	**Japan**	0.03	0.01	0.01	-1.4%	18	**Japan**	0.03	0.01	0.01	-1.4%
19	**Korea**	0.55	0.62	0.06	4.8%	19	**Korea**	0.55	0.62	0.06	4.8%
20	**Luxembourg**	1.13	0.76	0.89	-20.2%	20	**Luxembourg**	1.96	1.22	1.86	-23.1%
21	**Mexico**	1.52	0.35	2.21	5.0%	21	**Mexico**	1.52	0.35	2.21	5.0%
22	**Netherlands**	1.53	1.37	1.71	-25.5%	22	**Netherlands**	1.61	1.43	1.78	-25.8%
23	**New Zealand**	0.28	0.01	1.00	5.0%	23	**New Zealand**	0.31	0.01	1.15	5.0%
24	**Norway**	0.84	0.53	0.75	-30.0%	24	**Norway**	0.95	0.61	0.83	-29.5%
25	**Poland**	3.04	1.76	0.24	5.0%	25	**Poland**	3.04	1.76	0.26	5.0%
26	**Portugal**	1.92	1.26	0.24	3.5%	26	**Portugal**	2.15	1.33	0.59	5.0%
27	**Slovak Rep.**	4.90	3.64	1.10	5.0%	27	**Slovak Rep.**	5.03	3.70	1.12	5.0%
28	**Slovenia**	1.98	1.40	0.12	5.0%	28	**Slovenia**	2.10	1.47	0.13	5.0%
29	**Spain**	0.00	0.01	0.01	-0.3%	29	**Spain**	0.00	0.01	0.01	-0.3%
30	**Sweden**	0.00	0.00	0.00	0.0%	30	**Sweden**	0.00	0.00	0.00	0.0%
31	**Switzerland**	0.00	0.00	0.12	-1.6%	31	**Switzerland**	0.00	0.00	0.12	-1.8%
32	**Turkey**	3.04	2.95	2.21	5.0%	32	**Turkey**	3.04	2.95	2.21	5.0%
33	**UK**	1.44	1.06	1.20	4.5%	33	**UK**	1.66	1.08	2.12	3.7%
34	**United States**	3.13	1.48	2.09	-59.2%	34	**United States**	3.72	1.67	3.96	-52.7%
	OECD	1.38	0.89	0.75	-0.04		**OECD**	1.56	1.01	0.98	-0.04

Table 33 – Inefficiency and Outcome Loss Trends (2)

	Outcome Loss with Expenditures	2000-2011 Averages - Efficient			
		LE0	LE65	IM	Exp
1	Australia	0.26	0.06	1.12	-3.3%
2	Austria	1.45	0.82	1.58	-18.5%
3	Belgium	2.13	1.23	1.67	-4.3%
4	Canada	0.04	0.02	0.07	-1.5%
5	Chile	0.15	0.16	0.14	-2.1%
6	Czech Rep.	4.59	3.51	0.74	87.3%
7	Denmark	2.54	1.70	1.39	-11.0%
8	Estonia	8.30	4.43	0.86	171.4%
9	Finland	1.60	0.68	0.57	16.7%
10	France	0.59	0.03	0.89	-5.0%
11	Germany	1.71	1.22	1.37	-17.8%
12	Greece	0.54	0.46	0.23	29.5%
13	Hungary	7.64	4.39	2.49	76.0%
14	Iceland	0.00	0.03	0.01	-0.4%
15	Ireland	0.95	0.96	0.49	1.6%
16	Israel	0.30	0.40	0.64	26.7%
17	Italy	0.10	0.18	0.68	12.1%
18	Japan	0.03	0.01	0.01	-1.4%
19	Korea	2.55	2.24	0.72	78.3%
20	Luxembourg	1.13	0.76	0.89	-20.2%
21	Mexico	1.86	0.52	2.85	59.9%
22	Netherlands	1.53	1.37	1.71	-25.5%
23	New Zealand	0.80	0.32	1.73	48.0%
24	Norway	0.84	0.53	0.75	-30.0%
25	Poland	6.15	3.84	2.35	180.5%
26	Portugal	2.09	1.40	0.29	9.3%
27	Slovak Rep.	7.20	5.08	2.83	93.0%
28	Slovenia	3.09	1.95	1.02	50.4%
29	Spain	0.00	0.01	0.01	-0.3%
30	Sweden	0.00	0.00	0.00	0.0%
31	Switzerland	0.00	0.00	0.12	-1.6%
32	Turkey	5.13	4.03	3.71	159.1%
33	UK	1.59	1.21	1.20	12.2%
34	United States	3.13	1.48	2.09	-59.2%
	OECD	2.06	1.32	1.10	0.27

	Outcome Loss Total	2000-2011 Averages - Efficient			
		LE0	LE65	IM	Exp
1	Australia	0.35	0.07	1.44	1.8%
2	Austria	1.88	1.02	1.95	-12.8%
3	Belgium	2.42	1.54	1.70	-6.8%
4	Canada	0.04	0.02	0.07	-1.5%
5	Chile	0.15	0.16	0.20	-2.1%
6	Czech Rep.	5.72	4.55	0.72	73.9%
7	Denmark	3.02	2.02	1.85	-10.5%
8	Estonia	8.96	4.66	1.49	229.8%
9	Finland	1.95	0.83	0.72	14.4%
10	France	0.81	0.16	1.26	-4.1%
11	Germany	2.21	1.64	1.66	-16.9%
12	Greece	1.53	1.03	1.30	39.6%
13	Hungary	8.88	5.42	2.83	96.3%
14	Iceland	0.00	0.03	0.01	-0.4%
15	Ireland	1.69	1.34	1.38	1.7%
16	Israel	0.98	0.53	1.93	70.4%
17	Italy	0.28	0.20	1.10	18.7%
18	Japan	0.03	0.01	0.01	-1.4%
19	Korea	2.65	2.33	0.75	77.4%
20	Luxembourg	1.96	1.22	1.86	-23.1%
21	Mexico	1.91	0.55	2.97	67.5%
22	Netherlands	1.61	1.43	1.78	-25.8%
23	New Zealand	0.84	0.16	2.26	36.0%
24	Norway	0.95	0.61	0.83	-29.5%
25	Poland	6.60	3.92	2.99	204.2%
26	Portugal	2.84	1.57	1.47	36.7%
27	Slovak Rep.	7.75	5.51	2.95	103.5%
28	Slovenia	3.43	2.14	1.28	51.9%
29	Spain	0.00	0.01	0.01	-0.3%
30	Sweden	0.00	0.00	0.00	0.0%
31	Switzerland	0.00	0.00	0.12	-1.8%
32	Turkey	5.24	4.11	3.83	199.3%
33	UK	1.75	1.10	2.14	10.1%
34	United States	3.72	1.67	3.96	-52.7%
	OECD	2.42	1.52	1.50	0.34

Table 34 – Increase in Health Outcomes from production scaling, by Country, 2011

Scale Ratio	Australia	Austria	Belgium	Canada	Chile	Czech	Denmark	Estonia	Finland	France	Germany	Greece
1	1.52%	4.03%	4.97%	0.00%	1.69%	2.44%	4.51%	0.44%	2.23%	1.29%	4.80%	0.45%
1.1	1.78%	4.03%	5.20%	0.97%	2.67%	3.61%	5.84%	1.39%	2.76%	1.35%	4.83%	1.07%
1.2	2.01%	4.12%	5.57%	1.99%	2.91%	4.40%	6.32%	2.18%	3.26%	1.42%	4.83%	1.46%
1.3	2.24%	4.30%	5.57%	2.82%	3.04%	5.34%	6.66%	2.87%	3.76%	1.49%	4.83%	1.91%
1.4	2.31%	4.56%	5.80%	3.30%	3.10%	6.29%	6.89%	3.57%	4.26%	1.55%	4.83%	2.60%
1.5	2.38%	4.86%	6.01%	3.57%	3.12%	7.20%	7.02%	4.26%	4.62%	1.62%	4.83%	3.12%
1.6	2.50%	4.87%	6.01%	3.66%	3.12%	7.60%	7.15%	4.95%	4.62%	1.69%	4.83%	3.52%
1.7	2.62%	4.87%	6.01%	3.75%	3.12%	7.89%	7.34%	5.64%	4.62%	1.75%	4.83%	3.72%
1.8	2.74%	4.87%	6.01%	3.85%	3.12%	8.18%	7.56%	6.30%	4.62%	1.82%	4.83%	3.82%
1.9	2.87%	4.87%	6.01%	3.94%	3.12%	8.47%	7.78%	6.96%	4.62%	1.89%	4.83%	3.83%
2.0	2.87%	4.87%	6.01%	4.04%	3.12%	8.77%	7.78%	7.62%	4.62%	1.95%	4.83%	3.84%

Scale Ratio	Hungary	Iceland	Ireland	Israel	Italy	Japan	Korea	Luxembourg	Mexico	Netherlands	NZ	Norway
1	10.38%	0.00%	0.49%	0.41%	0.37%	0.36%	1.97%	4.39%	0.00%	0.00%	2.33%	1.76%
1.1	11.21%	0.00%	1.44%	1.01%	0.66%	0.68%	2.90%	4.48%	0.60%	2.79%	3.05%	3.62%
1.2	11.48%	0.00%	1.90%	1.38%	1.32%	0.68%	3.64%	4.53%	1.20%	4.26%	3.54%	3.97%
1.3	11.98%	0.00%	2.15%	1.42%	1.51%	0.68%	4.77%	4.58%	1.80%	4.41%	3.97%	3.97%
1.4	12.70%	0.00%	2.40%	1.56%	1.78%	0.68%	5.09%	4.63%	2.39%	4.49%	4.13%	3.97%
1.5	13.45%	0.00%	3.28%	1.73%	1.89%	0.68%	5.09%	4.65%	2.93%	4.58%	4.15%	3.97%
1.6	14.15%	0.00%	3.45%	1.88%	1.96%	0.68%	5.09%	4.65%	3.42%	4.62%	4.18%	3.97%
1.7	14.65%	0.00%	3.45%	2.00%	1.96%	0.68%	5.09%	4.65%	3.92%	4.65%	4.34%	4.06%
1.8	14.85%	0.00%	3.45%	2.12%	1.96%	0.68%	5.09%	4.65%	4.41%	4.72%	4.52%	4.19%
1.9	14.93%	0.00%	3.45%	2.24%	1.97%	0.68%	5.09%	4.65%	4.90%	4.83%	4.62%	4.32%
2.0	15.01%	0.00%	3.45%	2.32%	1.98%	0.68%	5.09%	4.65%	5.40%	4.94%	4.72%	4.47%

Scale Ratio	Poland	Portugal	Slovakia	Slovenia	Spain	Sweden	Switzerland	Turkey	UK	US
1	4.34%	0.00%	10.01%	2.89%	0.00%	0.00%	0.00%	9.46%	2.21%	2.68%
1.1	5.53%	0.95%	11.12%	3.97%	0.43%	0.31%	0.13%	10.31%	2.87%	4.90%
1.2	6.74%	1.31%	12.00%	5.15%	0.57%	0.61%	0.26%	11.26%	3.24%	5.23%
1.3	7.28%	1.67%	12.50%	5.71%	0.60%	0.92%	0.40%	11.95%	3.53%	5.60%
1.4	7.76%	1.98%	13.38%	5.94%	0.64%	1.23%	0.53%	12.57%	3.79%	6.02%
1.5	8.43%	2.21%	14.30%	6.18%	0.66%	1.54%	0.66%	13.35%	3.96%	6.25%
1.6	9.14%	2.50%	14.74%	6.53%	1.05%	1.80%	0.79%	14.03%	4.03%	6.52%
1.7	9.67%	2.91%	14.74%	6.53%	1.06%	2.00%	0.94%	14.77%	4.14%	6.60%
1.8	10.14%	3.15%	14.74%	6.53%	1.06%	2.19%	1.09%	15.21%	4.17%	6.68%
1.9	10.86%	3.36%	14.74%	6.53%	1.07%	2.39%	1.24%	15.45%	4.20%	6.77%
2.0	11.42%	3.56%	14.74%	6.53%	1.09%	2.59%	1.39%	15.65%	4.21%	6.85%

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