Taking into account environment : Re-ranking of the OECD countries healthcare systems using a stochastic frontier analysis [*]

By Armel Ngami [†]

Abstract

Efficiency analyses have been widely used in the literature to rank countries regarding their health system performance. However, little place has been given to the environmental aspect in that literature. Therefore, two countries with the same characteristics could experience completely different healthcare system outcomes just because they do not have the same level of pollution, which is a major determinant of inhabitants' health. This paper analyses the effect of the environmental quality on the OECD countries' health system outcome, measured by the life expectancy at birth. Using a stochastic frontier model, we show that the longevity league table of OECD countries changes significantly whether the environmental index is taken into account or not. This, once again, underlines the critical importance of the environment when addressing health issues.

JEL Classification C33 ; I12 ; I18 ; Q56.
Keywords Health, Healthcare system efficiency, Health Production Function, Environment, Stochastic Frontier Analysis, Panel Data.

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†. Corresponding author
Aix-Marseille University, CNRS, EHESS, Centrale Marseille, AMSE
5-9 Boulevard Bourdet, CS 50498, 13205 Marseille Cedex 1, France
e-mail : armel.ngami@univ-amu.fr

1 Introduction

Since the beginning of this century, there is a growing literature on the issue of health systems efficiency. This notion reflects the best way for a country to take advantage of several inputs or factors such as health expenditures, the level of education, etc. in order to produce the best health output for its population. With this in mind, countries could therefore be compared with respect to the extent to which this goal is achieved. For instance, in 2014, per capita, the US are 35% richer and spend almost twice more on health than France, but the life expectancy at birth is almost 4 years longer in France than in the US.

In the same time, the place devoted to environment in health system performances studies is tiny, despite the extensive literature that documents the relationship between the environment quality and individuals health status (Evans and Smith, 2005). Pollution is one of the major causes of diseases and was responsible of 9 million premature deaths around the world in 2015 (Landrigan *et al.*, 2018). Conversely, preserving ecosystem such as forests fosters health by improving air quality.

A study by World Health Organization (WHO) in 2000 was the first to propose an assessment and ranking of all national health system performances (Tandon *et al.*). The approach was to estimate a fixed-effect panel data model, with education and health expenditures as independent factors, to assess the time-invariant country health system inefficiency. This generated much debate and several authors afterwards suggests alternative methods, such as data envelopment analysis (Hollingsworth and Wildman, 2003) or stochastic frontier analysis (Ogloblin, 2011), to correct the WHO seminal study shortcomings.

Nevertheless, none of these studies includes the environmental quality as a factor of the health production process. Then, ranking health system efficiency accordingly could give an incomplete picture of the strengths and weaknesses a health care system has to account for. That is, a country could perform better than another with the same characteristics, just because it has a gifted environmental assets such as green forests that improve the air quality, several rivers to produce hydroelectricity that is carbon-free. On the contrary, it is more challenging to foster health in an area where air pollution is endemic and a part of the population does not have access to adequate sanitation facilities.

In this paper, we analyse the effects of the environment quality on healthcare system efficiency of OECD countries. Moreover, our aim is to highlight the changes in countries ranking when taking into account environment, with respect to WHO-like healthcare system performance league tables. [1]

For this purpose, we build a stochastic frontier model (SFA) that estimates the maximum potential health outcome a country can reach, together with how far the country is actually from that frontier. To assess environmental quality, we take advantage of an environmental performance index (EPI) documented by Wendling *et al.* (2018). Regarding the health system output, we will consider in a first step the life expectancy at birth for its availability and its quite intuitive interpretation. After this benchmark model, other health measures will be reviewed, such as the potential years of life lost, the health-adjusted life expectancy and finally an composite index of health output indicators.

The remainder of the paper proceeds as follows. The next section describes the theoretical rationale of the stochastic frontier model. Section 3 presents the data, especially the environmental performance index (EPI). Section 4 estimates health production function with no environmental dimension and Section 5 analyses the effects of environment on the healthcare system performance. Section 6 concludes.

1. See WHO (2000).

2 The Health production function

Let y_{it} the actual health outcome, for instance the life expectancy at birth, and x_{it} the inputs to the health care system.[2] Let also assume that health production function can be represented by a Cobb-Douglas function and there exists some inefficiencies in the process of producing health outcome. Therefore, the observed health outcome is defined by :[3]

$$y_{it} = f(x_{it}, \beta) exp(v_{it} - u_{it}) = A\, x_{it}^{\beta}\, exp(v_{it} - u_{it}) \tag{1}$$

v_{it} represents random errors or shocks that can affects the health production function. The are independent and identically distributed (iid) and follows a normal distribution $\mathcal{N}(0, \sigma_v^2)$. u_{it} is the inefficiency term, a non-negative iid term following the normal distribution $\mathcal{N}(\mu_{it}, \sigma_u^2)$.

Because u_{it} is non-negative and v_{it} is a zero-mean error, the (estimated) technical efficiency, TE_{it}, expressed in percentage, is given by :[4]

$$\widehat{TE}_{it} = exp(-\hat{u}_{it})$$

The econometric model equation is obtained by a log-transformation of the production function (1) :

$$Y_{it} = \alpha + \beta\, X_{it} - u_{it} + v_{it} \tag{2}$$

where $\alpha = ln(A)$, $Y_{it} = ln(y_{it})$ and $X_{it} = ln(x_{it})$. Therefore, the estimation for the frontier value is :

$$\widehat{FE} = exp(\hat{\alpha} + \hat{\beta}\, X_{it})$$

The inefficiency in the process of producing health, u_{it}, may depend on a set of other factors Z_{it} and its mean can be expressed as $\mu_{it} = \lambda\, Z_{it}$ and we have :

$$u_{it} = \lambda\, Z_{it} + w_{it} \tag{3}$$

where w_{it} is an iid truncated normal error $\mathcal{N}(0, \sigma_u)$. The truncation point is $-\lambda\, Z_{it}$.

2. For the sake of simplicity, a Cobb-Douglas production function has been chosen. One could have assume a more general function such as a transcendental logarithmic one and the underlying rationale still holds.

3. See Battese and Coelli (1992).

4. $\widehat{\ }$ means an estimated value.

3 Determinants of health outcomes

In this section, we describe the components of the health production function. First, we present the health determinants known from previous studies and afterwards, we present the data treatment we carry out and give some descriptive statistics of all variables.

3.1 Health inputs from the literature

The potential variables that can be included in the frontier are :

— Alcohol Consumption : It is the number of liters of pure Alcohol consumed by an adult in a year. Expected sign (-)

— Health Expenditures : It is the amount of money devoted to health per capita, in current PPP. Expected sign (+)

— Tertiary Educational Attainment : It is the percentage of the population aged 25 to 65 that have successfully completed tertiary studies (e.g. university, etc.). Expected sign (+)

— Obesity Prevalence : It is the percentage of the population with a Body Mass Index (BMI) larger or equal to 30. Expected sign (-)

— EPI : It is the Environmental Performance Index, ranges from 0 to 100. It measures the environment quality in a country. Expected sign (+)

Regarding the inefficiency potential explanators :

— GDP per capita : It is a proxy of income. Expected sign (-)

— Share of Public Health Expenditures : It is a percentage that gives the importance of the public actors in the health system. Expected sign (-)

— Gini Index : It ranges from 0 to 100,. it gives the level of income inequality in the country. Expected sign (+)

— EPI : The environmental Performance Index. Expected sign (-)

— Out-of-pocket expenditures : Expected sign (+)

3.2 Data treatment

The data used in this paper comes primarily from the OECD statistical database. The share of public health expenditures and the Gini index have been drawn from World Development Indicators (WDI) of the World Bank. The WHO database provide the prevalence of obesity for each country. Finally, the environmental performance index (EPI) have been constructed by the *Yale Center For Environmental Law and Policy*.

Our sample is made up of all OECD countries, except for Colombia, that joined the organization in 2020. That corresponds to 36 countries observed from 2007 to 2016. The observation period starts from 2007 to avoid a potential structural change issue due to the economic crisis. We assume that the underlying mechanism that governs health system performances is the same around 2007 onwards.

All the variables included in the model have been log-transformed, in order to interpret parameters estimation as elasticities. Some of them had a few missing values and we used a simple country linear trend model to impute variables. This applies to around 5% of observations in our database.

3.3 Descriptive Statistics

To have a first glimpse at the health production process, we present some summary statistics on all the variables included in the stochastic frontier analysis in the Table 1.

Variables	Obs	Mean	Std. Dev.	Min	Max
Life expectancy at birth	360	79.72	2.84	70.8	84.1
GDP per Capita	360	35,910	13,603	14,728	92,302
Gini Index	360	33.03	5.38	23.7	49.9
Health Exp per capita	360	3,236	1,617	733	9,904
Share Public Health Exp	360	73.03	9.62	43.64	86.46
Out-of-pockets Expenditures	360	20.56	8.77	7.89	52.50
Alcohol Consumption	360	9.28	2.70	1.3	14.8
Obesity Prevalence	360	21.34	5.70	2.9	36.2
Tertiary Educational Attainment	360	31.67	9.90	11.29	56.27

TABLE 1 – Summary statistics

Over the period of study, the life expectancy at birth is on average of eighty years (79.72), and varies from 70.8 in Latvia in 2007 to 84.1 years in Japan in 2016. This figures indicate a health output distribution skewed towards higher values, and correspond to developed countries. Thus, on average the GDP per capita is around 36,000 *US*$ and can even reach more than 3 times this amount in Luxembourg.

It is noteworthy that Mexico, the country with the highest income inequalities over the period of study, is also the poorest one, and it does not perform well in terms of health system outcome, with a life expectancy at birth of just 74.5 years. In addition, it is one of the countries with the lowest health expenditures per capita, maybe because the share of health expenditures supported by patients is very high ($52,5\%$). On the contrary, the US, the country with the highest health spending per capita ($9,904$ $US\$$) has a longevity below the average (78.6), despite the Affordable Care Act that came into effect in 2014, slightly decreasing the already high out-of-pockets health expenditures. Before that reform, the US was in the lower tail of the share of the public health expenditures.

Regarding the lifestyle, the US is the country where obesity is the most prevalent (36.2%) whereas Japanese are the slimmest of our sample (2.9%). Estonia, with 14.8 liters of pure alcohol consumed by an adult in a year, is the country with the highest alcohol consumption in our sample. Yet, this a associated with an lifespan below the average, just 76 years. Finally, with $56,27\%$ of its population with at least a tertiary education level, Canada is the country with the highest level of education, and this is associated with a life expectancy at birth of 81.3 years on average.

3.4 The environmental performance index

The environmental performance index (EPI) is an indicator produced since 2006 by *Yale Center for Environmental Law and Policy* that evaluates and ranks country with respect to their performances in environmental goal attainment. The index is made up of two components : the environmental health and the ecosystem vitality (Wendling *et al.*, 2018). The first component measures threats to environmental health and includes indicators like the fine particles exposure and the access to improved sanitation or to drinking water. The ecosystem vitality gauges the natural resources and ecosystem services. It encompasses indicators like the percentage of forest lost, the intensity of methane and CO2 emissions and the percentage of species living in a protected area (Figure 1).

The EPI ranges from 0 to 100, with 100 the highest possible score in achieving environmental goals. Over the period 2007 - 2016, the average score is 83.43 with a standard deviation of 5.61 (Table 2). The EPI distribution is concentrated and the minimal score, reached by Turkey in 2008 is rare. It is also the country that performs the least with respect to the environment according to EPI in 2013 and 2014. The top-5 countries of the EPI distribution in 2013 (Finland, Iceland, New Zealand, Sweden, UK), all have an above-the-average life expectancy. Let us also note that the US are ranked outside the top 20, both in 2013 and in 2014, largely due to their poor performance in terms of ecosystem vitality.

EPI	Obs	Mean	Std. Dev.	Min	Max
2007 - 2016	360	83.43	5.61	59.74	90.86
2013	36	83.53	5.66	64.49	90.59
2014	36	84.11	5.55	65.71	90.72

TABLE 2 – Summary statistics of the environmental perdormance index

4 Results

4.1 The SFA model estimation

The table 3 reports the results of the estimated stochastic frontier (Equation 2). First, a model with no environmental dimension (Model 1), the alcohol consumption and the prevalence of obesity are the main determinants of the frontier of health production function. Both have an elasticity of around -0.01, meaning that a rise by 1% of the alcohol consumption is associated with a decrease in the potential life expectancy at birth by 0.01%, in our sample, over the period 2007 - 2016. This could represents a month lost of life expectancy for a country like France. The effect of the health expenditures per capita is positive, but small and not statistically significant. The magnitude of this effect is in line with the findings of Ogloblin (2011) and Tandon *et al*. (2000), that the elasticity of health outcome with respect to health spending is very low. It seems that the level of education is not an important factor for the health outcome, as it is not statistically significant. This may be because the share of people that have a tertiary educational level is a less relevant education indicator than the share of people that have at least a high school diploma, when it comes to health.

Regarding health systems inefficiencies, all factors are statistically significant to explain health care performance across countries. The level of income seems to be the main factor of performance of health system. In our sample, the richer a country is, the more efficient its healthcare system is, over the period of study. This might be explained by the fact that wealthy countries benefit from more medical facilities, both public and private, and they are well-equipped in term of cutting-edge medical technology that preserves life. Conversely, a higher share of out-of-pocket expenditures in total health spending are related to lower performances of healthcare system. Indeed, this could dissuade ill people, especially poor, to go to hospital when necessary. They get to a health service only when they are in advanced stage of the disease, with a reduced chance of recovery.

A wider public health system is associated with more inefficiencies. This is contrary to expectations because one would think that a greater share of public health expenditures in the total health spending would result in an improved access to healthcare. However, this result may support the criticism of a public intervention that overlook individuals preferences and comes up with inefficiencies. Finally, the model also indicates that higher inequalities are associated with less inefficiencies, as the Gini index parameter is strongly statistically significant. This is surprising and contrary to expectations that a more unequal society hampers the access to healthcare for a significant share of the population.

These surprising results may be due to the sample mostly made up of rich countries. Another possible explanation could be the health output measures. Some critics have said that the life expectancy at birth is not a good health measure because it encompasses a lot of country history and does not give the full picture of recent health systems improvements.

Model 1 does not include the environmental dimension, that may change the efficiency estimation or the maximum attainable health output.

4.2 Taking into account environment

From Model 1 of Table 3, we can add the EPI either in the frontier (Model 2) or in the inefficiency term u_{it} (Model 3). Both models are statistically significant to explain the countries life expectancy at birth over the period of study. Taking into account the environment, significant factors in the health production process remain the same than in Model 1, but the magnitude of their effects is modified.

As expected, the EPI parameter is statistically significant in both model 2 and 3. This means environment is a relevant factor when studying OECD countries health system performance. With EPI in the frontier, a 1%-increase of the environmental quality index goes along with a rise by 0.125% of the life expectancy at birth. Therefore, all else equal, a country that preserves ecosystems and promotes the renewable energy can reach a higher maximum health output. On the contrary, a too polluted environment fosters health system inefficiencies.

The elasticity of health output with respect to the alcohol consumption is greater in Model 2 (0.0017%) and 3 (0.0016%), compared to model 1. We have the same findings regarding obesity, that is, an increase by 1% of the obesity rate in a country is associated with a decline by 0.017% (Model 2) or 0.014% (Model 3) of the life expectancy at birth. With respect to these two inputs, incorporating the environment results in a shortening of the maximum attainable health output. Despite a small increase in Model 3 compared to Model 1, the effects of health expenditures are still not statistically significant, as well as the level of education. The latter has a decreasing effect on longe-

Dependent Variable : *Life Expectancy at birth*

Frontier	Model (1)	Model (2)	Model (3)
Alcohol Consumption	-0.010^{***}	-0.017^{***}	-0.016^{***}
	(-3.46)	(-5.71)	(-4.95)
Health Exp per capita	0.001	0.001	0.003
	(0.48)	(0.29)	(0.76)
Obesity Prevalence	-0.011^{***}	-0.017^{***}	-0.014^{***}
	(-5.58)	(-8.71)	(-6.63)
Tertiary Educ Attainment	0.028	-0.018	0.027
	(0.47)	(-0.38)	(0.55)
Tertiary Educ Attainment^2	-0.004	0.002	-0.005
	(-0.65)	(0.25)	(-0.70)
EPI		0.125^{***}	
		(7.12)	
Inefficiency			
GDP per Capita	-0.229^{***}	-0.208^{***}	-0.193^{***}
	(-12.75)	(-12.02)	(-12.17)
Share Public Health Exp	0.174^{***}	0.183^{***}	0.175^{***}
	(4.64)	(4.43)	(4.18)
Gini Index	-0.127^{***}	-0.136^{***}	-0.135^{***}
	(-7.66)	(-8.02)	(-8.33)
OOP	0.071^{***}	0.082^{***}	0.082^{***}
	(4.85)	(4.92)	(4.74)
EPI			-0.133^{***}
			(-4.87)
Number of Obs	360	360	360
Wald			

*, **, *** *indicate that the coefficient is significant respectively at* 10%, 5% *and* 1%.

TABLE 3 – Estimates of the Stochastic Frontier model with out-of-pocket expenditures

vity in Model 2 whereas the relationship between the two are concave in other models.

Regarding the inefficiency term, including environment lessens the elasticity related to GDP per capita. From 0.229 in model with no environmental consideration, it falls to 0.193 in Model 3. The magnitude of the effects of the share of public expenditures and of the income inequalities are almost unchanged, with a slight increase compared to the values in the baseline model. A climb by 1% of the share of out-of-pocket health expenditures is associated with a decrease by 0.082% of the health output in Model 2 and 3, compared to 0.071% in the baseline model.

After presenting the econometric estimations of the SFA models, we will now rank countries performances accordingly, to check whether or not their ranking may be modified when the environment is included in the analysis.

4.3 Ranking healthcare systems efficiency

Figure 11 ranks OECD countries with respect to their health system efficiency scores in 2014. We have not chosen 2016 estimations because data at the edge of the observation period can still be subject of up-to-date modifications by their providers a few months or years later. That is why results for that year must be interpret with caution. For each of the three econometric models, we have the corresponding ranking, along with the histogram in descending order of the heath system efficiency (Figure 11). The figure suggests countries at the top are very close in terms of health performance, whatever the model, and efficiency decreases steadily at the bottom of the distribution.

In a model with no environmental dimension, Luxembourg and the US are at the top of the health performance league table. In 2014, their observed health output corresponded respectively to 99.93% and 99.92% of their maximum potential life expectancy at birth. The remaining represents respectively a lost of 20 and 24 days of life due to inefficient process (Figure 13). [5] Western and northern Europe countries are over-represented at the top whereas eastern countries are relegated to the bottom of the distribution. More than half of health systems reached at least 99% of their potential output in 2014. The least performing country is Mexico with 91.4% of efficiency. France held the 7^{th} place corresponding to almost a month and a half of longevity lost due to inefficiencies.

When including environment in the frontier, the health system performance distribution is more concentrated than in model with no environmental consideration. It ranges from 91.9% to 99.93% with Luxembourg still at the top and Latvia at the bottom. For low performing countries, it seems that adding environment narrows the

5. Considering a 30-day month.

gap between their actual health output and the frontier, as the bottom 10 countries are doing better in Model 2 than in Model 1, in terms of efficiency. The US are still at the 2^{nd} position and the podium remains the same compared to the model with no environmental dimension. France climbs two places in the ranking even though its health efficiency score has not changed. Belgium improved its rank the most, jumping up 4 places in the ranking. Israel and Turkey also advance two positions in the league table. On the contrary, Scandinavian countries lose the most. Norway, Denmark and Iceland drop by 3 ranks compared to their rankings with Model 1.

When environment is considered as an inefficiency factor, the health system performance league table is still dominated by Luxembourg and the USA in 2014 whereas Latvia and Mexico bring up the rear with respectively 92.15% and 91.08% of their potential health output attained. The greatest jump in the ranking is from New Zealand that moved up 5 places from the ranking with no environmental dimension. Japan and Israel lost 3 ranks with model 3 compared to Model 1.

In this subsection, we focus on the health system efficiency in 2014. However, that does not say much on its dynamics and can overlook potential improvements in the health production process.

Conclusion

The aim of this analysis was to In this paper, we study the effect of environment on health system efficiency for OECD countries over the period 2007 - 2016. For that purpose, we estimate a stochastic frontier model in which an environmental index is included either in the frontier or in the inefficiency term. We find that environment is a major determinant of the health production function. When it is taken into account, the elasticities related to other health factor such as obesity, alcohol or the Gdp per capita are significantly changed. Countries health system ranking is also altered. This may indicate that adding environment helps to better capture the maximum attainable health output. Therefore, without environment, some countries does not perform well, only because they are not endowed with the same area of green trees like an other with the same characteristics. That also explain why countries at the bottom of the league table in previous study get better efficiency score when environment is included.

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Appendix

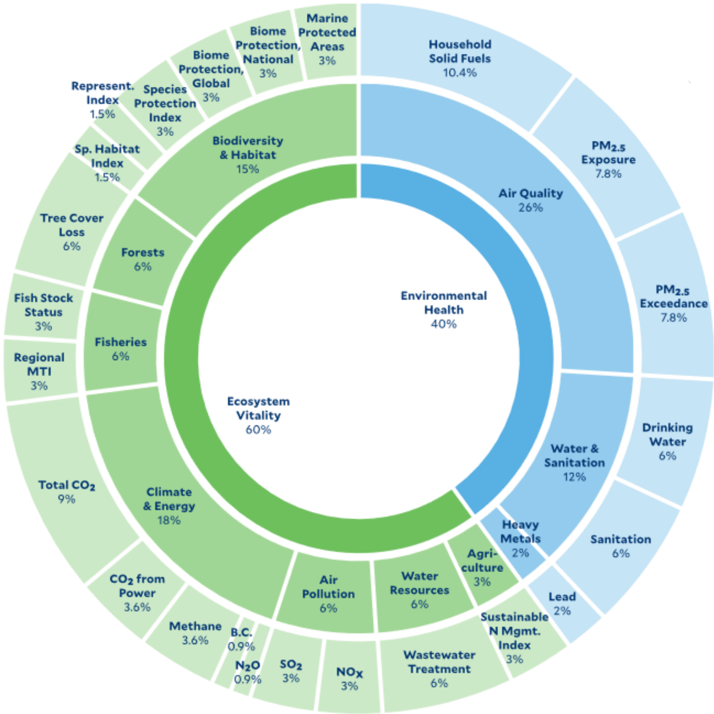


FIGURE 1 – Components of the Environmental Performance Index (Wendling *et al.*, 2018)

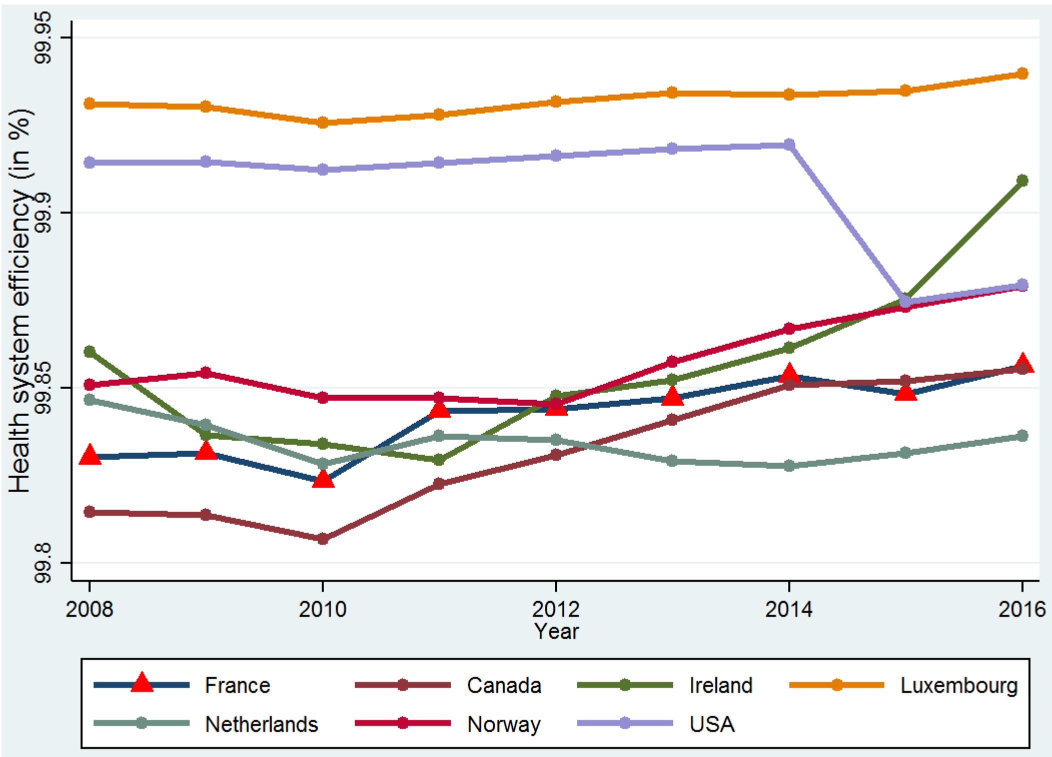


FIGURE 2 – The dynamics of the performance of health systems in top performing countries, with the model (1)

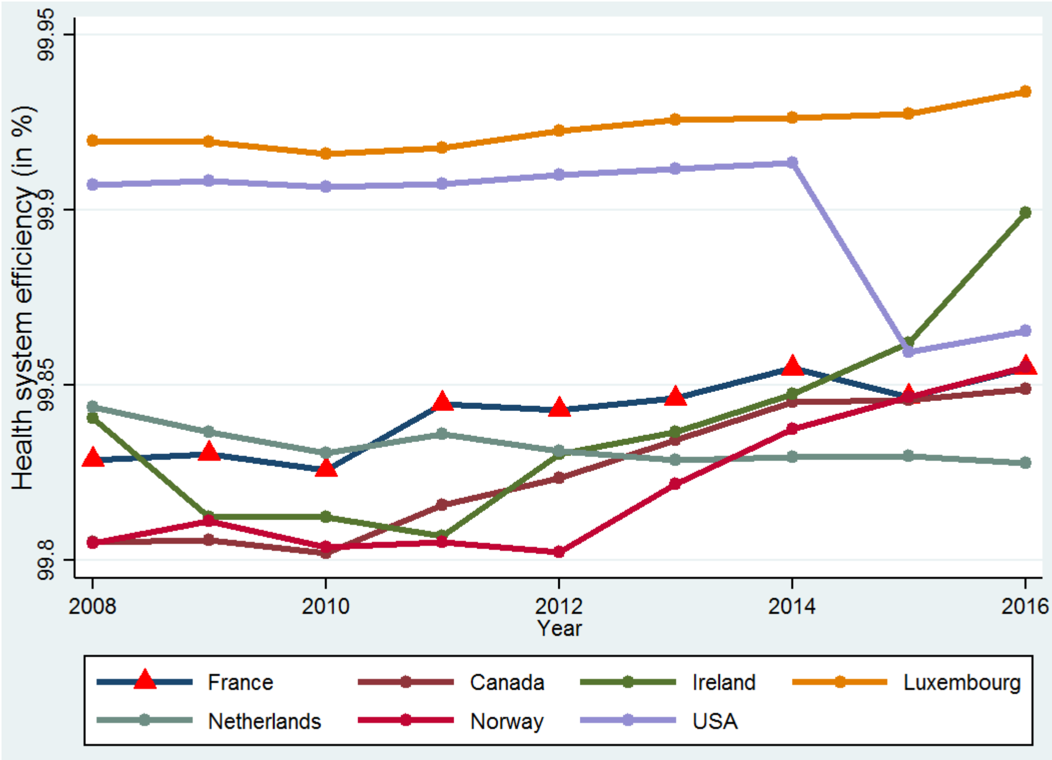


FIGURE 3 – The dynamics of the performance of health systems in top performing countries, with the model (2)

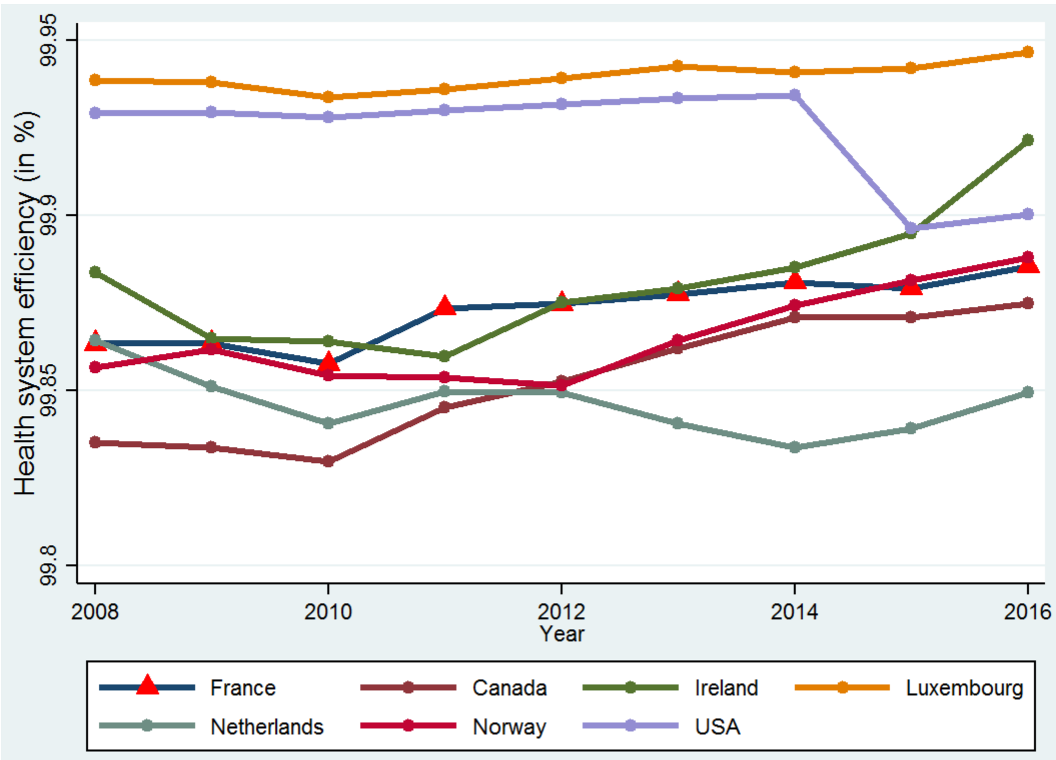


FIGURE 4 – The dynamics of the performance of health systems in top performing countries, with the model (3)

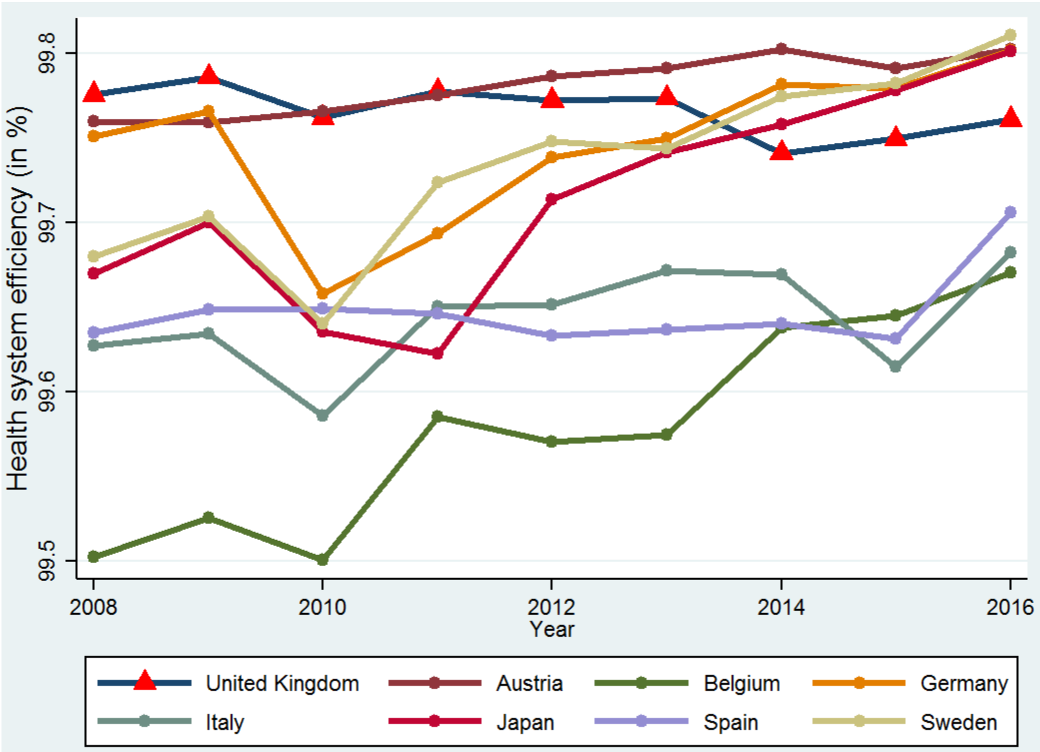


FIGURE 5 – The dynamics of the performance of health systems in medium performing countries, with the model (1)

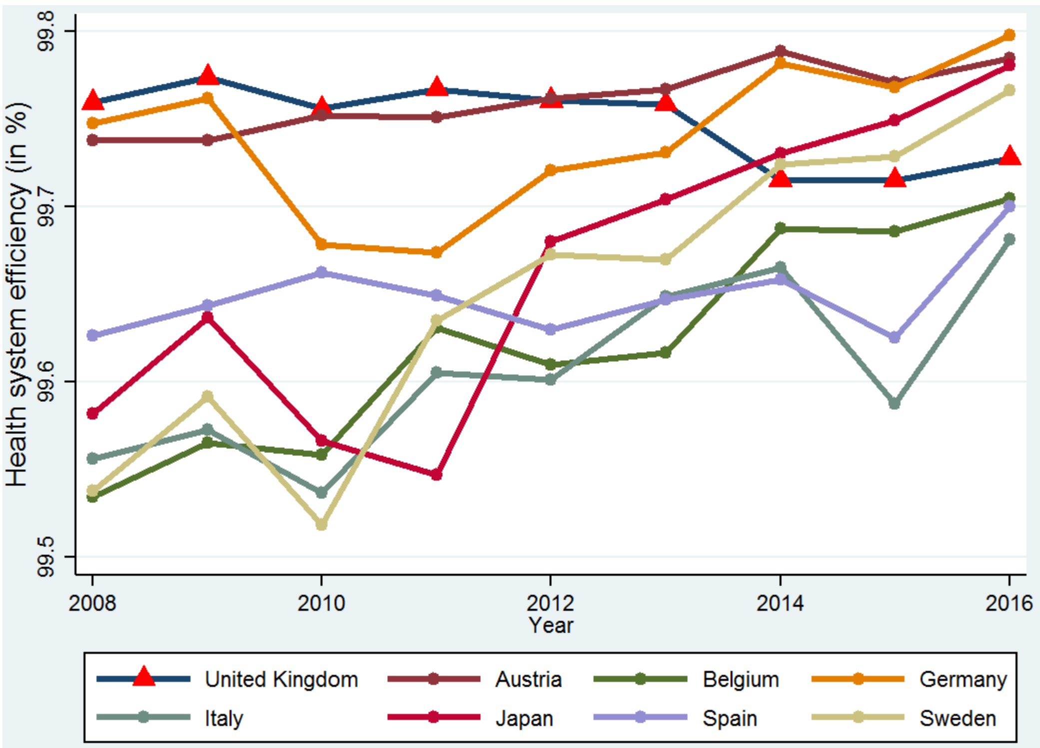


FIGURE 6 – The dynamics of the performance of health systems in medium performing countries, with the model (2)

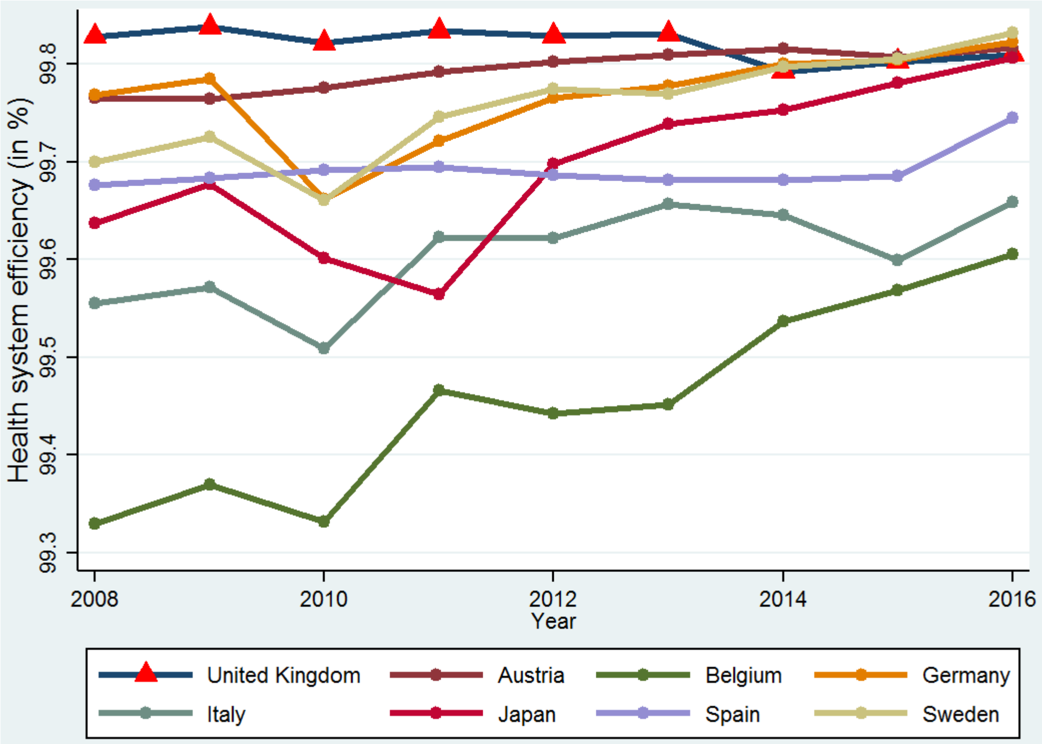


FIGURE 7 – The dynamics of the performance of health systems in medium performing countries, with the model (3)

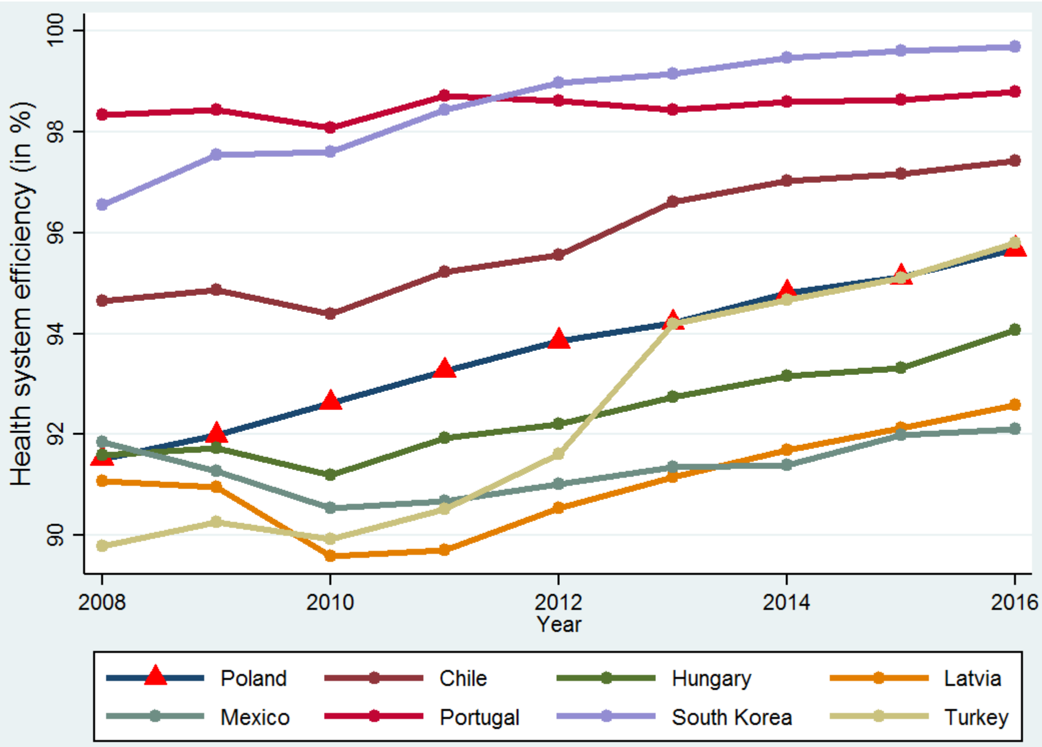


FIGURE 8 – The dynamics of the performance of health systems in low performing countries, with the model (1)

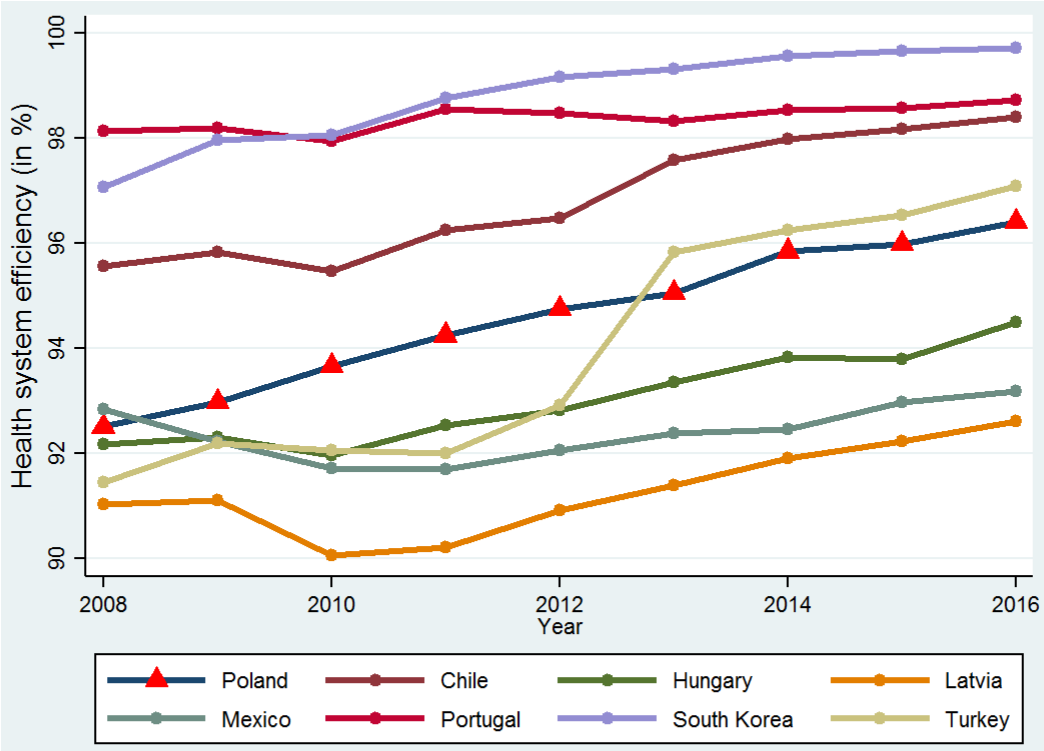


FIGURE 9 – The dynamics of the performance of health systems in low performing countries, with the model (2)

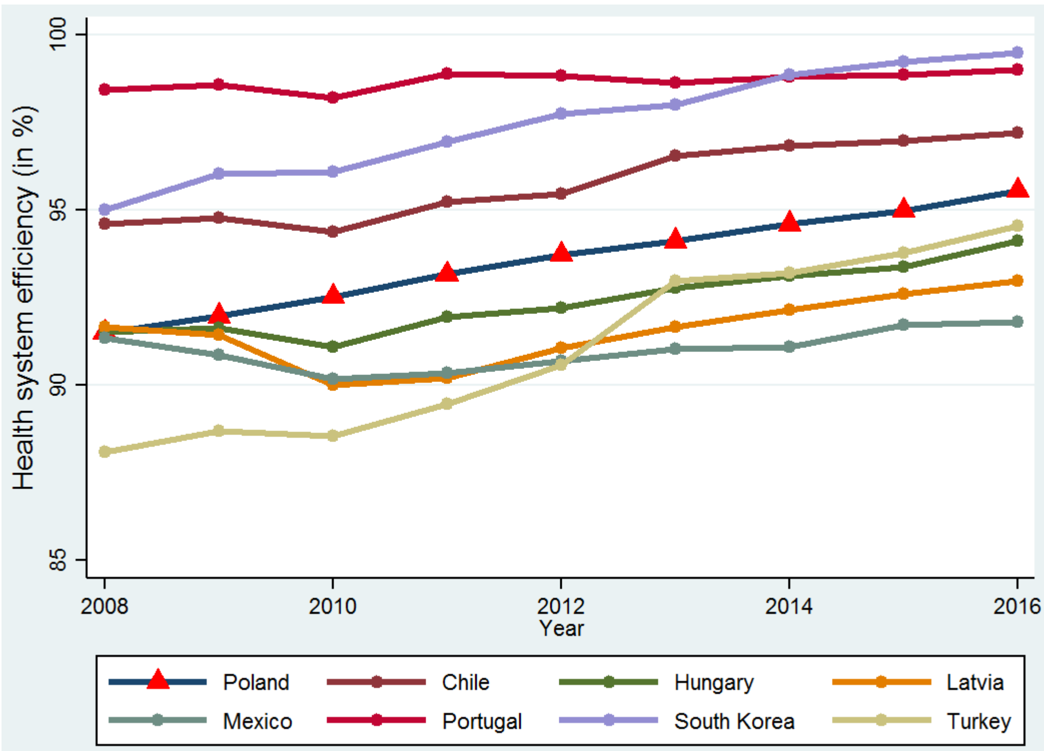
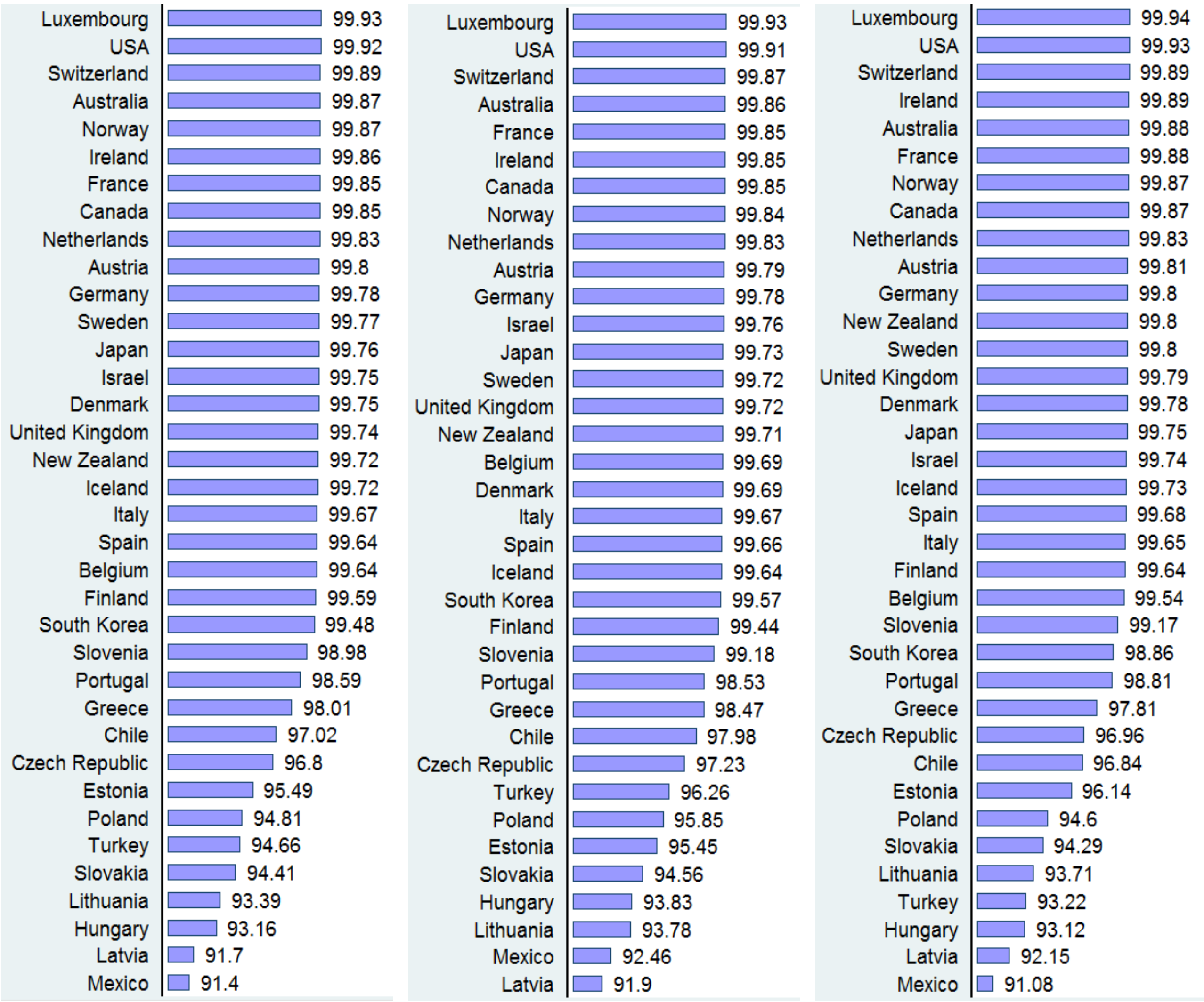
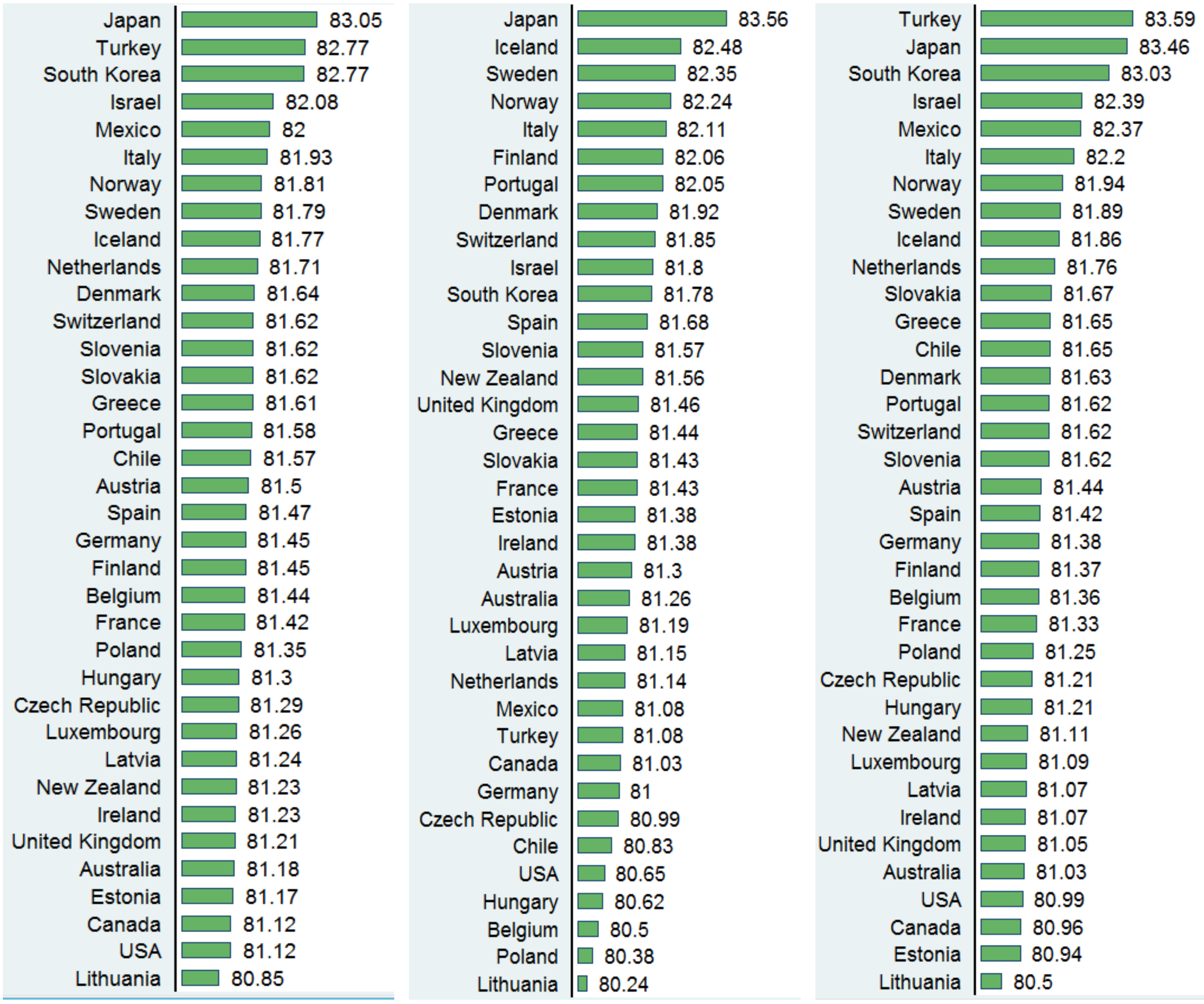


FIGURE 10 – The dynamics of the performance of health systems in low performing countries, with the model (3)



(a) Model (1) (b) Model (2) (c) Model (3)

FIGURE 11 – Health systems Efficiency (in %) from models with out-of-pocket expenditures in 2014



(a) Model (1) (b) Model (2) (c) Model (3)

FIGURE 12 – The frontier of the health system (in years) from models with out-of-pocket expenditures in 2014

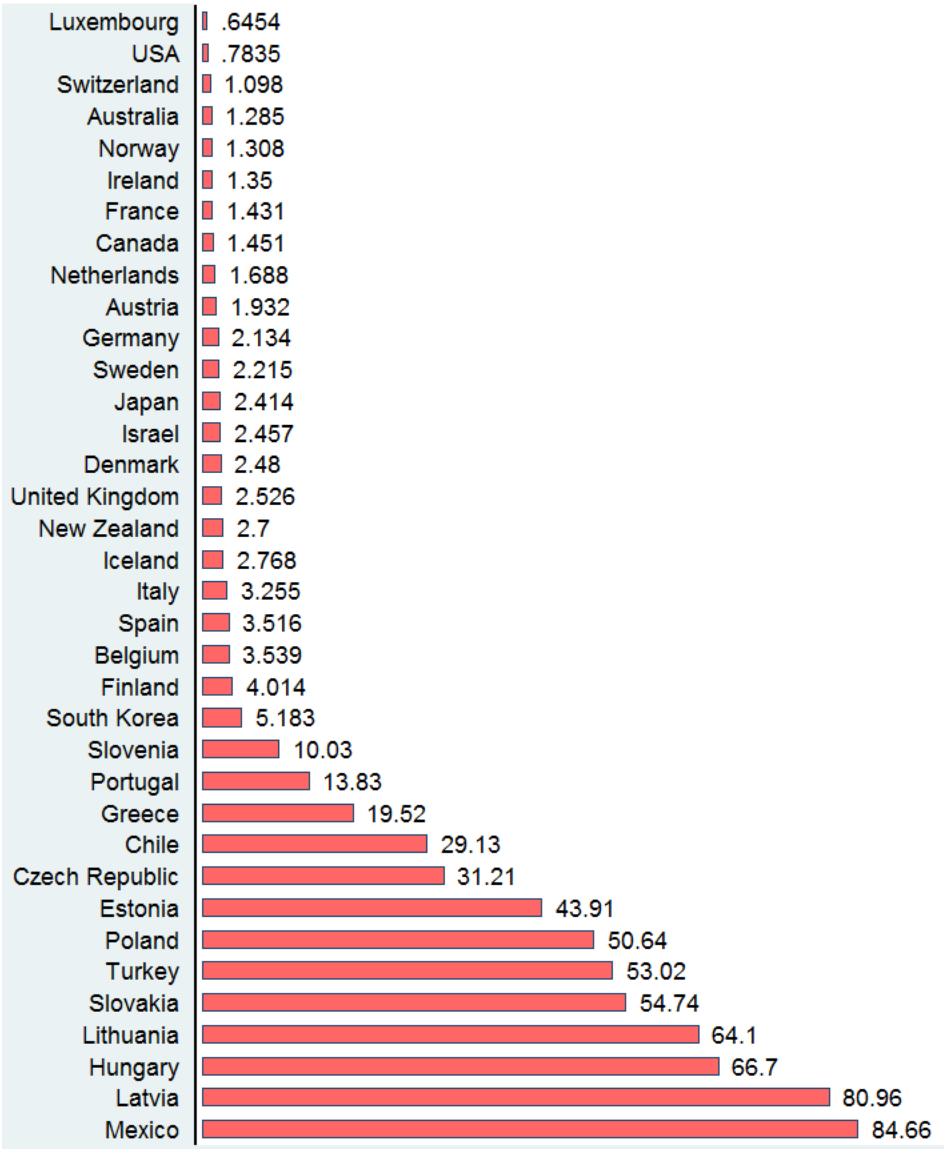


FIGURE 13 – The number of months of life lost due to inefficiencies from models with out-of-pocket expenditures in 2014