International Conference on Business and Economics - Hellenic Open University

Vol 5, No 1 (2025)

Proceedings of the ICBE-HOU 2025

Benchmarking the Efficiency of Health Systems Across the European Union: A Data Envelopment Analysis Approach

Theodora Gesthimani Asimopoulou, Angeliki Flokou, Panagiotis Theodorou, Vassilis Aletras, Dimitris Niakas

To cite this article:

Asimopoulou, T. G., Flokou, A., Theodorou, P., Aletras, V., & Niakas, D. (2026). Benchmarking the Efficiency of Health Systems Across the European Union: A Data Envelopment Analysis Approach . *International Conference on Business and Economics - Hellenic Open University*, *5*(1). Retrieved from https://eproceedings.epublishing.ekt.gr/index.php/ICBE-HOU/article/view/9735

Benchmarking the Efficiency of Health Systems Across the European Union: A Data Envelopment Analysis Approach

Theodora Gesthimani Asimopoulou[1], Angeliki Flokou[*2], Panagiotis Theodorou[3], Vassilis Aletras[4], Dimitris Niakas[5]

[1] School of Social Sciences, Hellenic Open University, Patras, Greece
E-mail: std166497@ac.eap.gr
[2] School of Social Sciences, Hellenic Open University, Patras, Greece
E-mail: flokou.angeliki@ac.eap.gr
[3] School of Social Sciences, Hellenic Open University, Patras, Greece
E-mail: panostheodor@yahoo.gr
[4] School of Social Sciences, Hellenic Open University, Patras, Greece &
Department of Business Administration, School of Business Administration, University of Macedonia
E-mail: valetras@uom.edu.gr
[5] School of Social Sciences, Hellenic Open University, Patras, Greece &
Medical School, National and Kapodistrian University of Athens
E-mail: dimitris.niakas@gmail.com

Abstract

Between 2014 and 2022, the European Union faced a series of complex challenges, stemming, on the one hand, from the prolonged effects of the 2008 financial crisis and, on the other hand, the outbreak of the COVID-19 pandemic, which caused profound social and economic changes. In response to these pressures, healthcare systems across the EU underwent significant adjustments — both in terms of structural organization and financing — under the guidance of policymakers. Amidst this socioeconomic turmoil, performance evaluation has emerged as a critical means of safeguarding the operational integrity of healthcare systems and ensuring the continued quality of healthcare delivery. As part of this effort, Data Envelopment Analysis (DEA) has proven to be a particularly valuable tool, as it assesses the extent to which inputs are effectively converted into outputs, allowing for both cross-country comparisons and the detection of improvements in performance. This study aims to evaluate the technical efficiency of the 27 EU Member States by applying DEA models under the assumption of constant (CRS), variable (VRS), non-increasing (NIRS), and non-decreasing (NDRS) returns to scale. The objective is to identify fully efficient countries, investigate the possible causes of inefficiency, and propose policy recommendations to improve the performance of national healthcare systems.

JEL Classifications: C61, D24, H51, I18

Keywords: Health care systems, Efficiency, Data Envelopment Analysis (DEA), Benchmarking, European Union

*Corresponding author: flokou.angeliki@ac.eap.gr

1 Introduction

Over the last decade, European societies have been facing an increasing number of complex challenges that have a significant impact on health systems. The aging population, the increase in chronic diseases that impact living standards, and the COVID-19 pandemic since 2020 have put intense pressure on the restructuring and more rational allocation of available resources. Despite advances in medical science and the development of technologically sophisticated medical equipment, there remains a particularly important need to reduce costs, address human resource shortages, and enhance the efficiency of services provided (Moolla & Hiilamo, 2023).

Over the last decade, European societies have faced an increasing number of complex challenges that have had a significant impact on health systems. The aging population, the rise in chronic diseases affecting living standards, and the COVID-19 pandemic have put intense pressure on the restructuring and more rational allocation of available resources. Despite advances in medical science and the development of technologically sophisticated medical equipment, there remains a critical need to reduce costs, address human resource shortages, and enhance the efficiency of service delivery (Moolla & Hiilamo, 2023).

According to the World Health Organization (World Health Organization, 2016, 2023) the main objectives of health systems include equity and social justice, as well as enabling patients to participate in decision-making and planning their care. Consequently, there is a need to improve services, enhance efficiency, and manage resources effectively, with the aim of improving the quality of health services provided and, ultimately, improving the health of the population.

Systematic evaluation of efficiency is an essential prerequisite for evidence-based and effective decision-making. Current developments highlight the need to modernize and strengthen healthcare systems in order to improve their operational efficiency and ensure higher levels of public health. In this context, the efficient use and fair, evidence-based distribution of resources are key requirements for sustainability and equity in healthcare systems (Mbau et al., 2022).

Our study aims to assess the efficiency of healthcare systems in the 27 Member States of the European Union (EU-27), reflecting the EU composition after 2020, following the withdrawal of the United Kingdom. To ensure a consistent country set across the analysis, the United Kingdom is excluded from all calculations, including the 2014 reference year, although the EU formally comprised 28 Member States at that time. The analysis focuses on the years 2014 and 2022, which were selected as reference years, as 2014 reflects the state of healthcare systems after the effects of the economic crisis, while 2022 reflects the impact of the COVID-19 pandemic on European health systems. These are treated as two separate reference-year snapshots, and the findings are interpreted within each year's context, without implying direct causal comparisons between the two years. Within each reference year, the study adds value by providing an EU-27 benchmarking analysis using a common DEA framework and harmonized data sources, and by applying complementary model variants (CRS, VRS, NIRS/NDRS, and super-efficiency scores).

The remainder of the paper is structured as follows: Section 2 presents the literature review; Section 3 states the research question(s) and hypotheses; Section 4 describes the methodology, data sources, and variables; Section 5 presents the results; and Section 6 discusses the findings, implications, and conclusions.

2 Research questions

This study addresses two research questions assessed separately for 2014 and 2022.

RQ1: What is the relative technical efficiency of EU-27 health systems under a common DEA specification? This question explores the extent of cross-country variation in efficiency scores within a common production framework and identifies the fully efficient countries that serve as benchmarks for the remaining countries.

RQ2: How does super-efficiency discriminate among fully efficient (frontier) units within each reference year? This question explores whether the super-efficiency approach yields a more refined ranking of frontier countries by identifying differences not captured by the standard DEA model.

3 Literature Review

3.1 Health Systems

A health system "consists of all organizations, people, and actions whose primary purpose is to promote, restore, or maintain health" (World Health Organization, 2007). Under this definition, health systems constitute the institutional and organizational framework for the provision of prevention, diagnosis, treatment, and rehabilitation. They include public and private service providers, regulatory mechanisms, and financing flows (World Health Organization, 2007).

The primary objectives of health systems are to improve the health status of the population, respond to citizens' expectations and needs, and use available resources effectively and equitably, with a view to improving health outcomes (European Commission, 2004; World Health Organization, 2000). Intermediate objectives on the path from consumption of inputs to improved health include enhancing accessibility and coverage of the population, as well as ensuring the quality and safety of the services provided (World Health Organization, 2007).

The performance of health systems is assessed on the basis of criteria such as access, meeting the needs, quality, and safety of services. Regular evaluation of policies and outcomes helps to prioritize and reduce unnecessary spending, although it is often implemented in a fragmented manner. In an environment of intense demographic and epidemiological pressures, the rational use of available resources is crucial, while the evaluation of efficiency is a basic precondition for the smooth functioning and sustainability of health systems (World Health Organization, 2010).

3.2 Understanding Efficiency in Health Systems

Efficiency in the healthcare sector refers to the degree to which productive factors (inputs) are successfully converted into desired outcomes (outputs), i.e., ultimately, into improvements in the health of the population (World Health Organization, 2000). The production process utilizes multiple inputs (financial and human resources, equipment, infrastructure) with the aim of achieving better health as the final output. However, because it is difficult to quantify health quality directly, the measurement of efficiency is often based on intermediate outputs—work output indicators that are comparable in space and time, such as infant mortality rate, life expectancy at birth, healthy life years (HLY) at birth, maternal mortality rate, disability-adjusted life years (DALYs), etc. (Berki, 1972; Butler, 1995; Gómez-Gallego et al., 2021; Mbau et al., 2022; Quentin et al., 2016). This indirectly addresses the ultimate health outcome, while allowing for comparative efficiency assessments between systems, regions, or providers.

Operational efficiency consists of output efficiency and X-efficiency. The former is divided into two sub-types: scale efficiency and scope efficiency. Similarly, X-efficiency is divided into technical X-efficiency and allocative (or price) efficiency (Aletras, 1997).

3.3 Determinants affecting the efficiency of health systems

High levels of funding and, more generally, abundant resources do not automatically translate into greater efficiency or better health outcomes. Positive results are achieved when the health system manages resources rationally, with an appropriate combination of funding methods, market functioning, provider organizational structure, and accountability mechanisms that ensure stability. Beyond that, efficiency is significantly influenced by the profile of the population (demographic and socioeconomic characteristics), the macroeconomic environment at the national level, governance characteristics, and structural features of the health system itself (Cylus et al., 2016; Gavurova et al., 2021; Mbau et al., 2022).

Demographics are a key driver of efficiency. According to a systematic review, a higher proportion of very young or very old people in the population is associated with reduced technical efficiency, as care needs and costs increase (Hajizadeh et al., 2025; Mbau et al., 2022). Population density also affects efficiency, with evidence of both positive and negative effects, depending on the context and circumstances. The challenge remains to align structures with local needs and ensure universal accessibility, regardless of place of residence. As reflected in relevant studies, rural areas more often record lower efficiency due to lower income, underutilization of services, and infrastructure/staff shortages (Flokou et al., 2024; Mbau et al., 2022).

In the socioeconomic dimension, low levels of socioeconomic status, high rates of illiteracy/low educational attainment, and lack of access to basic sanitation infrastructure and safe drinking water are negatively correlated with technical efficiency. These factors increase morbidity, weaken health literacy and prevention culture, and reduce the ability to recognize and address health problems in a timely manner. This results in more serious health consequences and longer-term, more costly care needs for health systems (Anton et al., 2024; Mbau et al., 2022).

The health and well-being of the population directly affect the demand for services and the use of resources. Aging and the absence of effective prevention policies for lifestyle-related diseases (e.g., smoking, increased body weight) lead to higher and more complex use of services— especially towards the end of life—due to multimorbidity and chronic conditions. This translates into greater pressure on facilities and increased costs, with negative consequences for efficiency (Allin et al., 2016; Mbau et al., 2022).

3.4 The impact of the COVID-19 pandemic on the efficiency of health systems

The COVID-19 pandemic has put immense pressure on healthcare systems worldwide. The urgent demand for resources, diagnostic tests, and healthcare personnel—in conditions where capacity was already stretched to the limit—has highlighted the need to redefine input-output relationships and make more rational use of available resources by policymakers (Manavgat & Audibert, 2024).

International literature has examined efficiency in different temporal and spatial contexts, leading to varied findings. In terms of time, some studies have focused on individual years within the pandemic period (Breitenbach et al., 2021; Kuzior et al., 2022; Ordu et al., 2021; Selamzade et al., 2023; Singh et al., 2023; Štěpánek et al., 2021; Yu et al., 2024), others compared periods before and during COVID-19 (Manavgat & Audibert, 2024; Paraschi, 2023), while there are also approaches that have identified distinct phases/waves of expansion and recession (Lupu & Tiganasu, 2022). In terms of grouping, countries were sometimes studied on the basis of geographical or institutional clusters, such as Europe (Lupu & Tiganasu, 2022; Paraschi, 2023; Štěpánek et al., 2021) and the OECD (Manavgat & Audibert, 2024; Selamzade et al., 2023; Singh et al., 2023; Yu et al., 2024), sometimes based on the intensity of the pandemic and infection rates (Breitenbach et al., 2021; Ordu et al., 2021) or the type of financing of the system (Bismarck, Beveridge, or free market) (Kuzior et al., 2022).

In most applications, the number of doctors, nurses, and beds per 1,000 inhabitants, recorded COVID-19 cases, and health expenditures (per capita and as a percentage of GDP) were used as inputs. The outputs used were COVID-19 mortality, recovery rate, number of cases, overall mortality, and life expectancy at birth. The choice of variables was mainly determined by the availability and objectivity of the data, their previous use in efficiency studies, the analytical power of the indicators, and their relevance to the objectives of health systems and the specific research context (Ordu et al., 2021; Yu et al., 2024; Singh et al., 2023; Štěpánek et al., 2021; Pereira et al., 2022; Breitenbach et al., 2021; Lupu & Tiganasu, 2022; Paraschi, 2023; Manavgat & Audibert, 2024; Selamzade et al., 2023).

In most countries, during the pandemic, the average technical efficiency of health systems remained low, with a clear decline compared to pre-pandemic years. Changes were also observed between successive phases of COVID-19, which were reflected both in the number of efficient countries and in the levels of efficiency per country (Lupu & Tiganasu, 2022). In particular, countries that were severely affected at the outset (Italy, Spain, the United Kingdom, Belgium, China, South Korea) improved their efficiency during the recession phases by adopting measures such as lockdowns, mass testing, and information campaigns, without, however, becoming fully efficient (Ordu et al., 2021; Pereira et al., 2022). The opposite trend was recorded in other countries, mainly in Eastern Europe (Lupu & Tiganasu, 2022; Paraschi, 2023). In economically developed countries, indicators showed higher performance in the ability to provide healthcare (Pereira et al., 2022; Yu et al., 2024), but no country showed 100% efficiency over a long period of time to serve as a benchmark (Štěpánek et al., 2021).

Efficiency was influenced by demographic, economic, and social factors, as well as health care models of organization (Singh et al., 2023). Comparatively, Beveridge-type systems showed higher efficiency, followed by Bismarck systems, while market-based systems recorded the lowest performance (Kuzior et al., 2022).

Furthermore, a negative correlation was documented between efficiency and the unemployment rate, the share of the population aged ≥65, and income inequality (Gini index), while high vaccination rates were positively correlated with efficiency. In contrast, GDP had no significant effect on productivity during the COVID-19 period (Manavgat & Audibert, 2024).

Taken together, the literature highlights that health system efficiency is shaped by resource levels, structural characteristics, and contextual shocks, while empirical assessments vary in country coverage, model specifications, and variable choices. This supports the need for a consistent EU-27 benchmarking exercise within clearly defined reference-year contexts, which in turn motivates the research questions and hypotheses presented in the next section.

4. Methodology (Data Envelopment Analysis – DEA)

4.1 Overview of DEA

Data Envelopment Analysis (DEA) is one of the most widely used methods for determining the technical efficiency (TE) of a complex of homogeneous units operating under a common production system. It is a non-parametric method based on the principles of linear programming. Its use focuses on identifying the optimal combinations of inputs and outputs, based on available empirical observations, in order to assess the actual efficiency of the units and rank them comparatively as efficient or inefficient. The subject of the analysis is the Decision-Making Units (DMUs), with the aim of determining the level of efficiency of each unit (Flokou et al., 2024).

Within the context of the DEA method, and based on available empirical data, the relative technical efficiency of DMUs is determined by identifying the optimal combinations of inputs and outputs, according to the following models:

CCR model (named after its creators – Charnes, Cooper, and Rhodes, 1978) in which DEA is applied under constant returns to scale. According to this model, it is assumed that, due to the constant returns to scale under which DMUs operate, an increase in total inputs by a certain ratio implies an increase in output rates by the same ratio, given the production technology (Charnes et al., 1978).

BCC model (from the initials of its founders, Banker, Charnes, Cooper, 1984), according to which not all DMUs operate under constant returns to scale, but in some DMUs production technology is subject to increasing or decreasing returns to scale (Banker et al., 1984).

In this study, each EU country is treated as a DMU, and the DEA models are estimated separately for each reference year (2014 and 2022) using the same EU-27 country set and the same input–output specification in each run (Breitenbach et al., 2021; Lupu & Tiganasu, 2022; Manavgat & Audibert, 2024; Paraschi, 2023; Selamzade et al., 2023).

The selection of the model depends on whether the DMU’s environment operates with scale effects or not. By comparing the efficiency of the DMUs under consideration, an "optimal efficiency frontier" is formed, which is defined by those that are 100% efficient, while those that have an efficiency deficit are outside it. To assess the efficiency of the latter, their radial distance from the frontier is calculated, while their efficiency targets are derived from the points where they project onto the optimal efficiency frontier (Farrell, 1957).

CRS and VRS specifications are reported in parallel to support benchmarking under alternative standard assumptions and to facilitate interpretation of potential differences attributable to scale-related effects.

4.2 Study sample

The study applies Data Envelopment Analysis (DEA) to assess the technical efficiency of health systems in European Union countries (EU-27) as defined after the withdrawal of the United Kingdom (2020). The time frame was chosen to cover the two major crises of the last decade — the economic crisis and the COVID-19 pandemic—through the years 2014 and 2022, which represent periods after the peak of each crisis, when their effects are being reflected in the available primary data.

The analysis uses the two years as separate reference-year snapshots; results are interpreted within each year’s context, without implying direct causal comparisons between 2014 and 2022.

4.3 Data sources

Input and output data were collected from internationally recognized and reliable databases, including Eurostat (via the data browser), the OECD's annual Health at a Glance reports (both those covering OECD countries and those covering Europe in particular), and Index Mundi. The aim was to collect data from widely used and validated databases covering most of the study period and which could be used to supplement missing values for specific years. For example, data on the number of doctors per 100,000 inhabitants for Greece during the study period were not available from Eurostat. Therefore, the corresponding values were retrieved from the OECD's “Health at a Glance” reports.

To enhance replicability, all variables were harmonized to consistent units (per 100,000 population or per capita) and aligned to the same reference year across sources.

4.4 Selection of Inputs and Outputs

The inputs used were the number of hospital beds per 100,000 inhabitants, the number of doctors per 100,000 inhabitants, the number of nurses per 100,000 inhabitants, and per capita health expenditure. Life expectancy at birth, healthy life years, and infant survival rate (ISR) were selected as outputs.

The selections are aligned with the relevant international literature on health system efficiency, as they adequately reflect the process of "health production" and service provision at the systemic level (Breitenbach et al., 2021; Lupu & Tiganasu, 2022; Manavgat & Audibert, 2024; Paraschi, 2023; Selamzade et al., 2023).

Infant survival rate (ISR) was chosen as the output instead of infant mortality rate (IMR) because, in the context of DEA, higher output values are associated with greater efficiency. The IMR is by nature an "undesirable" output (a higher value means a worse health outcome) and, if used as such, violates the output maximization direction required by the method. In order to maintain the logic of the model and comparability with other positive outputs (life expectancy, healthy life years), the IMR was transformed into an infant survival index according to the following formula (Mirzosaid, 2011):

$$\boxed{Infant\ Survival\ Rate\ (ISR) = \frac{1000 - IMR}{IMR}} \qquad (1)$$

Technical efficiency was estimated using constant returns to scale (CRS) models, variable returns to scale (VRS) models, as well as non-increasing (NIRS) and non-decreasing (NDRS) returns, to determine the type of returns to scale of the decision-making units (DMUs). In addition, the super-efficiency model was applied for the comparative evaluation and ranking of fully efficient countries (100%).

NIRS and NDRS specifications are used to support the standard returns-to-scale classification within each reference year, while super-efficiency is reported to further discriminate among fully efficient DMUs under the same input–output set and orientation.

The model was input-oriented, with the aim of estimating the minimum level of resources necessary to achieve a specific level of output (Breitenbach et al., 2021; Gavurova et al., 2021;

Manavgat & Audibert, 2024; Paraschi, 2023). An input orientation is appropriate in this context because resource levels (e.g., beds, workforce, and spending) are more directly actionable for policy and management, whereas outcomes typically adjust more slowly and are also shaped by a broader set of socioeconomic determinants that extend beyond the health system itself.

The analysis was performed using EMS software (Scheel, 2000), while the statistical organization/presentation of the results was done in Microsoft Excel 2016.

Methodological extensions. Future work could extend the present benchmarking by (i) applying bootstrapped DEA to quantify uncertainty in efficiency estimates, (ii) adopting a longitudinal DEA approach (e.g., window analysis) to examine efficiency over time when a multi-year panel is available, and/or (iii) conducting second-stage analyses to explore associations between efficiency and contextual determinants, subject to data availability.

5 Results

5.1 Overview of inputs and outputs

Table 1 shows the values of the seven variables and summarizes their basic statistics. In 2014, the average number of doctors was 359 per 100,000 inhabitants, with the highest value in Greece (630) and the lowest in Poland (231). Conversely, in terms of the number of nurses per 100,000 inhabitants, Greece recorded the lowest value (320), while Denmark recorded the highest (1,650), approximately 5.2 times higher. Sweden had the lowest number of hospital beds (254 per 100,000) and at the same time the highest per capita health expenditure (€4,954.9), while the lowest expenditure was recorded in Bulgaria (€457.6). In terms of outputs, Healthy Life Years (HLY) had an average value of 61.6 years, while the difference between countries was approximately 20 years (maximum 73.4 in Malta and minimum 53.4 in Latvia). In the same year, the difference in life expectancy between Member States was approximately 9 years (Spain 83.3 and Italy 83.2 compared to Bulgaria 74.5, Latvia 74.5, and Lithuania 74.7). Infant survival rate (ISR) varied greatly—from 130.6 in Bulgaria to 554.6 in Slovenia—with an average of 305.5.

Table 1: Input and Output Values for the 27 European Countries (2014)

	Country	Doctors	Nurses	Beds	Exp. p. cap	HLY	L.E.	ISR
1	Austria	502	800	758	4,041.6	57.7	81.6	332.3
2	Belgium	316	1,060	585	3,814.1	64.1	81.4	293.1

3	Bulgaria	398	440	713	457.6	64.0	74.5	130.6
4	Croatia	316	580	594	686.4	59.3	77.9	199.0
5	Cyprus	338	500	342	1,421.5	66.0	82.3	475.2
6	Czechia	370	790	672	1,138.8	64.1	78.9	415.7
7	Denmark	388	1,650	269	4,854.7	60.9	80.7	249.0
8	Estonia	336	570	490	970.3	55.2	77.4	369.4
9	Finland	269	1,410	453	3,705.4	58.2	81.3	453.6
10	France	309	960	619	3,736.4	63.8	82.9	284.7
11	Germany	411	1,310	823	3,985.7	56.5	81.2	311.5
12	Greece	630	320	424	1,284.0	64.5	81.5	269.3
13	Hungary	332	640	698	758.9	59.9	76.0	221.2
14	Ireland	301	1,190	257	3,984.6	66.9	81.4	302.0
15	Italy	388	620	321	2,374.1	62.4	83.2	356.1
16	Latvia	322	480	566	647.4	53.4	74.5	262.2
17	Lithuania	431	760	726	772.6	59.7	74.7	255.4
18	Luxembourg	288	1,200	505	4,869.3	63.8	82.3	356.1
19	Malta	360	800	459	1,829.5	73.4	82.1	199.0
20	Netherlands	342	1,000	355	4,207.8	61.2	81.8	276.8
21	Poland	231	520	663	675.6	61.3	77.8	237.1
22	Portugal	440	610	332	1,554.5	56.9	81.3	343.8
23	Romania	270	620	671	380.1	59.0	75.0	121.0
24	Slovakia	343	580	579	970.0	55.1	77.0	171.4
25	Slovenia	277	860	454	1,551.7	58.7	81.2	554.6
26	Spain	380	520	297	2,018.7	65.0	83.3	356.1
27	Sweden	411	1,120	254	4,954.9	72.9	82.3	453.6
Mean		359	811	514	2,283.2	61.6	79.8	305.5
SD		81	333	171	1,602.0	4.9	2.9	105.3
Range		399	1,330	569	4,574.8	20.0	8.8	433.6
Minimum		231	320	254	380.1	53.4	74.5	121.0
Maximum		630	1,650	823	4,954.9	73.4	83.3	554.6

In 2022, there was an improvement in several variables. The average number of doctors per 100,000 people increased to 414, while per capita health spending rises from €2,283.2 to €3,267.5 (+43% in eight years), indicating increased investment, possibly related to the impact of COVID-19. Greece remains first in terms of the number of doctors (660) but continues to have a very low number of nurses (387), suggesting a structural imbalance in the human resource mix. The average Healthy Life Years (HLY) at birth has increased to 62.1 years (from 61.6), with significant improvements in Slovenia (+8.0), Italy (+5.0) and Germany (+4.6), but also decreases in Sweden (–6.4) and Denmark (–5.0), possibly reflecting the differentiated effects of the pandemic or inequalities in access. Life expectancy remains virtually unchanged (from 79.8 to 79.9), while infant survival has improved (average 329.9 from 305.5), with

Finland (499) and Sweden (453) performing best. In summary, the period 2014–2022 saw an increase in inputs (particularly expenditure and doctors), an uneven improvement in outputs (increase in HLY with heterogeneity between countries) and stability in life expectancy, while the improvement in infant survival is broader but not uniform. The indicators for Greece confirm over-medicalization combined with understaffing of nurses.

Table 2: Input and Output Values for the 27 European Countries (2022)

	Country	Doctors	Nurses	Beds	Exp. p. cap	HLY	L.E.	ISR
1	Austria	545	1,100	672	5,518.5	60.9	81.4	415.7
2	Belgium	356	1,163	544	5,104.9	63.7	81.8	343.8
3	Bulgaria	445	434	823	989.8	66.7	74.2	207.3
4	Croatia	396	770	584	1,279.2	60.3	77.7	242.9
5	Cyprus	519	530	313	2,699.7	66.0	81.6	321.6
6	Czechia	432	900	654	2,277.8	61.8	79.0	433.8
7	Denmark	450	1,036	248	6,109.9	55.9	81.3	302.0
8	Estonia	347	660	419	1,874.2	59.3	78.1	453.6
9	Finland	360	1,413	262	4,666.1	57.9	81.2	499.0
10	France	319	884	550	4,607.0	64.4	82.3	249.0
11	Germany	455	1,198	766	5,831.6	61.1	80.7	311.5
12	Greece	660	387	426	1,682.7	67.0	80.8	332.3
13	Hungary	347	550	665	1,171.3	62.6	76.0	276.8
14	Ireland	333	1,330	291	5,997.9	66.0	82.6	311.5
15	Italy	423	650	309	2,977.6	67.4	82.8	433.8
16	Latvia	340	417	503	1,556.7	54.2	74.5	415.7
17	Lithuania	444	750	568	1,724.1	60.3	75.8	332.3
18	Luxembourg	300	1,173	399	6,590.2	60.2	83.0	284.7
19	Malta	449	790	406	3,124.9	70.2	82.4	187.7
20	Netherlands	392	1,153	245	5,469.8	58.5	81.7	311.5
21	Poland	357	570	629	1,137,1	62.4	77.2	262.2
22	Portugal	570	750	348	2,437,2	59.1	81.8	383.6
23	Romania	365	820	728	857,7	59.0	75.1	174.4
24	Slovakia	370	570	569	1,560.5	57.3	77.0	184.2
25	Slovenia	337	1,040	412	2,593.9	66.7	81.3	399.0
26	Spain	430	617	294	2,745.3	61.2	83.2	383.6
27	Sweden	440	1,090	190	5,636.6	66.5	83.1	453.6
Mean		414	842	475	3,267.5	62.1	79.9	329.9
SD		84	294	179	1,913.3	4.0	2.9	90.4
Range		360	1,026	634	5,732.5	16.0	9.0	324.6
Minimum		300	387	190	857.7	54.2	74.2	174.4
Maximum		660	1,413	823	6,590.2	70.2	83.2	499.0

5.2 Efficiency with a constant returns to scale (CRS) model

Table 3 presents the results of the Data Envelopment Analysis under the assumption of constant returns to scale (CRS) for the 27 EU countries for the years 2014 and 2022.

Table 3: CRS and VRS efficiency scores (%) across EU-27

	Country	CRS (2014)	VRS (2014)	CRS (2022)	VRS (2022)
1	Austria	63.1	63.9	65.4	69.3
2	Belgium	84.8	90.7	90.4	90.4
3	Bulgaria	100.0	100.0	100.0	100.0
4	Croatia	98.8	100.0	99.8	99.9
5	Cyprus	100.0	100.0	100.0	100.0
6	Czechia	96.3	100.0	82.2	90.5
7	Denmark	93.4	94.9	92.2	94.3
8	Estonia	100.0	100.0	100.0	100.0
9	Finland	100.0	100.0	100.0	100.0
10	France	86.9	100.0	100.0	100.0
11	Germany	64.1	67.3	70.9	70.9
12	Greece	100.0	100.0	100.0	100.0
13	Hungary	85.8	86.1	100.0	100.0
14	Ireland	100.0	100.0	100.0	100.0
15	Italy	94.2	96.1	100.0	100.0
16	Latvia	100.0	100.0	100.0	100.0
17	Lithuania	86.2	90.9	87.3	89.2
18	Luxembourg	95.1	100.0	100.0	100.0
19	Malta	97.4	100.0	93.9	100.0
20	Netherlands	90.4	91.1	98.5	99.9
21	Poland	100.0	100.0	100.0	100.0
22	Portugal	98.5	99.9	97.9	98.0
23	Romania	100.0	100.0	100,0	100.0
24	Slovakia	88.8	89.6	94.8	95.9
25	Slovenia	100.0	100.0	100.0	100.0
26	Spain	100.0	100.0	100.0	100.0
27	Sweden	100.0	100.0	100.0	100.0
Mean		93.5	95.2	95.3	96.2
SD		10.1	9.5	9.1	8.2
Range		36.9	36.2	34.7	30.7
Minimum		63.1	63.9	65.4	69.3
Maximum		100.0	100.0	100.0	100.0

Each country is assessed in terms of its distance from the efficiency frontier (best-practice frontier), defined by units that achieve a score of 100%. For clarity of presentation, the countries are grouped into four categories: fully efficient, high efficiency, medium efficiency, and low efficiency, as defined in Table 4, while Table 5 summarizes the number of countries in each category for each reference year.

Table 4: Efficiency level classification

Efficiency Level Ranking	Range	Meaning
Maximum	100%	Fully efficient units are located on the efficiency frontier. They serve as benchmarks for the rest.
High	[90% – 100%)	Nearly efficient units that are close to the efficiency frontier but are not benchmarks.
Average	[75% – 90%)	Units with moderate efficiency and clear room for improvement.
Low	<75%	Units with a significant distance from the efficiency frontier and limited performance.

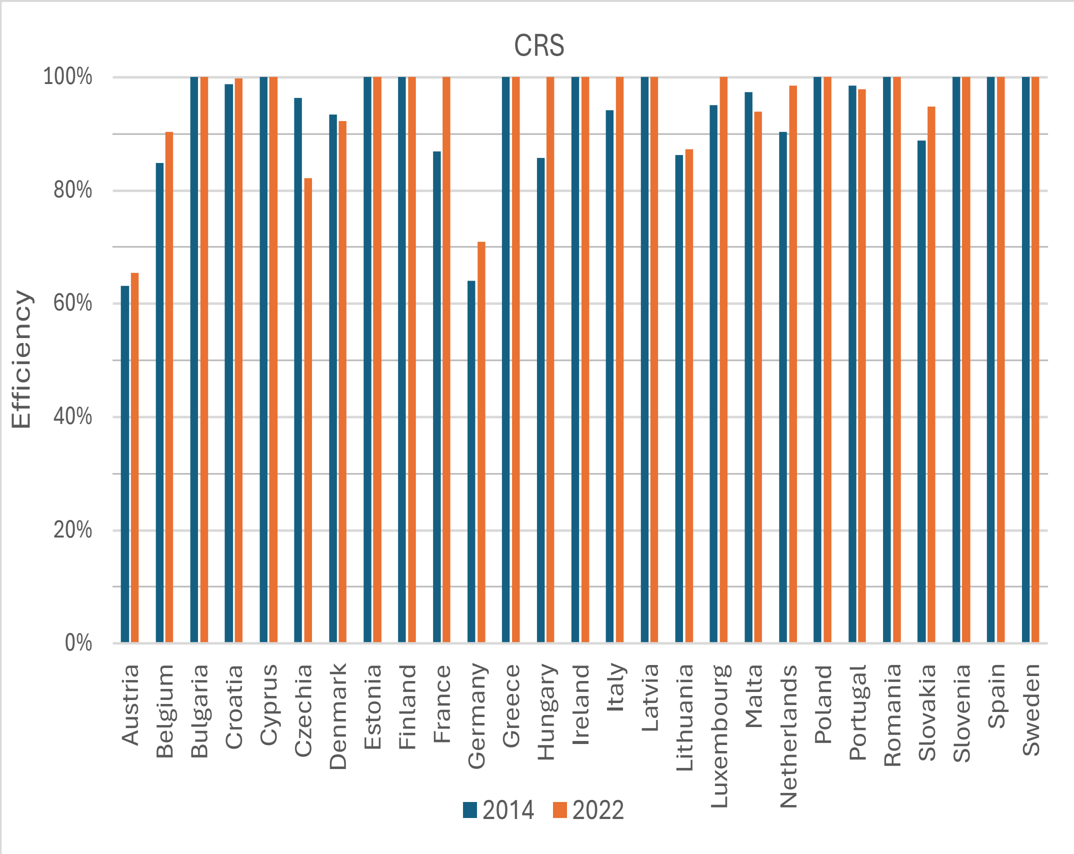
For 2014, the average efficiency is 93.5%, and twelve countries—including Greece, Ireland, Spain, Cyprus, Poland, Slovenia, Sweden, Finland, Bulgaria, Latvia, Estonia, and Romania—are at the frontier (100%), serving as benchmarks. Eight countries are classified in the 90–99.9% category, five countries in the 75–89.9% category, while Austria (63.1%) and Germany (64.1%) are in the <75% category (see Figure 1 and Table 5).

Table 5: Classification of countries into efficiency levels under CRS and VRS

Efficiency Level Ranking	CRS		VRS	
	(2014)	**(2022)**	**(2014)**	**(2022)**
Maximum (100%)	12	16	17	17
High [90% – 100%)	8	7	6	7
Average [75% – 90%)	5	2	2	1
Low (0, 75%)	2	2	2	2

For 2022, the average score is 95.3%, and the number of fully efficient countries is 16. For example, countries such as Hungary, France, and Luxembourg are on the frontier, while there are also cases of marginally lower scores (e.g., Portugal, Malta, Czech Republic). Austria (65.4%) and Germany (70.9%) are also classified in the <75% category in 2022. These results are presented descriptively, without drawing direct comparisons or conclusions about convergence/divergence, due to the time gap between the two years.

Figure 1: Efficiency scores for the years 2014 and 2022 (CRS)



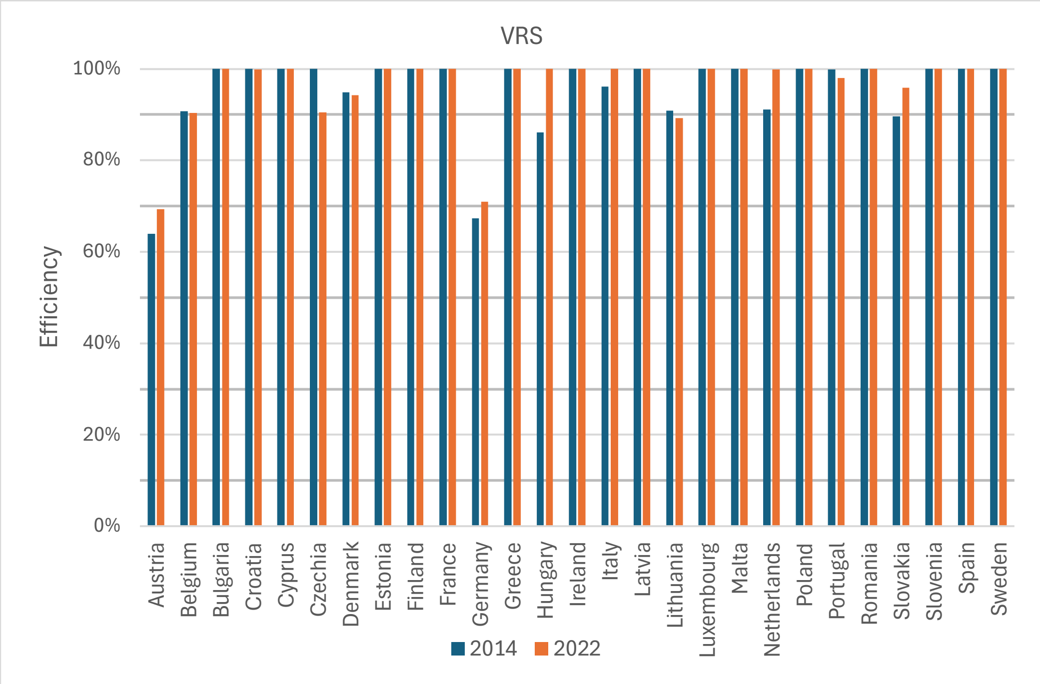
5.3 Efficiency with the variable returns to scale (VRS) model

Table 3 presents the results of the Data Envelopment Analysis under the assumption of variable returns to scale (VRS) for the 27 EU countries for the years 2014 and 2022. As expected, the VRS estimates are higher than the CRS estimates (averages of 95.2% and 96.2% compared to 93.5% and 95.3%), as VRS reflects pure technical efficiency regardless of operating size. Overall, high VRS efficiency values are recorded in both years. The standard deviation is 9.5% in 2014 and 8.2% in 2022.

In terms of the country's distribution, many units are at the efficiency frontier (100%) in both years, while some countries are marginally below 100%. Descriptively, at the individual country level, there are cases of high performance (e.g., Italy, Hungary, the Netherlands, Slovakia) as well as lower values (e.g., Austria) in one or both years. There are also isolated declines (e.g., Czech Republic, Lithuania, Portugal) and slight decreases (Belgium, Denmark).

Finally, the range of values from 36.2 to 30.7 percentage points is also reported as a descriptive finding indicating greater efficiency convergence. Overall, the picture indicates high levels of net technical efficiency under VRS for the EU-27 in both years, with a mixed pattern countries, as shown in Table 5 and Figure 2.

Figure 2: Efficiency scores for the years 2014 and 2022 (VRS)



5.4 Efficiency with non-increasing/non-decreasing returns to scale models (NIRS/NDRS)

Table 6 presents the results obtained from solving the NIRS (Non-Increasing Returns to Scale) and NDRS (Non-Decreasing Returns to Scale) models for the 27 countries of the European Union for the years 2014 and 2022.

Table 6: Efficiency scores (%) using the NIRS and NDRS models

	NIRS (2014)	NIRS (2022)	NDRS (2014)	NDRS (2022)
Mean	95.1	96.0	93.6	95.5
SD	9.5	8.3	10.1	9.1
Range	36.2	30.7	36.9	34.7
Minimum	63.9	69.3	63.1	65.4
Maximum	100.0	100.0	100.0	100.0

Table 7 reports the observed ordering of mean scores across model variants (CRS ≤ NDRS ≤ VRS and CRS ≤ NIRS ≤ VRS) for each reference year (2014 and 2022).

Table 7: Escalation of CRS, VRS, NIRS and NDRS scores (%)

		2014	2022
CRS	Constant Returns to Scale	93.5	95.3

NDRS	Non-Decreasing Returns to Scale	93.6	95.5
NIRS	Non-Increasing Returns to Scale	95.1	96.0
VRS	Variable Returns to Scale	95.2	96.2

A group of 12 countries (Bulgaria, Greece, Estonia, Ireland, Spain, Cyprus, Latvia, Poland, Romania, Slovenia, Sweden, Finland) are reported as fully efficient (100%) under NIRS and NDRS in both reference years. In other cases (e.g. Belgium, the Netherlands, Portugal, Italy), high values are recorded in close proximity to the frontier. At the other end of the scale, Austria and Germany are at the lower end, with efficiency below 75% under both NIRS and NDRS.

5.5 Model of super-efficiency - unit ranking

The application of the super-efficiency model in the context of DEA, both under the assumption of constant returns to scale (CRS) and variable returns to scale (VRS), allows for a more detailed distinction between units that appear fully efficient (score = 100%) in the basic models. The process consists of temporarily excluding each fully efficient unit from the frontier and recalculating its performance relative to the others. In this way, the estimated efficiency may exceed 100%, enabling a descending ranking of "best among the best".

Indicatively, for 2014, Greece recorded exceptionally high performance (CRS 152.1% and VRS 154.3%), while Cyprus, Sweden, Bulgaria, Slovenia, and Romania also showed high super-efficiency values (CRS >130%) (Table 8). In the VRS model, for the same year, Bulgaria ranks first (193.1%), followed by Greece, Romania, Poland, and Ireland.

Table 8: Super–efficiency scores (%) according to CRS and VRS (2014)

Country	SUPER-CRS	RANKING	SUPER-VRS	RANKING
Greece	152.1	1	154.3	2
Cyprus	138.5	2	∄	--
Slovenia	138.3	3	∄	--
Sweden	134.8	4	∄	--
Bulgaria	133.1	5	193.1	1
Romania	132.9	6	133.4	3
Poland	124.5	7	125.8	4
Ireland	119.3	8	120.4	5
Spain	111.7	9	∄	--
Latvia	111.4	10	112.6	6
Estonia	102.7	11	102.7	12
Finland	102.1	12	103.2	11

Croatia	98.8	13	105.0	10
Portugal	98.5	14	99.9	13
Malta	97.4	15	∄	--
Czechia	96.3	16	107.6	8
Luxemburg	95.1	17	106.4	9
Italy	94.2	18	96.1	14
Denmark	93.4	19	94.9	15
Netherlands	90.4	20	91.1	16
Slovakia	88.8	21	89.6	19
France	86.9	22	111.0	7
Lithuania	86.2	23	90.9	17
Hungary	85.8	24	86.1	20
Belgium	84.8	25	90.7	18
Germany	64.1	26	67.3	21
Austria	63.1	27	63.9	22

For 2022, Sweden ranks first in the CRS super-efficiency results (151.8%), while Bulgaria ranks first in the VRS super-efficiency results (166.4%). Greece ranks 4th in CRS and 3rd in VRS, while Romania, Latvia, Estonia, Luxembourg, and Finland record super-efficiency values above 120% in at least one of the two models (Table 9).

Table 9: Super efficiency scores (%) according to CRS and VRS (2022)

Country	SUPER-CRS	RANKING	SUPER-VRS	RANKING
Sweden	151.8	1	∄	--
Latvia	136.7	2	137.8	4
Bulgaria	130.4	3	166.4	1
Greece	129.3	4	150.2	3
Finland	122.1	5	∄	--
Romania	118.8	6	120.6	6
Estonia	114.1	7	159.7	2
Ireland	112.2	8	116.7	8
Slovenia	111.5	9	119.9	7
Luxemburg	109.4	10	132.5	5
Italy	109.1	11	∄	--
Cyprus	107.4	12	107.9	11
Spain	106.3	13	∄	--
France	105.2	14	109.3	10
Poland	104.7	15	112.6	9
Hungary	103.6	16	104.6	12
Croatia	99.8	17	99.9	14
Netherlands	98.5	18	99.9	13
Portugal	97.9	19	98.0	15

Slovakia	94.8	20	95.9	16
Malta	93.9	21	∄	--
Denmark	92.2	22	94.3	17
Belgium	90.4	23	90.4	19
Lithuania	87.3	24	89.2	20
Czechia	82.2	25	90.5	18
Germany	70.9	26	70.9	21
Austria	65.4	27	69.3	22

Countries for which it is not possible to calculate super-efficiency in the VRS model are marked with the symbol "∄", as is the case with Sweden, for example. This symbol does not indicate an error but reflects the fact that when the specific unit is excluded from the frontier, no feasible solution is found, either due to a particularly efficient or divergent production profile. This makes the specific unit incomparable with the profile of the others under the assumption of variable returns to scale (VRS), thus leading to a theoretically indeterminate level of super-efficiency. Super-efficiency CRS scores are depicted in Figures 3, 4, and 5.

Figure 3: Super–efficiency scores for the years 2014 and 2022 (CRS)

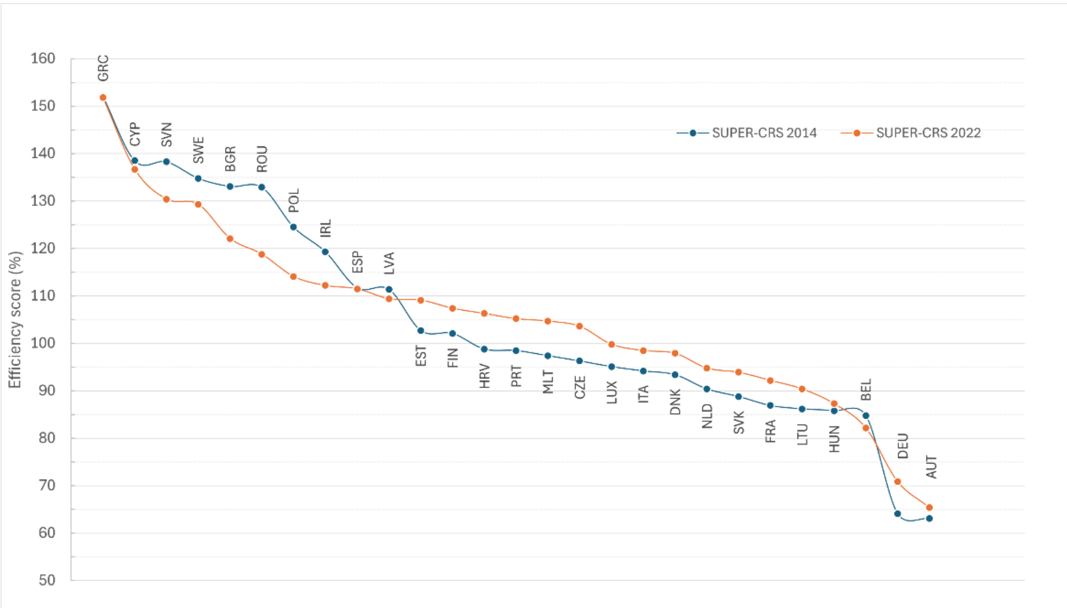


Figure 4: Super–efficiency CRS scores country map (2014)

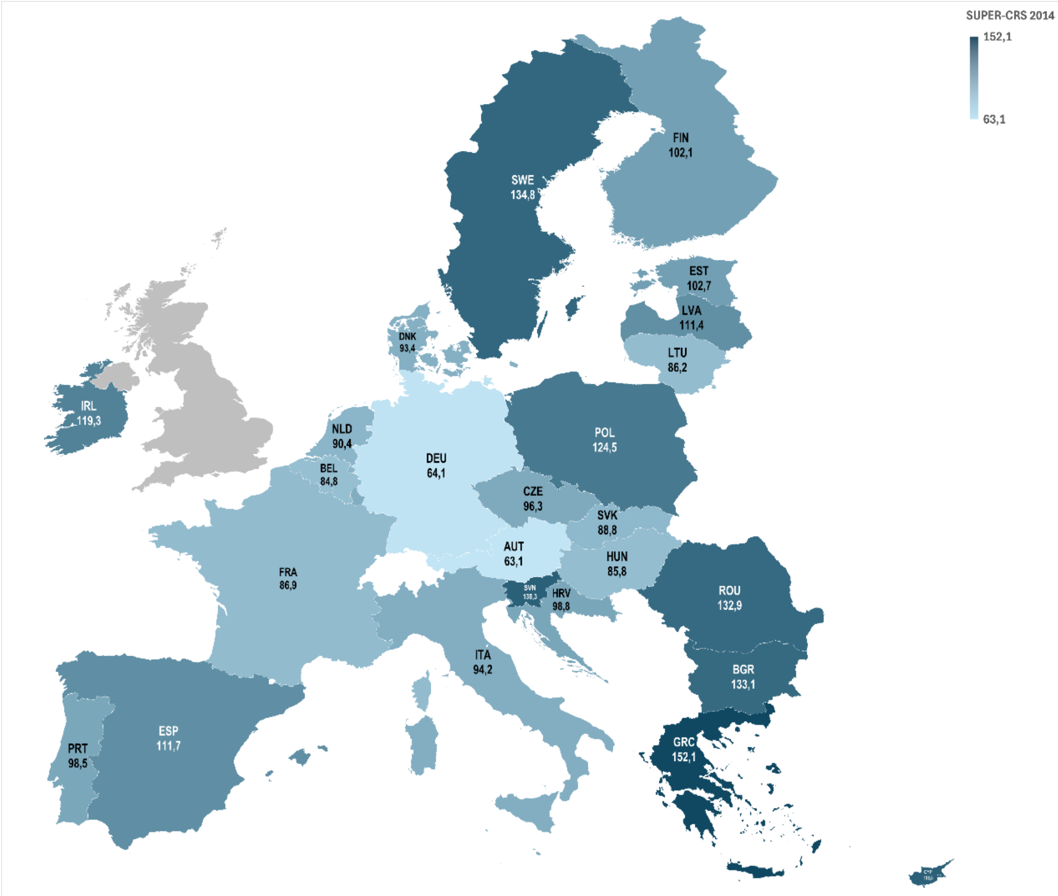
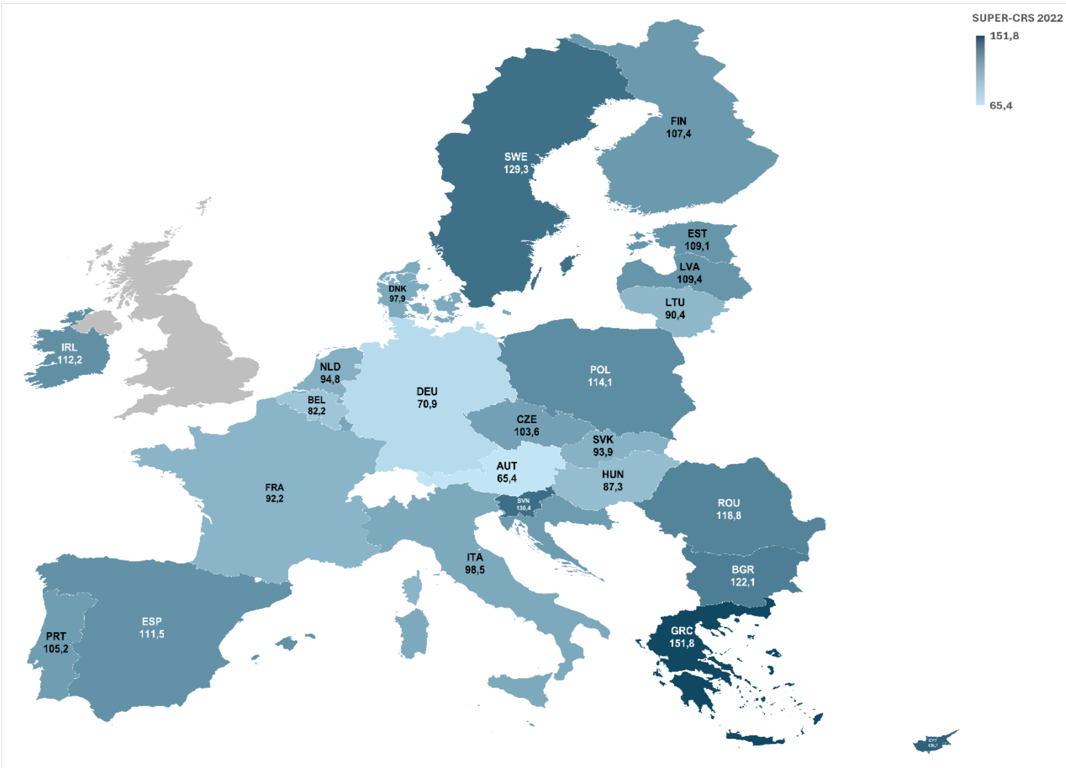


Figure 4: Super–efficiency CRS scores country map (2022)



6 Discussion

Efficiency in the health sector is fundamental to the functioning of systems, as it involves producing optimal results through the rational use of limited resources. Modern challenges—demographic aging, increase in chronic diseases, budget constraints—make effective management of inputs critical to maximizing outputs. Measuring efficiency requires a clear definition of the decision unit under analysis, from the micro to the macro level (Mbau et al., 2022).

In Europe, recent decades have been marked by intense fluctuations resulting from both socioeconomic and health-related changes. Since 2008, the financial crisis has forced adjustments to health systems and has had a measurable impact on citizens' health. Many countries have recorded spending cuts, particularly in hospital and pharmaceutical care, and stricter negotiations with the pharmaceutical market (e.g. Austria, Latvia, Poland, Slovenia), while other countries (Denmark, Greece, Latvia, Portugal, Slovenia) specifically limited hospital spending. At the same time, several systems (Czech Republic, Estonia, Finland, Romania, Italy, Ireland, France, Netherlands) increased private participation to offset fiscal pressure (Karanikolos et al., 2013). These conditions were associated with adverse health trends (increased mortality, mental health burdens, higher alcohol/tobacco consumption, worsening dietary habits), leading to additional care needs and, ultimately, a future increase in healthcare costs (Flokou et al., 2017; van Gool & Pearson, 2014). Economically weaker countries have adopted measures to curb healthcare spending (higher deductibles, greater private participation, stricter budgetary limits). Subsequently, as economies recovered, the improvement in GDP appears to have been associated with a recovery in a number of health indicators, confirming the positive relationship between economic performance and health status (Prędkiewicz et al., 2022). During the COVID-19 period, policy interventions boosted health financing, raising per capita spending to meet increased needs amid uncertainty (Berardi et al., 2024). In this context, systems with strong primary health care acted as a first-line filter, preventing hospital overload and limiting the progression to acute forms of disease (Mauro & Giancotti, 2023). Efficiency fluctuated throughout the pandemic, with no consistent country "benchmark" emerging over time (Štěpánek et al., 2021).

In this study, the efficiency of EU health systems is reported as high within each reference year across all models. This contrasts with several OECD-focused DEA studies conducted during the COVID-19 period, under alternative model specifications and input–output sets, which reported substantial inefficiency in a large share of the sample (around 60%), including in some higher-income OECD countries (e.g., Singh et al., 2023; Manavgat & Audibert, 2024), and potential savings of fiscal resources of approximately 54.8% (El Husseiny & Badawy, 2022).

While these findings are not directly comparable across different samples, periods, and specifications, the difference may partly reflect the extraordinary increase in resources mobilised during the pandemic and the challenges of allocating them efficiently under conditions of uncertainty (Breitenbach et al., 2021).

To address RQ1, the CRS averages are 93.5% (2014) and 95.3% (2022), while the VRS averages are 95.2% and 96.2% respectively, reflecting the standard distinction between CRS (overall technical efficiency) and VRS (pure technical efficiency). Under CRS, 12 countries show full efficiency (100%) in 2014 and 16 in 2022, while under VRS, 17 countries are efficient in both years. Among the countries that maintain 100% efficiency in all models in both years are Bulgaria, Greece, Estonia, Ireland, Spain, Cyprus, Latvia, Poland, Romania, Slovenia, Sweden, and Finland. In contrast, Germany and Austria are in the lowest positions in both years. The findings are in line with the study by Lacko et al. (2023), who rank Greece, Spain, Sweden, Latvia, Estonia, Croatia, Finland, and the Netherlands among the most efficient countries, while identifying lower efficiency in Germany and Austria.

To address RQ2, the super-efficiency model allows for differentiation among fully efficient countries within each reference year. Greece, Cyprus, Slovenia, Sweden, and Bulgaria occupy the highest CRS super-efficiency positions in 2014, while in 2022 Sweden, Latvia, Bulgaria, Greece, and Finland rank highest under CRS. For some countries, super-efficiency under VRS is not computable (marked as “∄”), which does not indicate an error but reflects a non-feasible solution when the unit is excluded from the frontier under VRS assumptions, leading to a theoretically indeterminate super-efficiency value.

The DEA analysis identified the efficiency frontier in the EU-27 and suggests that high technical efficiency is not tied to a single organizational model but may be achieved through different production profiles. In crisis-period settings, the literature has reported a small relative advantage of Beveridge-type systems in terms of efficiency and resilience (Kuzior et al., 2022); however, this association does not emerge clearly in the present EU-27 analysis under the specific DEA MODEL and input–output set applied. The nature of the method explains why systems with limited resources can appear efficient when they effectively convert their own mix of inputs into outputs, while systems with higher levels of inputs may appear disproportionately "heavy" in relation to the observed level of outputs. This finding is not a judgment on quality or an assessment of overall well-being; it emphasizes that efficiency measures how resources are converted into selected health indicators. Furthermore, beyond a certain point, additional inputs do not convert proportionally into outputs—especially when a significant portion of spending is directed toward dimensions such as quality, patient experience, and resilience, which are not fully captured in traditional output indicators. In the same vein, the recording of lower technical efficiency for countries such as Germany and Austria, despite their developed economic and health profiles, does not imply low quality; it reflects that a larger proportion of inputs is not converted into corresponding outputs in these specific indicators, while parameters such as patient satisfaction and infrastructure quality remain more difficult to measure (Lacko et al., 2023).

The number of hospital beds is an indicator of hospitalization capacity and is linked to patterns of use, as greater supply tends to be accompanied by higher admission rates (according to Roemer's law, "a bed that is built tends to be filled"). This differentiation reflects different production profiles. A more hospital-centric model fills available beds more easily, while a system with enhanced primary care is associated with better health outcomes and higher efficiency, as it reduces preventable admissions and shifts the resource mix towards high-yield interventions (World Health Organization, 2018).

For example, Sweden consistently combines low hospital bed availability with high outputs (life expectancy, healthy life years, infant survival), by relying on strong primary care and shifting services outside the hospital. The national vision for "good quality, local healthcare" and the use of digital solutions have established practices that reduce preventable admissions, shorten the average length of stay, and relieve pressure on tertiary care (Ludvigsson et al., 2025). At the same time, the gradual expansion of day surgery and the development of intermediate care/home care are improving the "conversion" of inputs into outputs without a corresponding increase in hospital capacity (Ludvigsson et al., 2025). Although low bed availability has been associated in some studies with concerns about quality (e.g., QALYs) (Siverskog & Henriksson, 2022), in the Swedish context, the emphasis on primary care and strong outpatient management seems to offset potential disadvantages by reducing unnecessary hospitalizations and in-hospital infections (Ludvigsson et al., 2025). At the same time, telemedicine services are developing rapidly, but their use to date appears to be disproportionately higher in urban populations; targeted interventions are needed to ensure that digital expansion does not exacerbate geographical/social inequalities in access (Eriksson et al., 2024).

In addition, Finland, which is fully efficient in the present analysis, makes extensive use of digital primary healthcare. A significant proportion of visits are carried out remotely by nurses and general practitioners, increasing access and coordination, relieving pressure on clinics, and reducing preventable admissions (Väisänen et al., 2025). Finally, during the COVID-19 period, several Member States strengthened the prevention/PHC component of their expenditure mix. For example, countries such as Austria, Denmark, and the Netherlands recorded a significant increase in the share of prevention spending, which was consistent with a more efficient, proactive allocation of resources (OECD, 2023).

For Greece, which in this analysis is on the efficiency frontier, and serves as a benchmark in all models (CRS, VRS, NIRS, NDRS) and ranks high in the super-efficiency model, it is worth highlighting the marked imbalance in the mix of inputs (historically very high density of doctors compared to particularly low staffing levels for nurses). Combined with the understaffing of primary health care and numerical/geographical inequalities, this situation creates limitations in terms of quality, continuity of care, equal access, and user satisfaction (Flokou et al., 2024; Karaferis et al., 2024). In terms of efficiency, the finding suggests that "proximity" to the frontier may be achieved due to an unbalanced production profile. A score of 100% in DEA expresses relative efficiency compared to the current frontier and is not a measure of absolute performance or evidence that there is no room for improvement.

Bulgaria, despite ranking high in terms of efficiency, has low life expectancy, while some of its inputs exceed the European average and per capita health expenditure remains among the lowest. Romania, also efficient, combines low per capita expenditure with low infant survival rates, in an environment of limited availability of staff and medical equipment (OECD & European Observatory on Health Systems and Policies, 2019). In such contexts, high efficiency can be achieved under tight budgetary constraints and coexist with pressures that are not always reflected in traditional output indicators (e.g., safety, readmissions, patient experience/satisfaction); this requires a parallel, independent assessment of quality variables to ensure that resource efficiency goes hand in hand with real health outcomes.

Comparative European data often show a pattern of "low expenditure–low performance" and "high expenditure–high performance" (Bocean & Vărzaru, 2024). Nevertheless, the findings of this analysis show that some systems achieve high technical efficiency with limited resources, while others, despite increased funding, do not proportionally convert inputs into outputs. This highlights that, beyond the total amount of expenditure, the distribution and quality of resource use are critical. Interpretatively, in DEA, some units excel because they produce high outputs with given inputs, while others stand out because they achieve the necessary level of outputs with minimal resources. The inherently relative nature of the method means that "improvement" is assessed against the sample in question and does not automatically imply a shift in the efficiency frontier itself. In summary, the DEA method can be a useful tool for assessing the efficiency of health systems and for comparative evaluation between countries. Although it focuses mainly on the quantitative dimension of resource utilisation, it can provide valuable information for policy-making.

The results of the EU-27 benchmarking can support priority setting by highlighting peer countries with comparable outputs and lower input requirements within each reference year, informing targeted policy actions and efficiency reviews (e.g., workforce mix, bed capacity, and expenditure composition). For low-scoring cases, the results provide a starting point for investigation (e.g., whether input levels are aligned with selected outcomes and whether resources are directed towards measurable population health benefits), while for frontier countries the analysis helps identify achievable benchmark profiles rather than the "best" systems in an absolute sense. By providing transparent benchmarking across countries based on a common specification, the study can contribute to public debate on sustainable financing and resource allocation, while emphasizing that efficiency scores reflect the conversion of selected inputs into selected outcomes and not the overall quality of the system.

The inclusion of additional parameters, such as quality, accessibility, and patient satisfaction, could enhance the usefulness of the results. However, this study provides a starting point for future research by offering a comparable EU-27 benchmarking baseline; future work could enrich the set of inputs and outputs and extend the temporal coverage (e.g., through window analysis), where data permit, to support a more nuanced assessment of health system performance in the EU.

References

Aletras, V. (1997). Economic analysis of the operation of nursing units: An econometric approach [Aristotle University of Thessaloniki]. https://www.didaktorika.gr/eadd/handle/10442/16529

Allin, S., Grignon, M., & Wang, L. (2016). The determinants of efficiency in the Canadian health care system. *Health Economics, Policy and Law*, *11*(1), 39-65. https://doi.org/10.1017/S1744133115000274

Anton, E., Todosia, M., Răcoare, F.-C., Iuliana- Claudia, M., & Dumitraşcu, I. (2024). The Economic Benefits of Health Education. *Revista Romaneasca pentru Educatie Multidimensionala*, *16*, 395-406. https://doi.org/10.18662/rrem/16.2/863

Banker, R. D., Charnes, A., & Cooper, W. W. (1984). Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis. *Management Science*, *30*(9), 1078-1092. https://doi.org/10.1287/mnsc.30.9.1078

Berardi, C., Schut, F., & Paolucci, F. (2024). The dynamics of international health system reforms: Evidence of a new wave in response to the 2008 economic crisis and the COVID-19 pandemic? *Health Policy*, *143*, 105052. https://doi.org/10.1016/j.healthpol.2024.105052

Berki, S. E. (1972). *Hospital Economics*. Lexington Books, Massachusetts.

Bocean, C. G., & Vărzaru, A. A. (2024). Assessing social protection influence on health status in the European Union. *Frontiers in Public Health*, *12*, 1287608. https://doi.org/10.3389/fpubh.2024.1287608

Breitenbach, M. C., Ngobeni, V., & Aye, G. C. (2021). Global Healthcare Resource Efficiency in the Management of COVID-19 Death and Infection Prevalence Rates. *Frontiers in Public Health*, *9*, 638481. https://doi.org/10.3389/fpubh.2021.638481

Butler, J. R. G. (1995). *Hospital Cost Analysis*. Kluwer Academic Publishers, Dordrecht/ Boston/ London.

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of Operational Research*, *2*(6), 429-444. https://doi.org/10.1016/0377-2217(78)90138-8

Cylus, J., Papanicolas, I., & Smith, P. C. (2016). A framework for thinking about health system efficiency. Στο *Health system efficiency: How to make measurement matter for policy and management [Internet]*. European Observatory on Health Systems and Policies. https://www.ncbi.nlm.nih.gov/books/NBK436891/

El Husseiny, I., & Badawy, M. (2022). Evaluating the efficiency of fiscal responses to COVID-19 pandemic in the OECD countries: a two-stage data envelopment analysis approach. *International Journal of Computational Economics and Econometrics, 12*(4), 459. https://doi.org/10.1504/IJCEE.2022.126325

Eriksson, J., Calling, S., Jakobsson, U., Wolff, M., Borgström Bolmsjö, B., & Milos Nymberg, V. (2024). Inequity in access to digital public primary healthcare in Sweden: A cross-sectional study of the effects of urbanicity and socioeconomic status on utilization. *International Journal for Equity in Health*, *23*(1), 72. https://doi.org/10.1186/s12939-024-02159-7

European Commission. (2004). *Health system objectives of particular interest to different european committees*.

Farrell, M. J. (1957). The Measurement of Productive Efficiency. *Royal Statistical Society. Journal. Series A: General*, *120*(3), 253-281. https://doi.org/10.2307/2343100

Flokou, A., Aletras, V. H., Miltiadis, C., Karaferis, D. C., & Niakas, D. A. (2024). Efficiency of Primary Health Services in the Greek Public Sector: Evidence from Bootstrapped DEA/FDH Estimators. *Healthcare*, *12*(22), 2230. https://doi.org/10.3390/healthcare12222230

Flokou, A., Aletras, V., & Niakas, D. (2017). A window-DEA based efficiency evaluation of the public hospital sector in Greece during the 5-year economic crisis. *PLOS ONE*, *12*(5), e0177946. https://doi.org/10.1371/journal.pone.0177946

Gavurova, B., Kocisova, K., & Sopko, J. (2021). Health system efficiency in OECD countries: Dynamic network DEA approach. *Health Economics Review*, *11*(1), 40. https://doi.org/10.1186/s13561-021-00337-9

Gómez-Gallego, J. C., Gómez-Gallego, M., García-García, J. F., & Faura-Martinez, U. (2021). Evaluation of the Efficiency of European Health Systems Using Fuzzy Data Envelopment Analysis. *Healthcare*, *9*(10), 1270. https://doi.org/10.3390/healthcare9101270

Hajizadeh, A., Hafezi, R., Torabi, F., Akbari Sari, A., & Tajvar, M. (2025). Consequences of Population Ageing on Health Systems: A Conceptual Framework for Policy and Practice. *Ethiopian Journal of Health Sciences*, *35*(1), 51-62. https://doi.org/10.4314/ejhs.v35i1.8

Karaferis, D. C., Niakas, D. A., Balaska, D., & Flokou, A. (2024). Valuing Outpatients' Perspective on Primary Health Care Services in Greece: A Cross-Sectional Survey on Satisfaction and Personal-Centered Care. *Healthcare*, *12*(14), 1427. https://doi.org/10.3390/healthcare12141427

Karanikolos, M., Mladovsky, P., Cylus, J., Thomson, S., Basu, S., Stuckler, D., Mackenbach, J. P., & McKee, M. (2013). Financial crisis, austerity, and health in Europe. *The Lancet*, *381*(9874), 1323-1331. https://doi.org/10.1016/S0140-6736(13)60102-6

Kuzior, A., Kashcha, M., Kuzmenko, O., Lyeonov, S., & Brożek, P. (2022). Public Health System Economic Efficiency and COVID-19 Resilience: Frontier DEA Analysis. *International Journal of Environmental Research and Public Health*, *19*(22), 14727. https://doi.org/10.3390/ijerph192214727

Lacko, R., Hajduová, Z., Bakalár, T., & Pavolová, H. (2023). Efficiency and Productivity Differences in Healthcare Systems: The Case of the European Union. *International Journal of Environmental Research and Public Health*, *20*(1), Article 1. https://doi.org/10.3390/ijerph20010178

Ludvigsson, J. F., Bergman, D., Lundgren, C. I., Sundquist, K., Geijerstam, J.-L. af, Glenngård, A. H., Lindh, M., Sundström, J., Kaarme, J., & Yao, J. (2025). The healthcare system in Sweden. *European Journal of Epidemiology*. https://doi.org/10.1007/s10654-025-01226-9

Lupu, D., & Tiganasu, R. (2022). COVID-19 and the efficiency of health systems in Europe. *Health Economics Review*, *12*(1), 14. https://doi.org/10.1186/s13561-022-00358-y

Manavgat, G., & Audibert, M. (2024). Healthcare system efficiency and drivers: Re-evaluation of OECD countries for COVID-19. *SSM - Health Systems*, *2*, 100003. https://doi.org/10.1016/j.ssmhs.2023.100003

Mauro, M., & Giancotti, M. (2023). The 2022 primary care reform in Italy: Improving continuity and reducing regional disparities? *Health Policy*, *135*, 104862. https://doi.org/10.1016/j.healthpol.2023.104862

Mbau, R., Musiega, A., Nyawira, L., Tsofa, B., Mulwa, A., Molyneux, S., Maina, I., Jemutai, J., Normand, C., Hanson, K., & Barasa, E. (2022). Analysing the Efficiency of Health Systems: A Systematic Review of the Literature. *Applied Health Economics and Health Policy*, *21*(2), 205. https://doi.org/10.1007/s40258-022-00785-2

Mirzosaid, S. (2011). Health Expenditure Efficiency in the Commonwealth of Independent States: A Data Envelopment Analysis Approach. *Transition Studies Review*, *18*(2), 384-404. https://doi.org/10.1007/s11300-011-0204-4

Moolla, I., & Hiilamo, H. (2023). Health system characteristics and COVID-19 performance in high-income countries. *BMC Health Services Research*, *23*(1), 244. https://doi.org/10.1186/s12913-023-09206-z

OECD. (2023). *Health at a Glance 2023*. OECD. https://www.oecd.org/en/publications/health-at-a-glance-2023_7a7afb35-en.html

OECD, & European Observatory on Health Systems and Policies. (2019). *Romania: Country Health Profile 2019, State of Health in the EU*. OECD Publishing. https://www.oecd.org/content/dam/oecd/en/publications/reports/2019/11/romania-country-health-profile-2019_e32e8e77/f345b1db-en.pdf

Ordu, M., Akin, H. K., & Demir, E. (2021). Healthcare systems and Covid19: Lessons to be learnt from efficient countries. *The International Journal of Health Planning and Management*, *36*(5), 1476. https://doi.org/10.1002/hpm.3187

Paraschi, E. P. (2023). *Healthcare Efficiency Assessment in the Southeastern European Countries Using Two-Stage DEA Analysis*. https://www.scienceopen.com/book?vid=601329d6-a8de-4d84-9a90-915fa6821a07

Pereira, M. A., Dinis, D. C., Ferreira, D. C., Figueira, J. R., & Marques, R. C. (2022). A network Data Envelopment Analysis to estimate nations' efficiency in the fight against SARS-CoV-2. *Expert Systems with Applications*, *210*, 118362. https://doi.org/10.1016/j.eswa.2022.118362

Prędkiewicz, P., Bem, A., Siedlecki, R., Kowalska, M., & Robakowska, M. (2022). An impact of economic slowdown on health. New evidence from 21 European countries. *BMC Public Health*, *22*(1), 1405. https://doi.org/10.1186/s12889-022-13740-6

Quentin, W., Geissler, A., & Busse, R. (2016). Measuring and comparing health system outputs: Using patient classification systems for efficiency analyses. Στο *Health system efficiency: How to make measurement matter for policy and management [Internet]*. European Observatory on Health Systems and Policies. https://www.ncbi.nlm.nih.gov/books/NBK436877/

Scheel, H. (2000). *EMS Data Envelopment Analysis Software*. https://www.holger-scheel.de/ems/

Selamzade, F., Ersoy, Y., Ozdemir, Y., & Celik, M. Y. (2023). Health Efficiency Measurement of OECD Countries Against the COVID-19 Pandemic by Using DEA and MCDM Methods. *Arabian Journal for Science and Engineering*, *48*(11), 15695–15712. https://doi.org/10.1007/s13369-023-08114-y

Singh, S., Charles, V., & Pandey, U. (2023). Examining operational efficiency with prudent risks of Covid-19: A contextual DEA analysis with an undesirable intermediate measure. *Annals of Operations Research*. https://doi.org/10.1007/s10479-023-05207-7

Siverskog, J., & Henriksson, M. (2022). The health cost of reducing hospital bed capacity. *Social Science & Medicine*, *313*, 115399. https://doi.org/10.1016/j.socscimed.2022.115399

Štěpánek, L., Habarta, F., Malá, I., & Marek, L. (2021). Data Envelopment Analysis Models Connected in Time Series: A Case Study Evaluating COVID-19 Pandemic Management in Some European Countries. *2021 International Conference on e-Health and Bioengineering (EHB)*, 1-5. https://doi.org/10.1109/EHB52898.2021.9657597

Väisänen, V., Satokangas, M., Huhtakangas, M., Antikainen, H., & Sinervo, T. (2025). Medical deserts in Finland: Measuring the accessibility and availability of primary health care services. *BMC Health Services Research*, *25*(1), 281. https://doi.org/10.1186/s12913-025-12409-1

van Gool, K., & Pearson, M. (2014). Health, Austerity and Economic Crisis. *OECD*. https://www.oecd.org/en/publications/health-austerity-and-economic-crisis_5jxx71lt1zg6-en.html

World Health Organization. (2000). *The world health report 2000—Health systems: Improving performance*. https://apps.who.int/gb/ebwha/pdf_files/WHA53/ea4.pdf

World Health Organization. (2007). *Everybody's business—Strengthening health systems to improve health outcomes*. https://www.who.int/publications/i/item/everybody-s-business----strengthening-health-systems-to-improve-health-outcomes

World Health Organization. (2010). *Monitoring the building blocks of health systems: A handbook of indicators and their measurement strategies*. World Health Organization. https://iris.who.int/handle/10665/258734

World Health Organization. (2016). *Patient engagement*. World Health Organization. https://iris.who.int/handle/10665/252269

World Health Organization. (2018). *Building the economic case for primary health care: A scoping review*. https://www.who.int/publications/i/item/WHO-HIS-SDS-2018.48

World Health Organization. (2023). *Engaging patients for patient safety: Advocacy brief*. WHO. https://iris.who.int/bitstream/handle/10665/375011/9789240081987-eng.pdf?sequence=1

Yu, Y., Liao, J., Ma, D., & Zhu, W. (2024). Measuring the COVID-19 treatment efficiency in OECD countries: A multiplicative network DEA approach. *INFOR: Information Systems and Operational Research*, *62*(3), 419-448. https://doi.org/10.1080/03155986.2024.2337978