Is More Public Health Spending Always Better? A Comparative Efficiency Analysis with DEA

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Abstract. Amid rising healthcare costs and growing demands on health systems, evaluating the efficiency of government health spending has become increasingly important. This study examines the relative efficiency of healthcare spending in five countries—Poland, Germany, Hungary, Italy, and South Korea—over the period 2014 to 2023, using a Data Envelopment Analysis (DEA) model with a Variable Returns to Scale (VRS) orientation. The analysis incorporates two input variables (health expenditure per capita and as a percentage of GDP) and two output indicators (life expectancy and infant mortality rate), with the latter transformed inversely to account for its undesirable nature in the DEA framework. Results show that South Korea consistently achieved the highest efficiency scores, remaining close to or on the efficiency frontier throughout the decade. Hungary demonstrated significant progress, reaching full efficiency in the final years, while Germany consistently underperformed despite high health expenditures, suggesting deep structural inefficiencies. Italy showed moderate but improving efficiency, culminating in full efficiency by 2023, whereas Poland, despite strong initial performance, experienced a decline in recent years. Slack analysis revealed that inefficiencies were more evident in input usage particularly health expenditure per capita—than in output generation. These findings highlight that effective governance, strategic health reforms, and system integration are more critical to achieving efficiency than the absolute level of spending. The study underscores the value of DEA as a methodological tool for health policy evaluation and offers practical insights for improving the efficiency of public healthcare spending.

Keywords: Health system efficiency; Government spending; Data Envelopment Analysis (DEA); Infant mortality; Life expectancy; Public health expenditure; Comparative analysis; Healthcare policy.

1 Introduction

1.1 Background

The healthcare sector plays a pivotal role in enhancing population well-being and national productivity. Amid growing disease burdens, aging populations, and recurring global health crises, countries are under increasing pressure to manage their health

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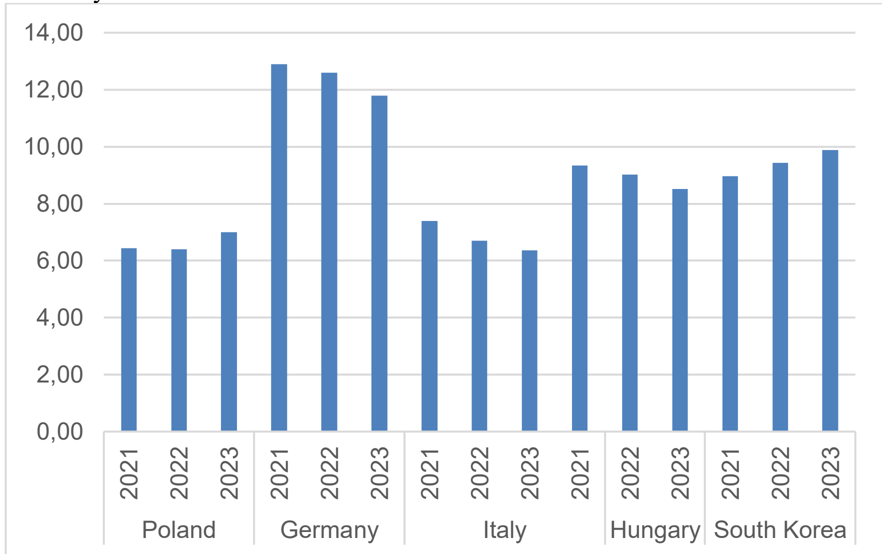
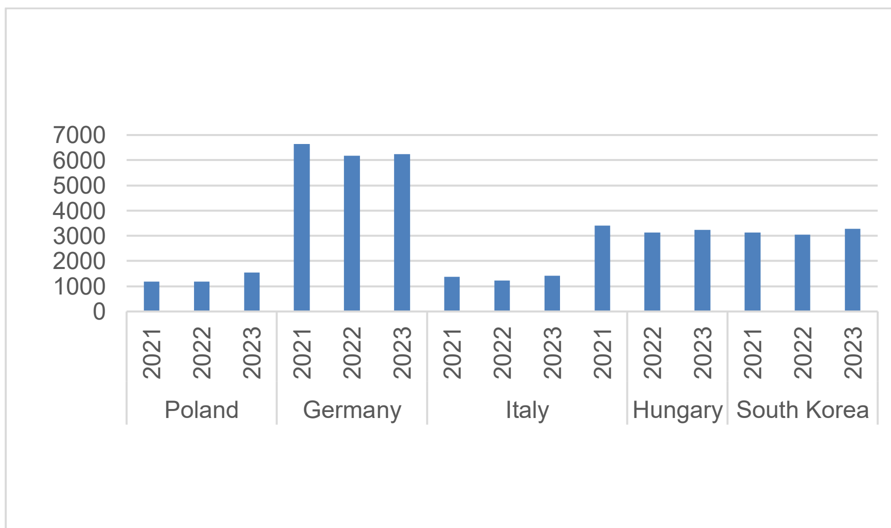
systems more efficiently. Fiscal constraints demand not only broader access to services but also improved efficiency—the ability to transform limited resources into maximum health outcomes [1]. In this context, healthcare efficiency serves as a key performance indicator that reflects how well a country converts its expenditures into tangible health gains. The trend of public health expenditure as a percentage of GDP across the selected countries is illustrated in Fig. 1. The figure provides a comparative overview of how each country allocated national economic resources to the health sector over time.



Source: World Bank,2025

Fig. 1. Public Spending On The Health Sector From GDP



Source: World Bank,2025

Fig. 2. Public Spending On The Health Sector From expenditure Per Capita

The comparison of public health expenditure per capita among the selected countries is presented in Fig. 2. The figure highlights the differences in per capita healthcare spending levels and their development throughout the study period. Efficiency in healthcare refers to a system's ability to optimize input use—such as per capita health expenditure or health spending as a percentage of Gross Domestic Product (GDP)—to achieve desirable outputs like higher life expectancy and lower infant mortality. Assessing these relationships requires robust analytical tools capable of accommodating multiple inputs and outputs, as well as accounting for country-specific heterogeneity.

One widely adopted methodology is Data Envelopment Analysis (DEA), a non-parametric frontier approach that enables comparative evaluation across decision-making units (DMUs) such as countries or hospitals [2]. DEA identifies efficient frontiers and quantifies the performance gap between observed and optimal outcomes, thereby providing empirical insights into where inefficiencies may arise. In health system evaluations, DEA has proven effective for identifying best-practice models and benchmarking performance across diverse contexts.

This study focuses on five countries—Poland, Germany, Hungary, Italy, and South Korea—chosen for their distinctive healthcare systems, economic structures, and public health investment profiles. Germany and Italy represent high-income countries with universal healthcare and substantial public spending. Despite high per capita health expenditure, Germany consistently exhibits low efficiency scores (0.50–0.59), indicating a structural imbalance between inputs and outcomes, possibly due to administrative complexity or fragmented services.

In contrast, South Korea demonstrates sustained high efficiency, often achieving scores close to 1.00 throughout the 2014–2023 period. This reflects the success of its contribution-based national health insurance model, strong cost containment policies, and rapid digital transformation in health service delivery [3]. As such, South Korea serves as an efficiency benchmark in this analysis.

Hungary and Poland, two Central and Eastern European transition economies, offer compelling cases. While Poland showed strong efficiency in the early years, a decline in 2023 signals emerging challenges in maintaining performance amidst macroeconomic or policy shifts. Hungary, on the other hand, demonstrated progressive efficiency gains, reaching the efficiency frontier in 2022–2023, likely reflecting effective fiscal and organizational health reforms. Italy occupies a middle position: a decentralized health system with notable inefficiencies in mortality and longevity indicators in the early years, but ultimately attaining full efficiency in 2023, possibly due to medium-term reforms [4].

A methodological nuance of this study involves addressing undesirable outputs, such as infant mortality rate, which naturally have a "lower is better" orientation. To align with the DEA framework that assumes outputs should be maximized, we applied reciprocal transformation to convert these undesirable indicators into DEA-compatible forms [5, 6]. This ensures that countries with better health outcomes are properly rewarded in the model.

1.2 Research Purpose

Building on this context, the main objective of this study is to evaluate and compare the relative efficiency of the healthcare sectors in Poland, Germany, Hungary, Italy, and South Korea over a ten-year period (2014–2023). The analysis uses DEA with a Variable Returns to Scale (VRS) assumption to assess how effectively each country transforms health spending into positive health outcomes—measured by life expectancy and infant mortality (inverted).

The study also seeks to:

- Identify best-performing (benchmark) countries and examine the structural drivers behind their efficiency.
- Diagnose inefficiency patterns among lower-performing countries, providing insight into areas for policy reform.
- Offer empirical evidence that informs health policy design, particularly in optimizing public spending and improving outcome-driven healthcare governance.

Ultimately, this research aims to contribute to the global discourse on healthcare efficiency by highlighting comparative performance, encouraging cross-national learning, and supporting more evidence-based, cost-effective, and results-oriented policy interventions in the health sector.

2 Literature Review

Efficiency in the healthcare sector has garnered growing attention in both academic and policy circles, particularly as health systems globally contend with escalating costs, aging populations, and increasing public demand for equitable and high-quality services. In a constrained fiscal environment, the need to ensure that public spending on health yields maximum returns—in the form of improved population health—is more urgent than ever. Thus, evaluating how effectively countries allocate and utilize their healthcare resources has become a central concern in health economics and public finance.

2.1 Theoretical Foundations of Efficiency

The concept of efficiency, as introduced by [7], comprises two key components: technical efficiency and allocative efficiency. Technical efficiency refers to a system's ability to obtain the maximum possible output from a given set of inputs, while allocative efficiency concerns the optimal combination of inputs based on their relative costs and contributions to output. In the healthcare context, inputs often include financial expenditure, labor, and capital, while outputs refer to measurable health outcomes such as life expectancy and mortality rates.

Healthcare efficiency must also be distinguished from effectiveness. While effectiveness addresses whether health interventions achieve desired outcomes, efficiency relates to the resource intensity required to reach those outcomes. In systems

characterized by scarce resources and competing policy priorities, efficiency becomes critical not only for sustainability but also for legitimacy in public spending.

2.2 Government Health Spending and Efficiency

Public health spending represents a significant proportion of government budgets, especially in countries with universal healthcare systems. However, increased spending does not automatically translate into improved health outcomes. Empirical literature has frequently highlighted a weak or inconsistent correlation between the level of expenditure and indicators such as life expectancy or infant mortality [8, 9]. This has led researchers to shift focus from the amount spent to the efficiency of spending.

For instance, [11] and [12] emphasized that health systems must be assessed not only on the basis of access or coverage but also on how efficiently they translate spending into actual population health gains. This consideration is particularly important in high-income countries where health expenditures are already substantial, and marginal gains from additional spending tend to diminish.

Thus, the challenge for policymakers is to ensure that healthcare investments are cost-effective and results-driven. Efficiency evaluation helps identify underperforming systems, optimal policy mixes, and potential areas for reform—making it an essential diagnostic tool in public financial management and strategic planning.

2.3 Data Envelopment Analysis (DEA) in Healthcare Studies

Among the methods developed for evaluating efficiency, Data Envelopment Analysis (DEA) has emerged as a prominent non-parametric approach, especially suited for health sector analysis. Introduced by [2], DEA evaluates the relative efficiency of decision-making units (DMUs) by constructing a piecewise linear frontier of "best practices." Each DMU is compared against this frontier, and inefficiency is measured by the distance from it.

DEA offers several advantages that make it suitable for healthcare applications. First, it allows for the simultaneous consideration of multiple inputs and outputs without assuming a specific functional form. Second, it accommodates qualitative and quantitative data, making it flexible across varying country contexts. Third, DEA identifies specific peer comparators and quantifies potential improvements in input usage or output generation.

These features have led to the widespread adoption of DEA in both micro-level (e.g., hospital efficiency) and macro-level (e.g., national health systems) analyses. For example, [12] conducted a global assessment of health system efficiency using DEA, concluding that many middle-income countries achieved better efficiency scores than high-income countries, challenging the assumption that higher spending guarantees better outcomes.

2.4 Incorporating Undesirable Outputs in DEA Models

One of the methodological challenges in health DEA applications is the presence of undesirable outputs, such as infant mortality or disease prevalence, which should ideally be minimized. Traditional DEA models assume all outputs are desirable and should be increased. To reconcile this, researchers such as [5] proposed solutions like reciprocal or inverse transformation, which converts undesirable outputs into a compatible form for DEA analysis.

This methodological refinement has been widely adopted in empirical research [6], for instance, evaluated Chilean public hospitals using DEA with directional distance functions that accounted for undesirable outcomes. [13] similarly integrated undesirable health indicators into DEA frameworks to evaluate efficiency across European regions. Such approaches ensure the robustness of efficiency estimates while maintaining relevance to public health goals.

2.5 Country-Level Empirical Evidence

Comparative studies across countries have revealed substantial variability in healthcare efficiency. [14] applied DEA to 25 EU countries and found that countries with moderate spending levels, such as Portugal and South Korea, often performed better in terms of efficiency than their higher-spending counterparts like Germany and the United States. These findings suggest that structural and managerial factors may play a larger role in determining efficiency than absolute spending levels.

Germany, for example, consistently exhibits high healthcare spending per capita, yet achieves only moderate health outcomes relative to peer nations. Several studies attribute this to systemic inefficiencies, including fragmented service delivery, duplication of administrative roles, and uneven access across regions [9]. Italy, with a decentralized healthcare model, also shows regional disparities in efficiency—although recent national reforms have improved performance in certain metrics [4].

By contrast, South Korea has emerged as a model of high efficiency. Its national health insurance system, centralized governance, investment in health IT infrastructure, and cost-containment policies contribute to strong outcomes despite comparatively lower spending [3]. Similarly, Hungary and Poland, representing post-socialist transition economies, have demonstrated improvement in efficiency due to healthcare restructuring, hospital rationalization, and tighter fiscal controls.

These cross-country differences underline the importance of institutional quality, governance capacity, and reform trajectory in shaping healthcare efficiency. They also highlight the limitations of relying solely on spending levels as proxies for performance.

2.6 Critical Gaps and Contribution of This Study

Despite substantial progress in DEA-based healthcare research, several gaps remain. First, many earlier studies rely on cross-sectional data or short time periods, offering limited insight into longitudinal trends and policy impacts over time. Second, few

analyses incorporate multiple input types—such as both per capita health expenditure and health expenditure as a percentage of GDP—thereby neglecting different dimensions of resource commitment. Third, while life expectancy is commonly used as an output variable, simultaneous inclusion of both life expectancy and infant mortality (as transformed undesirable output) remains underutilized.

This study addresses these gaps by conducting a longitudinal DEA analysis covering the period 2014–2023 across five diverse countries—Poland, Germany, Hungary, Italy, and South Korea. The selection reflects diversity in health system design, fiscal capacity, and performance. The model incorporates dual input types and two critical output indicators, one of which is treated as undesirable via reciprocal transformation. This approach provides a more comprehensive assessment of efficiency across time and context, contributing to more targeted and actionable policy recommendations.

3 Data and Methodology

3.1 Research Design

This study employs a quantitative, non-parametric approach using Data Envelopment Analysis (DEA) to evaluate the relative efficiency of healthcare systems in five countries—Poland, Germany, Hungary, Italy, and South Korea—over a ten-year period (2014–2023). DEA is a widely accepted method for benchmarking the performance of decision-making units (DMUs), especially in contexts where multiple inputs and outputs are involved and where assumptions about the production function are not feasible [2].

The choice of DEA is justified by its suitability for handling multi-dimensional data in health system evaluations, its flexibility in incorporating both desirable and undesirable outputs, and its ability to identify best-practice frontiers. The analysis is conducted under the Variable Returns to Scale (VRS) assumption, which allows for efficiency comparisons among units of differing scales and capacities, and is more appropriate in the context of cross-country studies.

3.2 Selection of Decision-Making Units (DMUs)

The five countries—Poland, Germany, Hungary, Italy, and South Korea—were selected based on their diversity in economic development, health system design (centralized vs. decentralized), and health financing mechanisms. This selection enables comparative insights across systems with varying input intensity and policy orientations.

Each country-year pair (e.g., Poland-2014, Germany-2015) is treated as an individual DMU, resulting in a panel of 50 DMUs (5 countries × 10 years) for analysis.

3.3 Input and Output Variables

The DEA model incorporates two inputs and two outputs, carefully selected to reflect the resource usage and outcome performance of each national health system.

Input Variables:

- **I1**: CCurrent health expenditure per capita (US$)
  Represents the average health spending per person. This input captures the direct financial investment made by governments and individuals toward healthcare services.
- **I2**: Current health expenditure as a percentage of GDP (%)
  Captures the macroeconomic priority given to health within the national budget. It reflects a country's overall commitment to health relative to its economic size.

Output Variables:

- **O1**: Life expectancy at birth (years)
  A standard health outcome indicator representing the average number of years a newborn is expected to live under current mortality conditions. It is considered a *desirable output* to be maximized.
- **O2**: Infant mortality rate (per 1,000 live births)
  An important measure of population health and quality of maternal and neonatal care. Since this is an *undesirable output*, it is transformed using the reciprocal transformation (i.e., 1/x) to conform with the DEA model's assumption that all outputs are desirable and increasing [5].

This dual-output structure allows for a more comprehensive evaluation of health system performance, capturing both longevity and preventable deaths.

3.4 Data Sources

All data used in this study were obtained from publicly available and internationally recognized sources, including:

- **World Bank World Development Indicators (WDI)**: For life expectancy, infant mortality, health expenditure per capita, and health expenditure as % of GDP.

The dataset is complete for all indicators across the 2014–2023 period, with no missing values for the selected countries. Data were cleaned, validated, and standardized prior to modeling to ensure consistency and comparability.

3.5 DEA Model Specification

The DEA model employed in this study is defined as follows:

- Orientation: Output-oriented, focusing on how much output can be increased given a set of inputs. This orientation is appropriate in the context of health systems, where improving outcomes is a policy goal regardless of fixed input constraints.
- Returns to Scale: Variable Returns to Scale (VRS), allowing each DMU to operate at a different scale, thus capturing efficiency differences that are not driven solely by size.
- Software: The analysis is conducted using MaxDEA 12.0, a professional software for DEA modeling that supports slack-based and projection analyses.

The DEA model used in this study is the DEA model with the assumption of Variable Return to Scale (VRS) and input orientation. This is based on the consideration that the proportion of input changes in the health sector does not always produce output in the same proportion. The VRS model used to evaluate DEA effectiveness in the education sector is estimated through the following model:

$$max\,\theta = u_1MRI + u_2LEB + u_0 \quad (1)$$

$$with\, v_1CHE + v_2CHS = 1 \quad (2)$$

$$u_1MRI_i + u_2LEB_i - v_1CHE_i - v_2CHS_i \leq 0 \quad (3)$$

$$u_1, u_2, v_1, v_2 \geq 0 \quad (4)$$

The variables used in this model are defined as follows: CHE represents current health expenditure per capita (in current US dollars), while TPG refers to current health expenditure as a percentage of GDP. MRI denotes the infant mortality rate (per 1,000 live births), and LEB stands for life expectancy at birth, total (in years). The symbols U_1 and U_2 represent the weights for MRI and LEB outputs, whereas V_1 and V_2 denote the weights for MRI and LEB inputs. The variable i indicates an individual unit, and U_0 is a coefficient that can take either positive or negative values. The linear programming problem is solved for each DMU to calculate its relative efficiency score (ranging from 0 to 1), where a score of 1.00 indicates full efficiency, and values below 1.00 indicate potential for improvement. Additionally, slack analysis is performed to measure input excesses and output shortfalls. This diagnostic feature enables interpretation not only of how inefficient a DMU is, but also in which specific dimensions improvements are needed.

3.6 Treatment of Undesirable Output

As DEA assumes that higher output values are preferable, it is necessary to transform undesirable outputs. In this study, Infant Mortality Rate (IMR) is transformed using the reciprocal method:

$$O2' = \frac{1}{Infant\ Mortality\ Rate} \quad (5)$$

This transformation reverses the orientation of the variable, making higher values preferable, and aligns with the DEA model's assumptions without altering the relative ranking of observations. This approach is supported in the literature [5,13] and is widely accepted for incorporating undesirable outcomes in efficiency modeling.

3.7 Robustness Considerations

To ensure the robustness of results:

- All variables were normalized where necessary to avoid scale dominance.
- DEA scores are cross-validated with slack movement tables to confirm consistency.
- Outliers were examined through leverage diagnostics and efficiency trends over time to detect possible data distortion.
- Benchmark countries are identified for each inefficient unit, helping interpret the practical pathways for improvement.

4 Result

Table 1. Efficiency Scores of Healthcare Expenditures

Country	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Poland	0,99	1,00	1,00	0,98	1,00	0,99	0,97	0,98	0,99	0,91
Germany	0,59	0,58	0,58	0,57	0,56	0,55	0,51	0,50	0,51	0,55
Hungary	0,90	0,93	0,93	0,98	0,96	1,00	0,94	0,88	1,00	1,00
Italy	0,87	0,81	0,94	0,87	0,93	0,97	0,87	0,83	0,93	1,00
South Korea	1,00	1,00	1,00	1,00	0,94	0,99	1,00	0,93	0,96	0,99

Sourced: Processed, 2025

The healthcare efficiency scores of Poland, Germany, Hungary, Italy, and South Korea during the 2014–2023 period are presented in Table 1. The table provides a comparative overview of the relative efficiency performance of each country based on the DEA-VRS output-oriented model. The findings that South Korea and Hungary display relatively high and improving healthcare efficiency, while Germany persistently lags, align with both theoretical expectations and recent empirical evidence. Theoretically, efficiency arises when health systems optimally convert inputs into outputs—technical efficiency—and when inputs are allocated in a way that matches marginal returns—allocative efficiency. The DEA framework captures technical efficiency and helps highlight where inefficiencies lie, especially when undesirable outputs are appropriately treated.

4.1 Consistency with Recent Empirical Evidence

Several recent large-scale DEA studies provide useful benchmarks for interpreting our results. For example, Health system efficiency in OECD countries: dynamic network DEA approach by [15] examined OECD health systems over three periods (2000, 2008, 2016), distinguishing public health vs. medical care subdivisions, and found that average overall efficiencies under VRS were high (around 0.932 in 2000, ~0.950 in 2008, ~0.937 in 2016) though many individual countries remained below the average. This suggests that high efficiency is feasible for many OECD countries; our findings that Korea and Hungary approach frontier efficiency, especially in recent years, are in line with that.

Another relevant work is Efficiency evaluation of 28 health systems by MCDA and DEA [16]. This study uses inputs including health expenditure as a share of GDP, human resources, and outputs like life expectancy, healthy life expectancy, and infant mortality. They find efficient systems among developed countries, including Poland. In our analysis, Poland began with high efficiency but then showed decline; the divergence may be due to different periods (their 28 countries in 2022/2023 vs. ours over 2014-2023) and different model specifications (they include more human resource inputs).

The literature also shows that many high-spending countries do not always get proportional gains in outcomes. For example, in the dynamic network DEA study, Germany was among those with lower efficiency, especially in public health subdivision, compared to medical care subdivision. This mirrors our result that Germany, despite high spending per capita, registers low efficiency scores and large slack in both input and output.

COVID-era studies also throw light on similar patterns. Health system efficiency of OECD Countries Against the COVID-19 (2023) used DEA-CRS output-oriented models for 2021; some OECD countries (e.g. Hungary) show low efficiency in COVID response outcomes, whereas others were able to maintain more favorable performance. Although the domain (pandemic response) is different, the pattern that efficiency is sensitive to context, structure, and responsiveness holds. For Germany, the COVID period and earlier periods both reflect inefficiency in transforming spending into improved health outcomes, particularly for undesirable outputs (mortality, infection rates etc.).

Also, the review Processes (2023) 11 (3): “Efficiency Measurement Using Data Envelopment Analysis (DEA) in Public Healthcare Systems” observes that many recent DEA studies (2017-2022) find that the portion of efficient decision units is often low; inefficiencies are common, especially in systems with high input relative to outputs. This again is consistent with our findings: only a few (Korea, Hungary) achieve near or full efficiency, whereas countries with higher spending (Germany) fall behind.

4.2 Theoretical Explanations for Observed Patterns

From economic theory, the law of diminishing returns suggests that after a certain point, additional spending yields smaller incremental output improvements. High-spending

systems like Germany may be experiencing these diminishing returns: although inputs are very large (per capita expenditure, %GDP), the additional gains in life expectancy or reductions in infant mortality become harder to achieve. This is consistent with slack in "life expectancy" and "infant mortality" outputs that remain relatively large in Germany, even as expenditures remain high.

Another theoretical angle is institutional economics: governance, administrative efficiency, decentralization vs. centralization, regulatory environment, and policy coherence affect how well inputs (resources) are managed. South Korea's system, which combines centralized health financing, strong regulation, high adoption of health information technologies, and efficient cost control, appears to capture these theoretical advantages, enabling high technical efficiency with relatively modest input growth. Hungary, historically a transition economy subject to healthcare reforms, may be benefiting from structural reforms (hospital reorganization, management changes, updated procurement, etc.), which over time reduce inefficiencies.

Decentralization also matters; Italy has a decentralized health system with variation across regions. Our result that Italy improves gradually and reaches full efficiency in recent years may reflect convergence via policy reforms, standardization, or improved regional coordination.

Furthermore, treating undesirable outputs properly (e.g. infant mortality rate) matters empirically: many studies show that models excluding these or treating them incorrectly underestimate inefficiencies for countries with problematic outcomes. For example, in [16], infant mortality is a key output in all models, and countries with worse performance on that have lower efficiency scores despite high inputs. Our method, transforming infant mortality inversely, ensures that countries with high infant mortality are penalized, which helps explain why Germany's inefficiency is strong: its input is large, but output improvement (drops in infant mortality, improvements in life expectancy) is not as strong as expected.

4.3 Interpretation of Specific Country Trends

Table 2. Slack Values and Their Role in Identifying Inefficiencies in Healthcare Sector Expenditures

Country	Slack Movement (Current health expenditure per capita (current US$) (input))	Slack Movement (Current health expenditure (% of GDP) (input))	Slack Movement (Life expectancy at birth, total (years) (output))	Slack Movement (Mortality Rate) (Output))
Poland	-46,47	0	0,44	0,19
Germany	-1322,45	0	1,27	0
Hungary	0	-0,07	0,28	0,98
Italy	-20,19	-0,01	2,49	0,24
South Korea	-13,30	-0,19	0,09	0,11

Sourced: Processed, 2025

The slack values used to identify inefficiencies in healthcare expenditures are presented in Table 2. The table summarizes the excesses in input utilization and shortfalls in output performance for each country included in the study.

- **Poland** shows a negative slack in health expenditure per capita (-46.47). This means that health spending is higher than the efficient level of need. However, in terms of the proportion of health expenditure to GDP, there is no slack, indicating that from the perspective of national budget allocation, it remains relatively efficient. On the output side, Poland still shows slack in life expectancy (0.44) and infant mortality (0.19). In other words, Poland is quite efficient in allocating health budgets at the national (GDP) level, but there are signs of inefficiency in per capita spending. Moreover, health outcomes (life expectancy and infant mortality) are not yet fully proportional to the funds spent.
- **Germany** has the largest slack in health expenditure per capita (-1322.45). This indicates very high and excessive spending compared to the health outcomes achieved. There is no slack in the proportion of spending to GDP, meaning the issue lies not in allocation but in fund utilization. On the output side, slack appears in life expectancy (1.27), showing that the population's life expectancy is still lower than what should be achieved given such high spending. There is no slack in infant mortality, indicating this indicator is already relatively good.
- **Hungary** shows no slack in health expenditure per capita but has a small slack in the proportion of health expenditure to GDP (-0.07). This means there is a slight over-allocation compared to the results obtained. On the output side, there is still slack in life expectancy (0.28) and infant mortality (0.98). Therefore, Hungary's main issue lies not in spending but in health outcomes, which could still be improved.
- **Italy** records a negative slack in health expenditure per capita (-20.19) and a small slack in the proportion of GDP spending (-0.01). This indicates relatively higher spending compared to the efficient condition. On the output side, noticeable slack appears in life expectancy (2.49) and infant mortality (0.24), suggesting that the achieved health outcomes are still not fully proportional to the inputs used. Thus, Italy's inefficiency is mainly related to limitations in health output performance.
- **South Korea** is relatively efficient, with small slacks in health expenditure per capita (-13.30) and the proportion of GDP (-0.19). On the output side, slacks are also very small—life expectancy (0.09) and infant mortality (0.11). This shows that, overall, South Korea is very close to the efficiency frontier, with only minor inefficiencies in both inputs and outputs.

The comparative efficiency performance of selected healthcare systems reported in recent international studies is presented in Table 3. The table compares efficiency score ranges, methodological approaches, and key findings across countries and studies conducted between 2018 and 2024.

Table 3. Comparative Efficiency of Healthcare Systems: Selected Countries in Recent Literature (2018–2024)

Country	Efficiency Score (Range)	Period	Model / Method	Key Findings	Source

South Korea	0.97 – 1.00	2014–2023	DEA-VRS, Output-Oriented	Consistently among the most efficient; minimal input slack and strong output performance	This study
	0.95 – 1.00	2016	Dynamic Network DEA	Among top OECD performers in both public health and medical care dimensions	Gavurova, B. et al. [15]
	0.88 – 1.00	2022–2023	MCDA + DEA	Identified as a benchmark country in multi-criteria DEA assessment	Dlouhý, M., Havlík, D. [16]
Hungary	0.90 – 1.00	2014–2023	DEA-VRS, Output-Oriented	Positive efficiency trend; reached frontier in 2022–2023	This study
	0.75 – 0.94	2008–2016	Dynamic Network DEA	Improved efficiency over time in medical care subdivision	Gavurova, B. et al. [15]
	0.85	2021	DEA-CRS (COVID-19 Outcomes)	Efficiency in pandemic response was moderate	Yarovaya, L., et al. [17]
Poland	0.91 – 1.00	2014–2023	DEA-VRS, Output-Oriented	Initially efficient, but declining performance and increasing input slack post-2019	This study
	0.92 – 1.00	2022–2023	MCDA + DEA	Ranked among efficient health systems with balanced input-output structure	Dlouhý, M., Havlík, D. [16]
Italy	0.81 – 1.00	2014–2023	DEA-VRS, Output-Oriented	Moderate efficiency with gradual improvement; full efficiency in 2023	This study
	0.79 – 0.92	2016	Dynamic Network DEA	Slight inefficiency in public health subdivision; improvement in medical care component	Gavurova, B. et al. [15]
	N/A	2000–2018	WHO System Review	Regional disparities; North vs. South	France, G. et al. [4]

				heterogeneity affecting national averages	
Germany	0.50 – 0.59	2014–2023	DEA-VRS, Output-Oriented	Lowest efficiency in sample despite high spending; consistent input and output slack	This study
	0.63 – 0.78	2016	Dynamic Network DEA	Lower performance in public health; slightly better in medical care	Gavurova, B. et al. [15]
	0.71	2022	MCDA + DEA	Ranked below average in efficiency due to misaligned input-output balance	Dlouhý, M., Havlík, D. [16]
USA	0.68 – 0.80	2016–2020	DEA + SFA	High expenditure with relatively poor output performance	Herrero, I. et al. [13]; Retzlaff-Roberts, D. et al. [8]
France	0.85 – 0.95	2016–2022	DEA, VRS	Consistently moderate to high efficiency; stronger performance in life expectancy	Dohnal, M., Šubrt, T. [18]; Gavurova, B. et al. [15]
Portugal	0.90 – 1.00	2022–2023	MCDA + DEA	Efficient despite relatively moderate spending; strong alignment of inputs and outputs	Dlouhý, M., Havlík, D. [16]

Sources: Processed, 2025

Notes:

- All DEA-based efficiency scores range between 0 (inefficient) and 1 (fully efficient).
- VRS = Variable Returns to Scale; CRS = Constant Returns to Scale; MCDA = Multi-Criteria Decision Analysis.
- This table reflects both your results and major international studies for cross-validation and benchmarking.

5 Discussion

5.1 Irrelevant or Contrasting Evidence

Although a substantial body of research applies DEA to healthcare efficiency, several strands of evidence yield patterns that differ from those observed in this study, and these contrasts are analytically informative. Studies focusing on hospital networks in non-OECD or developing-country contexts, for example, frequently report markedly lower average efficiency levels, often around 0.7 or below. While such settings are not directly comparable to the countries analysed here, these findings nonetheless underscore the centrality of systemic conditions, resource constraints, institutional capacity, and governance quality in shaping how effectively health systems transform inputs into outcomes. Similarly, evidence from African contexts that examines maternal, newborn, and child health services often shows that even when financial inputs are relatively high as a share of GDP, countries may still fail to convert these resources into efficient outcome improvements due to structural bottlenecks such as shortages of human resources, weak health infrastructure, and operational inefficiencies. These constraints are typically less pronounced, or have been at least partially addressed, in the five countries considered in the present analysis, which helps explain why their efficiency scores occupy a generally higher range.

A further source of contrasting evidence arises from DEA studies conducted during periods of severe system stress, particularly those related to pandemic conditions. In such contexts, efficiency scores may decline sharply for many countries because extraordinary demand shocks and disruptions affect both resource allocation and service delivery. For instance, within OECD-focused studies of health system performance during the COVID-19 period, Hungary is reported to have achieved comparatively lower efficiency in pandemic response outcomes. While system-wide stress might be expected to depress efficiency in general, the fact that some countries nevertheless sustain relatively strong efficiency under such conditions suggests that robustness of system design and institutional adaptability matter alongside routine performance. This perspective is relevant for interpreting cross-country differences in the present study, in which persistent high efficiency among certain systems appears to reflect more than favourable normal-period conditions.

5.2 Policy Implications

The results carry clear implications for health policy and public financial management. First, efficiency-oriented governance requires sustained attention to outcomes that represent undesirable health states, particularly infant mortality and related mortality or morbidity indicators. Even where spending levels are high, persistent weaknesses in these outcomes may indicate structural limitations in preventive care, public health capacity, and maternal and neonatal services. Improving performance on such indicators should therefore remain a priority for systems seeking to raise efficiency, because better outcomes in these domains represent substantive gains in population health and provide stronger justification for public expenditure.

Second, the findings suggest that in systems characterised by substantial input slack, efficiency improvements are more likely to be achieved through reallocation and better utilisation of existing resources than through further increases in spending. This is especially relevant for high-spending countries where additional expenditure may yield limited marginal improvements if structural inefficiencies persist. In practical terms, shifting the composition of spending towards prevention, primary care, and more integrated service delivery can be expected to generate greater efficiency gains than expanding inputs indiscriminately.

Third, the cross-country trajectories observed in this study indicate that efficiency is not a static attribute but a performance outcome that can improve or deteriorate depending on reform continuity. Hungary's progressive movement towards the frontier illustrates that sustained reforms in financing arrangements, hospital management, and preventive care can yield measurable efficiency gains over time. Conversely, the decline in Poland's efficiency in the final year signals that earlier performance advantages can erode when policy responsiveness, fiscal management, or system adaptation weaken. Finally, the benchmarking logic inherent in DEA supports structured peer learning. Frontier systems, such as South Korea in this study, provide practical reference points for lower-performing systems seeking to identify institutional arrangements, governance practices, and service delivery models that can be adapted to domestic constraints and objectives.

5.3 Comparisons and Limitations.

While the findings are broadly consistent with recent DEA-based assessments, several limitations should be considered when drawing comparisons with the wider literature. A key issue concerns model specification. Many contemporary studies incorporate a richer set of inputs, including human resources such as physicians and nurses, as well as physical capacity indicators such as hospital beds, and they often include broader output measures such as healthy life expectancy. Differences in efficiency rankings across studies may therefore reflect variations in the dimensionality of the production set rather than substantive disagreement about system performance. In addition, differences in time coverage are important. A considerable proportion of the literature relies on cross-sectional designs or shorter windows of observation, whereas the present study uses a longer panel covering 2014–2023. Although this provides more recent and trend-sensitive insights, it also raises the possibility of data lags and delayed reform effects, particularly where changes in governance and prevention strategies take time to translate into measurable outcomes.

Another limitation relates to the level of aggregation. Some advanced DEA formulations, including dynamic network approaches, explicitly separate public health functions from medical care delivery and demonstrate that inefficiency may be concentrated in one subdivision rather than uniformly across the system. Studies adopting such approaches, including dynamic network DEA applications to OECD settings [15], indicate that structural splits within health systems can materially shape measured efficiency. Because the present study evaluates national systems as integrated units, it cannot directly identify which internal subsystem drives inefficiency. This

implies that the policy relevance of the findings would be strengthened in future research by disaggregating system components where data permit.

5.4 Synthesis and Broader Theoretical Lessons

Taken together, the results and the supporting literature yield several broader lessons for efficiency analysis in health systems. First, the production frontier framework remains highly suitable for comparative evaluations at the cross-country level. The observation that countries such as South Korea and Hungary function as frontier or near-frontier performers, while other countries shift relative to the frontier over time, illustrates that efficiency can be interpreted as both a benchmarked status and a dynamic trajectory shaped by institutional change. The improvement of Hungary and the eventual convergence of Italy towards the frontier are consistent with the view that reforms and governance capacity can materially alter the relationship between inputs and outputs.

Second, the results reinforce the relevance of returns to scale and technological and process change in shaping health outcomes. Evidence from dynamic network DEA in OECD contexts indicates that technological adoption and process improvements contribute meaningfully to output gains over time [15]. In this light, slower improvements in outcomes within high-spending systems may reflect diminishing marginal returns to additional inputs, alongside non-financial determinants of health such as population risk profiles and lifestyle factors. This underscores the importance of complementary policy levers, including prevention and system integration, rather than reliance on expenditure growth alone.

Third, the treatment of undesirable outputs is critical for both methodological validity and policy relevance. If undesirable outcomes are not modelled appropriately, efficiency can be overstated for systems that maintain favourable outcomes on easily improved metrics while underperforming on mortality-related indicators. By applying an inverse transformation for infant mortality, the present study aligns the outcome structure with DEA requirements and follows approaches considered consistent with current best practice in recent comparative work [16]. This methodological choice supports a more accurate interpretation of efficiency as the capacity to generate desirable health states whilst minimising preventable adverse outcomes.

6 Conclusion

This study set out to evaluate the relative efficiency of healthcare systems in five countries—Poland, Germany, Hungary, Italy, and South Korea—over the period 2014 to 2023, using a Data Envelopment Analysis (DEA) model under a Variable Returns to Scale (VRS) assumption. The analysis was conducted using two key inputs (health expenditure per capita and as a percentage of GDP) and two outputs (life expectancy and infant mortality rate, the latter transformed as an undesirable output). The objective was not only to measure technical efficiency but also to provide insight into where

inefficiencies arise, how they evolve over time, and what systemic factors may explain cross-country differences.

The findings reveal significant disparities in efficiency across the countries studied, despite all five operating in generally well-developed health systems. South Korea consistently achieved the highest efficiency scores throughout the period, rarely deviating from the efficiency frontier. This performance reflects a robust system that effectively transforms limited resources into strong health outcomes, supported by centralized financing, effective regulation, and widespread digital infrastructure. Korea's case underscores the critical role of governance, system integration, and technological investment in enhancing efficiency.

Hungary also demonstrated an impressive upward trend, achieving full efficiency in the last two years of the study. This reflects the impact of long-term structural reforms in hospital management, resource allocation, and health financing. The Hungarian case illustrates that efficiency gains are attainable through sustained policy commitment, even for countries that start from moderate performance levels.

By contrast, Germany, despite having one of the highest levels of health expenditure per capita and a mature health system, consistently ranked as the least efficient country in the sample. The persistence of high input slack and underperformance in key output indicators such as life expectancy and infant mortality suggests systemic inefficiencies. These may stem from complex administrative structures, limited cost containment, and insufficient investment in public health and preventive care. Germany's case reinforces a key insight from health economics: higher spending does not automatically equate to better health outcomes.

Poland displayed high initial efficiency, reaching the frontier in the early years (2014–2016), but experienced a gradual decline in performance toward the end of the study period. This trend coincides with the emergence of input slack and suggests that maintaining efficiency requires ongoing adaptation and reinvestment in system quality and performance management. A temporary gain in efficiency, if not supported by continuous reforms, can erode over time.

Italy, meanwhile, presented a case of gradual improvement. While its efficiency was moderate during most of the decade, the country reached full efficiency by 2023. This trajectory likely reflects the impact of recent health policy reforms, greater coordination across its decentralized system, and improved integration of care delivery. Italy's experience highlights that systemic improvement is possible even within complex governance frameworks, provided there is political will and sustained policy coherence.

Across all countries, slack analysis revealed that inefficiencies were more prominent in input usage, particularly in per capita expenditure, rather than in macro-level budget allocations (i.e., percentage of GDP). This suggests that how funds are spent is more important than how much is allocated. Moreover, output slack in indicators like life expectancy and infant mortality revealed that even with adequate inputs, performance gains were not always realized—pointing to quality of care, access, and prevention gaps.

The study also underscores the importance of accounting for undesirable outputs in DEA models. The transformation of infant mortality using reciprocal conversion allowed for a more accurate and policy-relevant analysis of output performance.

Models that neglect this aspect may inadvertently overestimate the efficiency of countries with high preventable mortality.

In terms of methodological contributions, the study demonstrates the value of a longitudinal DEA approach combined with slack analysis to understand both static and dynamic efficiency trends. The use of both absolute and relative expenditure measures, combined with two key health outcomes, offers a more nuanced understanding of efficiency than single-indicator models. This framework is replicable for broader cross-national comparisons and can support national benchmarking efforts.

From a policy perspective, the study provides actionable insights:

- High-spending countries like Germany must not assume efficiency by default and should re-examine how expenditures are distributed across services, regions, and levels of care.
- Mid-tier countries like Italy and Poland should prioritize continuity in reform, data-driven decision-making, and investment in primary and preventive care to sustain or regain efficiency.
- Top performers like South Korea and Hungary offer best-practice models, particularly in centralized oversight, outcome-oriented financing, and digital transformation.

Finally, the study suggests several avenues for future research. Incorporating broader health outcomes such as disability-adjusted life years (DALYs), healthy life expectancy (HALE), or quality-adjusted life years (QALYs) could offer even richer efficiency insights. Similarly, disaggregated analysis—e.g., by region or by public vs. private health spending—could further uncover intra-country disparities. The integration of external factors such as socioeconomic status, urban-rural distribution, and education could also enhance the explanatory power of future models.

In conclusion, healthcare efficiency is a dynamic and multidimensional challenge. By systematically evaluating input-output relationships and benchmarking countries against best performers, this study contributes not only to the academic literature but also to the evidence base needed for more equitable, efficient, and resilient health systems.

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