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An assessment of economy- and transport-oriented health performance

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Abstract

Background Good health can prolong one's lifespan and is a fundamental human right. Thus, human health is being influenced by prejudiced from sociological, environmental, economic, and geographic aspects. The economy and transportation system pose a serious challenge to the assessment of the health performance of economies.

Objective This study aims to assess the health performance of Organization for Economic Cooperation and Development (OECD) economies by using economic and transport-related indicators and examining the role of health expenditure and governance in improving efficiency.

Methods This study measures the economy- and transport-oriented health efficiency of 35 OECD economies for the period of 2000–2022. In the first stage, this study employs a slacks-based measure and the data envelopment analysis–window analysis approach to conduct individual (economy and transportation) and joint assessments to measure health efficiency. In the second stage, this study uses the tobit regression method to investigate the effects of influencing factors, namely, government general health and pharmaceutical expenditures, the medical infrastructure, and governance, on health efficiency.

Results Empirical results reveal that a 1-unit change in the health expenditure during the research period improves economy-oriented health efficiency by 71% and transport-oriented health efficiency by 58%. The econometric analysis demonstrates that all the coefficients of economy- and transport-oriented health efficiency are significant and positive. Notably, a 1-unit change in the medical infrastructure increases economy- and transport-oriented health efficiency by 50.8%, and a 1% increase in pharmaceutical expenditure increases the health, economy, and transport efficiency scores by 16.3%, 33%, and 58.6%, respectively.

Conclusions The findings suggest that some of the economies were efficient with regard to their health-oriented outputs, that is, quality of life and mortality and morbidity rates, and most of the economies demonstrated excellent economic performance. The findings of the transport-oriented health efficiency assessment reveal that the economies were unable to perform well in the last year of the research period owing to the nationwide lockdowns. Nonetheless, they demonstrated efficiency in the first half of the research period. The joint assessment of economy- and transport-oriented health efficiency indicates that economic and transport input resources can adversely affect the GDP and life expectancy simultaneously, and the medical infrastructure, pharmaceutical expenditure, and number of medical graduates serve as constructive stimuli for health efficiency improvement.

Keywords Economy, Health expenditure, Efficiency, OECD economies

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Background

Health is a fundamental right of every individual and plays a vital role in economic and social development. However, the economic environment (e.g., economic activities) can drastically affect health-related performance. The effect of the economic environment may be progressive and harmful to society, such as the environment and human health [1–3]. Therefore, quantifying the term "health" is challenging [4–6]. Life expectancy is a desirable output, whereas mortality and morbidity are undesirable outputs. The idea indicates that desirable and undesirable outputs may coexist in a health system. Economies face several challenges with respect to the performance of their health, economic, and socioeconomic systems [7–10].

Some health systems demonstrate poor performance in controlling undesirable outputs and increasing life expectancy. According to an OECD report, in 2020 and in the first half of 2021, the number of deaths increased by 16% owing to COVID-19. In addition, life expectancy decreased in 24 of 30 countries compared with that in the United States (1.6 years) and Spain (1.5 years). Similarly, the lockdowns imposed to protect people's lives and improve their health caused a sharp decline in economic growth and travel activities, which drastically affected welfare maximization efficiency [11]. To address such issues, economies focused on reallocating their available capital to achieve optimal desirable outputs. Moreover, the pandemic strongly influenced current health-oriented systems and their associated arrangements [12, 13].

Health efficiency

The assessment of a country's health-related performance is an effective means for designing development strategies. Tariq [14] and Ateeq et al. [7] examined health-oriented data/information management, which can influence the performance of health-related decision makers. The authors suggested that healthcare units should use the latest technology to improve their performance. Lupu and Tiganasu [15] argued that the health system of European countries demonstrated high inefficiency in different time periods, because the countries were severely affected by the pandemic. Moreover, influencing factors such as population density, age, and comorbidities, including education, have a remarkable impact on health efficiency in three waves [16–18].

Lgün et al. [19] evaluated the performance of a health system by employing the data envelopment analysis (DEA) approach and found that the system's average efficiency score was higher than 90%, which indicated that the decision-making units (DMUs) continued to use the available resources optimally. In the second stage, the influencing variables demonstrated a significant correlation with health efficiency. Hajiagha et al. [20] assessed the performance of health-oriented DMUs and determined that healthcare units can improve their efficiency by effectively managing their available input–output resources. Furthermore, an improvement in the discrimination power of the DEA method can increase efficiency scores.

Meanwhile, by using the DEA approach, Lyu et al. [21] showed that public health institutions in eastern regions with the latest technology perform well. However, the authors' focal point suggests that the digital economy can stimulate the performance of public health institutions and improve the quality of government regulators. Md. Hamzah et al. [22] argued that increasing the COVID-19 management efficiency level by using the DEA method will produce desirable public health outputs. Moreover, ineffective medical care processes can substantially increase inefficiency. Nonetheless, disease or virus preparedness and effective response and resource allocation can increase the efficiency of healthcare units.

Hasan et al. [23] developed an analytical dataset to analyze the productivity of health workers and found that the large variation in productivity across health services can affect efficiency. In addition, the authors observed substantial dispersion in their measurement of the outputs of healthcare workers. Fraser-Hurt et al. [24] argued that health benefit packages can improve the efficiency of universal health coverage. Moreover, countries can increase the efficiency of their resource allocation by using a health intervention prioritization tool. Gómez-Gallego et al. [25] assessed the technical efficiency of European health systems by using DEA and fuzzy DEA (FDEA) methods. The authors' analytical outcomes exhibited a positive association between the FDEA and DEA approaches and that the health systems can be improved by measuring their efficiency. Furthermore, influencing factors such as income inequality and economic freedom may have a significant effect on health efficiency.

Effects of health expenditure

Prior research with supporting empirical evidence showed the effects of health expenditure on health systems and their performance. For example, El Khatib et al. [26] and Coates et al. [27] argued that internal and external factors, such as training and technology, can exert a substantial influence on health performance. Current models contribute to the literature by adding the most relevant causes of health performance improvement. Vysochyna et al. [28] and Ippolito et al. [29] argued that healthcare expenditure has a positive effect on the performance improvement of healthcare units. Oladosu et al. [30] claimed that public health spending exerts a remarkable impact on health performance. Specifically, a certain amount of the total government expenditure can improve mortality and morbidity rates. In addition, a 1% change in public health expenditure can drastically reduce undesirable health outputs by 15%. Influencing factors such as the gross domestic product (GDP), the literacy rate, and urbanization play a vital role in the attainment of health outcomes. Sieber et al. [31] debated on the role of the health expenditure of European countries. Social protection expenditure and health inequality are valuable for determining the effect of healthcare expenditure. The authors indicated that a negative correlation exists between socioeconomic health inequality and social protection health expenditure.

In addition, Bhattacharjee and Mohanty [32] examined out-of-pocket healthcare expenditure and found that influencing factors such as age, education, location, and caste have a drastic impact on such expenditure. Moreover, government hospital regulations can reduce out-of-pocket healthcare expenditure by improving healthcare information dissemination through the use of information communication technology. The Cinaroglu [33] debate on the effect of pharmaceutical expenditure, specifically, an out-of-pocket price policy for substantial pharmaceutical pricing reform, revealed a positive association between such expenditure and individuals. The argument revealed that an increase in pharmaceutical expenditure can cause household conflicts. However, economy-oriented health policies may positively affect the GDP, and the implementation of effective fiscal policies to control pharmaceutical prices and develop industrial health-related sectors may improve people's health.

Furthermore, Bashir et al. [34] found that health investment plays a vital role in improving public health in the OECD countries. In addition, an increase in the average public health expenditure can improve medical infrastructure such as hospitals, physicians, nurses, and staff and thus drastically prolong life expectancy. For example, Chen et al. [11] emphasized the importance of health expenditure in assessing macro efficiency. The authors disagreed on the amount that people should spend on healthcare as a proportion of their total income. Marginal expenditure can reduce other types of expenditure, such as household spending (i.e., education, transportation, travel, and so on). Furthermore, the authors indicated that economies underspend on healthcare. Elola-Somoza et al. [35] discussed the relationship between public health spending per capita and mortality rates in European countries but found no evidence to support the argument of the existence of a correlation between reduced public health expenditure and modest upshots during the COVD-19 pandemic.

Moreover, an incremental increase in funds can improve efficiency. Van Gool et al. [36] found that primary care investment has a drastic effect on the health performance efficiency of 34 OECD countries and indicated that large primary care investments will not improve the performance of health systems with regard to specific severe diseases, such as cervical cancer. However, primary care investment-oriented strategies and policies should be targeted to improve the performance of health systems. Herberholz and Phuntsho, S. [37] investigated the role of out-of-pocket health expenditure in the health system, specifically, healthcare-related transportation and spiritual expenses, and revealed that geographic, morbidity, and socioeconomic factors can influence health expenditure through transport activities. Moreover, transport activities can increase healthcare expenditure in rural areas.

Significance of the study

Prior studies did not emphasize the assessment of health efficiency related to the economy and transportation jointly or individually, specifically, desirable and undesirable outputs in the framework of a slacks-based measure (SBM). However, several studies examined the relationship between healthcare expenditure and the GDP and life expectancy. In addition, previous studies failed to assess health efficiency based on a moving average and considered it merely in absolute terms. Moreover, discussions on transportation variables as inputs that can be converted into desirable and undesirable health and economic outcomes are scarce. Another gap in the literature is the lack of investigations on the joint effects of the economy and transportation on health efficiency during the research period. Previous studies neglected to address the role of governance in the second-stage analysis, even though it plays a vital role in improving the efficiency of a country. Furthermore, previous studies did not examine the different types of health expenditure, such as the share of the government's general health expenditure in the current health expenditure, and the medical infrastructure.

This study explores the role of government health expenditure, the medical infrastructure, pharmaceutical expenditure, and governance in the health efficiency analyses. The aforementioned factors can influence health performance by providing financial incentives, health facilities, and law and order, including rules and regulations. Several studies examined factors that may be correlated with economic growth and health. However, no studies have conducted economy- and transport-oriented health efficiency analyses. By investigating the role of health expenditure as an external variable in improving health performance, this study can help economies develop improved health-oriented policies by allocating financial incentives, building health facilities, and implementing rules and regulations. Thus, this study examines whether undesirable and desirable outputs from economic and transport activities can simultaneously affect a country's performance and whether health expenditure is correlated with economy- and transport-related health efficiency.

Objective of the study

This assessment aims to determine the health performance of the OECD economies by using economic and transport indicators and examining the effect of health expenditure and governance on efficiency. This study chooses the OECD economies as the sample for several reasons. First, the OECD economies contribute significantly to the global GDP. Second, the economies receive millions of tourists per year; thus, they have extensive transport activities and produce desirable and undesirable outputs, such as high mortality rates. Third, according to an OECD report, the share of the health expenditure of the OECD countries for public health improvement in their GDP is small (approximately 9.9%). Thus, their health efficiency should be evaluated. Fourth, pharmaceuticals contribute significantly to life expectancy and quality of life improvement. The OECD economies spent approximately USD 410 (million) on pharmaceuticals at purchasing power parity per capita in 2005, which is lower than their current healthcare expenditure. Despite the OECD countries' modest healthcare expenditure, the question of whether and how healthcare expenditure, specifically, pharmaceutical expenditure and the medical infrastructure, affects the performance of the health system of the OECD economies with respect to their economic and transport input resources remains. Thus, an assessment of the impact of pharmaceutical expenditure, the medical infrastructure, and governance on the health efficiency of the OECD economies will have significant implications for public health.

Contributions of the study

This research makes numerous contributions to the literature. First, this study conducts individual and joint assessments of health efficiency (economy- and transport-oriented health efficiency). Second, this study incorporates the desirable and undesirable outputs of the economic and transport inputs by using an SBM, which can calculate the absolute efficiency scores. Third, this study calculates the efficiency scores based on a moving average by conducting DEA–window analysis (DEA–WA), rather than DEA, which can incorporate the absolute efficiency scores. Fourth, in the second stage, this study analyzes the effects of health expenditure on economy- and transport-oriented health efficiency, because the DEA approach does not investigate the relationships among variables. Last, this study investigates the effect of governance on the individual and joint assessments of health efficiency.

The findings of this study indicate that some of the economies, namely, Iceland, New Zealand, Sweden, and Switzerland, demonstrated transport-oriented health efficiency in the first year of the research period. By contrast, the other economies demonstrated inefficiency in the first year and remained inefficient during the middle and final years of the research period. In addition, none of the economies exhibited health efficiency with respect to transportation in the last year of the research period, perhaps because health-oriented restrictions, such as lockdowns, were imposed around the world in 2020 to control the spread of COVID-19. Furthermore, the countries' governance increased their transport-oriented health efficiency by 7.80%, and their medical infrastructure and pharmaceutical expenditure had a strong influence on their health performance with respect to transportation. The results suggest that the 50.8% improvement in the countries' economy- and transport-oriented health efficiency is due to the 1% change in their medical infrastructure. By contrast, the countries' medical infrastructure, such as doctors, nurses, employees, and hospital units, did not considerably improve their economy-oriented health efficiency.

The rest of this paper is structured as follows: the data sources and econometric models, as well as the methods, are described in the "Methods" section. The results of the investigation and the discussion are presented in the "Results" and "Discussion" sections, and the findings, policy implications, and future research directions are discussed in the "Conclusions" and "Limitations" sections.

Methods

Theoretical framework and model estimation

We propose a theoretical framework in this study to assess the performance of the OECD economies with regard to economy-, transport-, and health-oriented factors. Figure 1 illustrates the economy- and transport-oriented health efficiency model, which exhibits how economic inputs, namely, the total labor force, consumption expenditure, health expenditure, traffic, and transport infrastructure, can be converted into desirable outputs, that is, the GDP and life expectancy, and undesirable outputs, namely, mortality and morbidity, in the framework of parametric and nonparametric approaches. The conversion of resources through various methods may produce desirable and undesirable outputs, which

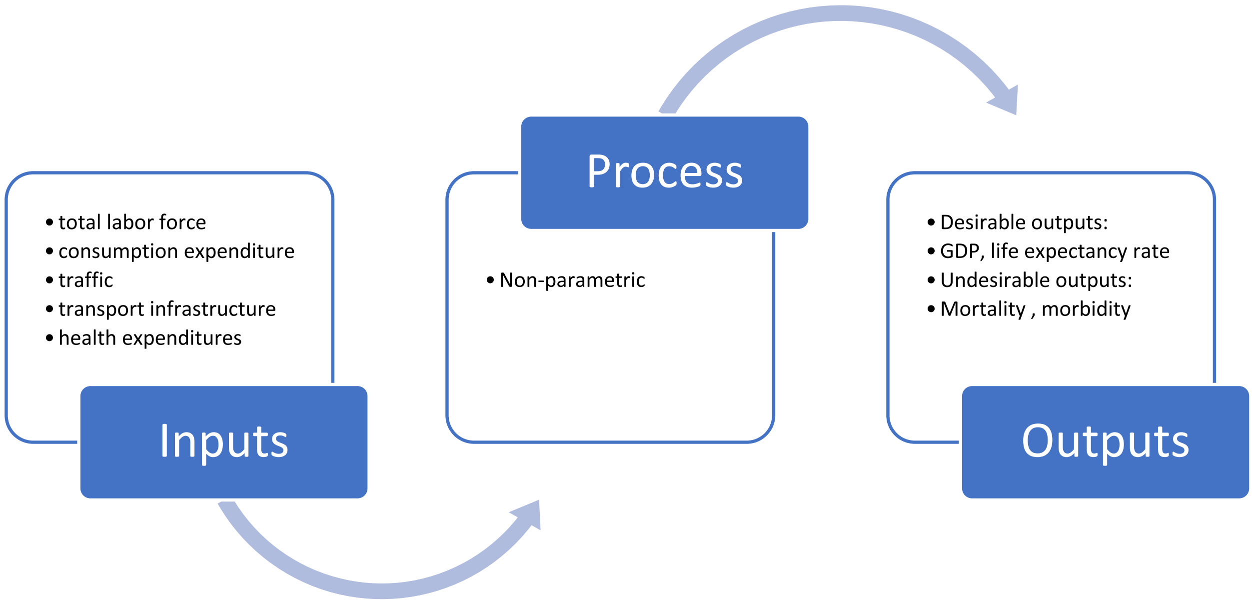

Fig. 1 Economic and transport-oriented health efficiency model

can indicate whether the resources can efficiently generate outputs at different scales [38–41].

We define the labor force as individuals who seek work based on their skills and abilities at a specific wage rate. We select the labor force as an input in the current model, because it can significantly contribute to economic growth and life expectancy. We define consumption expenditure as the amount of money spent by the nation on all goods and services to achieve the optimum level of utility. This factor can also substantially increase the GDP and life expectancy (because individuals spend specific amounts of money on health-oriented goods). Similarly, we define the health expenditure input as the amount of money spent on health-oriented commodities over a certain period. We use the indicator in the current model as an input for improving health performance. Moreover, the indicator can significantly contribute to the attainment of desirable outputs, namely, the GDP and life expectancy.

In this study, we define traffic as the movement of vehicles from one destination to another, which can cover a specific area in kilometers. This indicator can generate desirable (i.e., the GDP) and undesirable (i.e., mortality and morbidity rates) outputs. Similarly, we define the transport infrastructure as facilities provided by the government or private institutions to travelers. We choose the indicator for the current model, because it can contribute to the production/attainment of desirable and undesirable outputs. However, poor transport infrastructure can generate undesirable outputs. Efficiency can be measured through different aspects, such as inputs and outputs. An input-oriented approach exhibits a minimum level of input resources and a static output level. For instance, minimal input resources are required to achieve a certain GDP, life expectancy rate, and government general health expenditure, or economic resources such as the total labor force and consumption and health expenditures, including the transport infrastructure, are utilized at the minimum level to produce a certain level of output. The process that will lead to efficiency is determined through mathematical programming. Table 1 provides further information on the indicators.

After evaluation of health efficiency analysis for the economies, this study concentrates on factors affecting health efficiency and life expectancy, e.g., governance, general government health expenditure, medical infrastructure, pharmaceutical expenditures, and GDP per capita. The reason is that the non-parametric approach does not investigate the association among the variables. Thus, we employ econometric approaches to estimate the relationship. The empirical model is described as follows:

$$HE_{it} = \beta_0 + \beta_1(GOV_{it}) + \beta_2(MG_{it}) + \beta_3(MIF_{it}) + \beta_4(PHE_{it}) + \beta_5(GDPPC_{it}) + \varepsilon_{it}{}' \quad (1)$$

Equation (1) reveals that health efficiency (HE_{it}) is a function of governance (GOV_{it}), medical graduates

Table 1 Input/output indicators for DEA analysis

Indicator	DEA analysis	Definition
Total labor force	Input	Number of individuals who can work and meet the requirements for inclusive employment; used as an input for the efficiency analysis
Consumption expenditure	Input	Used as an input for the efficiency analysis, because the amount of money spent on final goods and services can increase desirable outputs and reduce undesirable outputs
Traffic	Input	Used as an important factor for the efficiency analysis, because it can produce dual outputs, such as GDP and deaths caused by traffic accidents
Transport infrastructure	Input	Facilities for travelers; quality of transport infrastructure can generate desirable and undesirable outputs; poor transport infrastructure quality can generate undesirable outputs; important for measuring efficiency
Health expenditure	Input	Important factor for efficiency analysis, because spending on health-oriented products can enhance life expectancy, as well as GDP incrementally
GDP	Desirable output	Desirable output that can affect economic development, including life expectancy; high GDP level can positively impact health performance
Life expectancy rate	Desirable output	Desirable output indicating the expected average life of individuals in term of number of years; important factor for analyzing the performance of a health system
Mortality rate	Undesirable output	State of being dead; intended/condition for death owing to different factors, such as congested traffic or poor transport infrastructure (e.g., accidents); undesirable output that can influence the performance of a health system
Morbidity rate	Undesirable output	State of having an illness/disease or mental or physical symptoms of a disease; may facilitate the poor performance of a health system

Source: author's derivation

(MG_{it}), medical infrastructure (MIF_{it}), pharmaceutical expenditure (PME_{it}), and gross domestic product per capita ($GDPPC_{it}$). Therefore, governance (GOV) is an important factor for health efficiency, and defined as structures and processes that ensure political stability, rule of law, quality of regulatory, transparency and accountability. GOV refers to Worldwide Governance Indicator (WGI), developed by World Bank to assess the governance quality. WGI contains six dimensions e.g., voice and accountability, governance effectiveness, rule of law, monitoring quality, political stability and absence of violence, and control of corruption. It is an anticipated to have a positive effect on health efficiency e.g., $\left({}^{\partial HE_{i,t}}/_{\partial GOV_{i,t}} > 0\right)$. The reason may behind that GOV can improve the health efficiency through adopting the rule and law, political stability and corruption free strategies. Several findings e.g., Hussain et al. [42, 43] and Zhou et al. [44] also argue that governance improve the country's economic efficiency over time. In addition, GHE is also important factor for health efficiency. It is defined as expenditures endure by governmental bodies related to health, which are shared of current health expenditures. MG is estimated by per 100,000 inhabitants those physicians/doctors who have expertise and training from well-reputed national and international institutions. Medical graduates have remarkable effects on health efficiency. More precisely, an increase in training on health's projects and development stimulates the better allocation of health's resources and provides better facilities to the health care, hospital and patients over time, especially doctor-patient ratio. Consequently, health could be improved and significantly contribute to the economic growth. Hence, it is an anticipated to have positive effect e.g., $\left({}^{\partial HE_{i,t}}/_{\partial MG_{i,t}} > 0\right)$. Al-Hanawi [45] also argues that health efficiency can be improved by increasing the general government health expenditures. Medical infrastructure (MIF) is a backbone for health system. It is defined as the facilities provided by an institution in form doctors (surgeon, physician etc.), assistant (nurses), hospital and staff to the individuals (patients). Thus, we construct the distinct term 'MIF' over factor analysis technique by using primary factors e.g., number of doctors, nurses, hospital and staff over time. This is projected to have progressive effect on health efficiency e.g., $\left({}^{\partial HE_{i,t}}/_{\partial MIF_{i,t}} > 0\right)$. The reason is that MIF provides the platform where health experts deliver their services to deal with diseases over time. Several studies e.g. Wu et al. [46], Chiu et al. [47] and Bashir et al. [48] debate that medical infrastructure has remarkable effects on health efficiency, suggesting that better allocation of health inputs improve the efficiency level by producing the desirable outputs (life expectancy). Subsequently, pharmaceutical expenditure (PHE) is a crucial indicator for health efficiency. It is defined as expenses on prescription medicines and self-medication including over-the counter is bear by medical entities such as hospital unit and patients. PHE can have remarkable impact on health efficiency. It is predicted that PHE positively effect on health efficiency e.g., $\left({}^{\partial HE_{i,t}}\big/_{\partial GHE_{i,t}} > 0\right)$. Former studies e.g., Xiong et al. [49] and Yang et al. [50] endorse that an increase in pharmaceutical expenditures can improve the health efficiency, because medicines directly deal with diseases. Consequently, individual's health is improved and come out from critical situation. Lastly, gross domestic product per capita (GDPPC) is also important factor health efficiency. Several studies e.g., Konca et al. [51] and Espinosa et al. [52] argue that GPP per capita improve the health efficiency, which means that highly income people spend more on their health. This is estimated to have constructive effect on health efficiency e.g. $\left({}^{\partial HE_{i,t}}\big/_{\partial GDPPC_{i,t}} > 0\right)$.

Data source

In order to measure the economic and transport-oriented health efficiency for 35 OECD economies, we collected the data on five inputs, four outputs and five explanatory variables from the World Development Indicator (WDI) and Organisation for Economic Co-operation and Development (OECD). Furthermore, the time period is selected from 2000 to 2022. The variables total labour force, consumption expenditure, health expenditure share of GDP, gross domestic product per capita, life expectancy, morality, and governance are collected from WDI for 23 years from 2000 to 2022. In addition, the variables namely traffic (road and railway movements), transport infrastructure (road and railway density), morbidity, general government health expenditure, medical infrastructure (doctors, nurses, hospitals, and employment) and pharmaceutical expenditures are

Table 2 List of variables

Variable	Definition	Measure	Code	Source
Total labor force	Number of individuals who can work and meet the requirements for inclusive employment	Total number in millions	TLF	WDI
Consumption expenditure	Amount of money spent on final goods and services	Share in GDP	CEX	WDI
Health expenditure share in GDP	Amount of money spent on health-oriented goods and services	Share in GDP	HEX	WDI
Traffic	Movement of people and goods from one place to another through roads, railways, and air	Index measure constructed for factor analysis	TRF	OECD
Transport infrastructure	Services provided by the government or institutions to people to enable their movement from one location to another	Index measure constructed for factor analysis	TIF	OECD
GDP per capita	Total outputs (from all sectors) of a country divided by number of people	Current USD	CGDPPC	WDI
Life expectancy	Average lifetime (number of years) of an individual; estimated number of years remaining to an individual who has reached a certain age	Life expectancy at birth	LXP	WDI
Morbidity	State of having an illness/disease or mental or physical symptoms of a disease	Total number of persons with illness/disease	MRB	OECD
Mortality	State of being dead; intended/condition for death	Per 1,000 births under five years of age	MRT	WDI
Governance	WGI developed by World Bank to assess governance quality; WGI contains six dimensions, namely, voice and accountability, governance effectiveness, rule of law, monitoring quality, political stability and absence of violence, and control of corruption	Index measure constructed for factor analysis	GOV	WDI
Medical graduates	Number of physicians/doctors with expertise and medical training from national and international institutions	Per 100,000 inhabitants	MG	OECD
Medical infrastructure	Facilities provided by institutions in the form of doctors (surgeons, physicians, and so on), assistants (nurses), hospitals, and staff to individuals (patients)	Index measure constructed for factor analysis	MIF	OECD
Pharmaceutical expenditure	Expenses related to prescription medicines and self-medication, including over-the-counter medicines borne by medical entities, such as hospital units, and patients	Index measure constructed for factor analysis	PHE	OECD

collected data from the OECD for the 23-year period from 2000 to 2022 for 35 economies. The further details are presented in Table 2.

Estimation methods

We employ a nonparametric method in this study, namely, DEA, as suggested by Charnes et al. [53]. The method can be used to assess the performance of individual DMUs through mathematical linear programming. A DMU refers to an autonomous unit, such as a country, a firm, or a company, that makes decisions based on the available resources to obtain an optimum level of outputs. DMUs are assessed based on the transformation of their inputs into outputs and compared with its own performance or other DMUs over time. Multicriteria analysis encompasses the multidimensional units identified by Barfod and Leleur [54]; however, standard DEA models focus only on desirable outputs, such as productivity, profit, and cost-of-production minimization, which implies that they evaluate performance from only one aspect. Undesirable outputs may also exist in such models; however, they remain unexamined. Thus, the role of undesirable outputs, as well as desirable outputs, should be investigated. The DEA–SBM and DEA–WA models are the most suitable methods for assessing the performance of the OECD countries. Previous studies showed that both models can be used to assess transport efficiency, economic efficiency, and health efficiency separately. However, the model used in this study incorporates the undesirable outputs, namely, mortality and morbidity, and the desirable outputs, namely, GDP and life expectancy, separately and jointly.

SBM

An SBM can be used to calculate efficiency scores via the DEA framework. The input/output slack degree relies on factors that are related to limitations, but in the objective function, the DMU creates slack. The model can also be used to measure efficiency scores with a nonoriented approach. Specifically, efficiency can be improved by being indebted to the minimization of the input/output slack values. The DEA–SBM approach makes no assumptions on the transformation of input–output variables in the proportional mode.

We express certain terms to formulate the model. For instance, the DMU yields undesirable outputs (h; mortality and morbidity). Furthermore, $= \{1, \ldots, m\}$,$\mathcal{R} = \{1, .., s\}$, and $\mathcal{F} = \{1, \ldots, h\}$ represent m, s, h sets, which are the inputs (i.e., total labor force, consumption expenditure, health expenditure, traffic, and transport infrastructure), desirable outputs (i.e., GDP and life expectancy), and undesirable outputs (i.e., mortality and morbidity), respectively.

$\therefore i - \text{th DMU } i \in \mathrm{I}$

Let x_{ia} = a-th input, g_{ib} = b-th desirable output, and b_{ic} = c-th treated. For $j\epsilon J, r\epsilon R, and f\epsilon F$.

The term d_a^x refers to all the observed inputs (ath), d_b^g represents the desirable outputs (bth), and d_c^b represents the undesirable outputs (cth). The unknown column vector of intensity is denoted by λ and articulates the weights of the DMUs, that is, 35 OECD economies. The SBM with undesirable outputs is expressed as follows:

$$\theta * = \min_{\lambda i, d_a^x, d_a^g d_a^b} \frac{1 - \frac{1}{m} \sum_{a=1}^{m} \frac{d_a^x}{xka}}{1 + \frac{1}{s+h} \left(\sum_{b=1}^{s} \frac{d_b^g}{gkb} + \sum_{c=1}^{h} \frac{d_c^b}{bkc} \right)}, \tag{2}$$

which is subject to

$$\textstyle\sum_{i=}^{n} x_{ia} \lambda_i + d_a^x = x_{ka} \ \ \left(a = 1, \ldots, \ m \ \ e.g., inputs\right). \tag{2.1}$$

$$\textstyle\sum_{i=1}^{n} g_{ib} \lambda_i - d_b^g = g_{kb} \ \ \left(b = 1, \ldots, s, e.g., desirable \ output\right). \tag{2.2}$$

$$\textstyle\sum_{i=1}^{n} b_{ic} \lambda_i - d_c^b = b_{kc} \ \ \left(c = 1, \ldots, h, undesirable \ output\right). \tag{2.3}$$

$$\lambda_i \geq 0 \ \ (i = 1, \ldots, n). \tag{2.4}$$

$$d_a^x \geq 0 (i = 1, \ldots, m). \tag{2.5}$$

$$d_b^g \geq 0 \ \ (i = 1, \ldots, s). \tag{2.6}$$

$$d_c^b \geq 0 \ \ (i = 1, \ldots, h). \tag{2.7}$$

In Eq. (2), $-d_b^g$ and $+d_c^b$ refer to the desirable and undesirable outputs, respectively. The equation reveals that extreme magnitude values for both terms will create low desirable outputs and high undesirable outputs. Notably, the SBM is not linear programmed owing to the logarithm fractional form, such as the ratio form, in the objective function. Therefore, slack variable fractions are used, along with a linear graphical record through Charnes–Cooper transformation [55]. The transformation implementation is as follows:

$$\varphi^* = \min_{\wedge i, D_a^x, D_a^g D_a^b} t - \frac{1}{m}\sum_{j=1}^{m} \frac{D_a^x}{x_{ka}}, \quad (3)$$

which is subject to

$$t + \frac{1}{s+h}\left(\sum_{b=1}^{s} \frac{D_b^g}{g_{kb}} + \sum_{c=1}^{h} \frac{D_c^b}{b_{kc}}\right) = 1. \quad (3.1)$$

$$\sum_{i=1}^{n} x_{ia} \wedge_i + D_a^x = x_{ka} t \ (a = 1, \ldots, m). \quad (3.2)$$

$$\sum_{i=1}^{n} g_{ib} \wedge_i - D_b^g = g_{kbt} \ (b = 1, \ldots, s) \quad (3.3)$$

$$\sum_{i=1}^{n} b_{ic} \wedge_i - D_c^b = b_{kct} \ (c = 1, \ldots, h) \quad (3.4)$$

$$\wedge_i \geq 0 \ (i = 1, \ldots, n). \quad (3.5)$$

$$D_a^x \geq 0 (i = 1, \ldots, m). \quad (3.6)$$

$$D_b^g \geq 0 \ (i = 1, \ldots, s). \quad (3.7)$$

$$D_c^b \geq 0 \ (i = 1, \ldots, h). \quad (3.8)$$

$$t > 0. \quad (3.9)$$

In Eq. (3), the linear fractional programming is derivatized through the corresponding linear programming model, as follows:

$$\theta^* = \varphi$$

$$\lambda_i^* = \frac{\Lambda_i^*}{t^*} \ (i = 1, \ldots, n),$$

$$d_a^{x*} = \frac{D_a^{x*}}{t^*} \ (i = 1, \ldots, m, inputs),$$

$$d_b^{g*} = \frac{D_b^{g*}}{t^*} \ (i = 1, \ldots, s, desirable\ outputs),$$

$$d_c^{b*} = \frac{D_c^{b*}}{t^*} \ (i = 1, \ldots, h, undesirable\ outputs),$$

The DEA approach does not investigate the statistical significance of and correlations among variables. Thus, we employ the tobit regression method to investigate the statistical significance of and the correlation between the variables.

DEA–WA approach

The DEA–WA approach can be used to calculate efficiency scores over time. However, the DEA–SBM approach can detect the absolute efficiency, rather than the relative efficiency. Moreover, each DMU is assessed and compared with other DMUs. We include the number of years, as suggested by Tulken and Vanden Eeckaut [56] and Asmild et al. [57]. In this investigation, we indicate that each window is not mechanically performed, because all the DMUs are assessed comparatively. Therefore, we suggest a three-year window and the inclusion of each DMU in the window for treatment. For instance, the first window covers the years from 2000 to 2002. Then, it increases the number of DMUs from 35 to 105 by using the product of the DMU and the window (DMU*window = n). We expect efficiency to improve over a specific period, which is the focal point of window analysis, rather than standard DEA models.

Results

Descriptive statistics results

We describe the primary analysis of the central tendency of the observations in Table 3, which shows that GDP and total labor force (TLF) have large mean values. However,

Table 3 Descriptive statistics of operational variables

Variable	Obs	Mean	S.D	Min	Max
TLF	805	15.636	1.51	12.039	18.93
CEX	805	4.880	3.261	3.63	24.112
HEX	805	2.047	0.419	0.095	2.866
LXP	805	4.362	0.046	4.17	4.435
MRB	805	4.153	0.269	2.884	4.552
MRT	805	1.806	0.83	0.642	4.675
MG	805	11.21	8.33	7.73	15.77
MIF	805	5.660	0.956	0.606	4.438
PHE	805	2.370	1.319	0.01	3.775
TIF	805	1.00	0.81	1.035	2.549
TRF	805	8.780	0.816	0.215	6.849
GDP	805	26.555	1.66	19.773	30.696
GOV	805	7.980	0.99	-3.036	1.384

Source: author's calculations

all variables are transformed into logarithm except mif, tif, trf and gov, because they are constructed by factor analysis their standard deviation values are small, which indicate that the observations are close to the mean. Similarly, HEX, LXP, MRB, MRT, MG, MIF, TIF, GOV demonstrate a large dispersion from their mean value by exhibiting a value that is less than 1. Moreover, consumption expenditure (HEX) demonstrates a large dispersion. Interestingly, the logarithmic value of governance (GOV) of the economies is negative, which suggests that the economies were poorly governed over time. By contrast, TLF, CEX, LXP, MRB, and GDP exhibit large minimum values in the current analysis.

The outcomes of the pairwise correlation are reported in Tables 4 and 5, which show that most of the variables have a positive correlation with one another. However, MRT has an unexpected correlation with the other variables horizontally and vertically. The reason behind this finding is that the variation in MRT is dispersed, which is a discrepancy compared with that in the other variables. We conduct a unit root test by employing the Levin–Lin–Chu unit root test. The outcomes suggest that the null hypothesis assumes that the variables have unit roots, whereas the alternative hypothesis posits that the variables are stationary. Thus, we reject the null hypothesis and reach the following conclusion: the variables are stationary at the value and at the lag value simultaneously. However, some of the variables yielded unexpected results, such as a probability over 5%, which can lead to the acceptance of the null hypothesis.

With regard to cross-sectional dependence, we employ the Pesaran [58] cross-sectional test (CD) to check the dependence of the economies based on the current variables. The outcomes indicate that the economies are interconnected through multiple channels, such as their economy, trade, investments, education, cultures, politics, diplomacy, social aspects, and regional advantages. All the variables are statistically significant at the 1%

Table 4 Pairwise correlation

Variable	TLF	CEX	HEX	LXP	MRB	MRT	MG	MIF	GOV	TIF	TRG	GDP
TLF	1.000											
CEX	0.098	1.000										
HEX	0.462	-0.153	1.000									
LXP	0.046	0.097	0.669	1.000								
MRB	0.132	0.040	0.536	0.540	1.000							
MRT	-0.065	-0.071	-0.294	-0.375	-0.212	1.000						
MG	0.338	-0.126	0.038	0.158	-0.125	-0.125	1.000					
MIF	0.415	-0.107	0.106	0.208	-0.235	-0.108	0.875	1.000				
GOV	-0.098	0.126	0.518	0.539	0.415	-0.429	-0.240	-0.088	1.000			
TIF	-0.039	0.183	0.117	0.083	-0.168	-0.231	0.169	0.213	0.136	1.000		
TRF	0.546	-0.045	0.428	0.102	0.164	-0.077	0.091	0.084	0.051	0.016	1.000	
GDP	0.947	-0.071	0.568	0.104	0.157	-0.086	0.179	0.281	0.053	0.001	0.641	1.000

Source: author's calculation

Table 5 Unit roots test and Cross-sectional dependence

Variable	LLC-value	Prob.value	LLC-value	Prob.value	Pesaran CD test		
	At value		At lag value		CD test	abs (corr)	Prob.value
TLF	-4.4055	0.0000	-3.6836	0.0001	59.13	0.773	0.000
CEX	-2.5475	0.0054	-2.2014	0.0139	01.03	0.943	0.000
HEX	-2.9697	0.0015	-4.3043	0.0000	12.43	0.332	0.000
LXP	-5.6558	0.0000	-6.6507	0.0000	104.54	0.935	0.000
MRB	0.0687	0.5274	-1.0978	0.1362	8.40	0.517	0.000
MRT	-8.0628	0.0000	-40.3025	0.0000	95.29	0.963	0.000
GOV	-2.7667	0.0028	-2.9435	0.0016	3.92	0.035	0.000
TIF	-2.0849	0.0185	-3.7433	0.0001	14.32	0.234	0.000
TRF	2.7456	0.9970	1.1541	0.8758	13.24	0.543	0.000
MG	1.1710	0.8792	-65.2475	0.0000	13.44	0.321	0.000

Source: author's calculation

level. In addition, we conduct a unit root test to check the stationarity of the variables. The statistics show that the lag values of all the variables are statistically significant, except those of MRB and TRF. This finding suggests that the null hypothesis is rejected, and the variables are stationary. By contrast, the coefficients of MRB, TRF, and MG are insignificant. We also check the cross-dependence of the variables for the economies, and the outcomes of the Pesaran CD test indicate that the coefficients of the variables are statistically significant at the 1% level and have a probability value of less than 5%. The results show that the economies demonstrate dependence in several factors, such as their economic activities, trade, investments, and social, diplomatic, and cultural aspects.

Efficiency analysis results

To assess the efficiency of the economies, we use the DEA–SBM method by incorporating the economy- and transport-oriented health efficiency scores. The

Table 6 Economic and Transport-oriented Health Efficiency

	ETHE			EHE			THE		
Country	First	Middle	Last	First	Middle	Last	First	Middle	Last
Australia	1	1	0.910	0.96	1	0.812	0.950	1	0.981
Austria	0.903	1	0.901	0.915	0.991	0.765	0.807	0.803	0.703
Belgium	1	1	0.811	0.914	1	0.891	0.910	1	0.923
Canada	1	1	0.994	0.953	1	0.950	0.721	1	0.904
Chile	0.906	0.917	0.798	0.904	0.970	0.799	0.610	0.714	0.709
Czech Republic	0.876	0.909	0.880	0.931	1	0.870	0.652	0.608	0.890
Denmark	0.970	1	0.990	0.970	1	0.998	0.789	1	0.888
Estonia	0.990	0.989	0.776	0.992	0.988	0.801	0.450	0.912	0.704
Finland	1	0.932	0.893	0.909	0.921	0.912	0.823	0.987	0.970
France	1	1	0.953	1	0.991	0.903	0.708	0.874	0.832
Germany	1	0.989	0.976	0.932	1	0.854	0.897	0.795	0.813
Greece	0.998	0.744	0.865	0.998	1	0.890	0.543	0.775	0.705
Hungary	0.858	1	0.823	0.908	0.997	0.792	0.782	1	0.840
Iceland	0.973	1	0.990	0.973	1	0.987	1	0.674	0.890
Ireland	1	1	0.902	0.992	0.975	0.890	0.670	0.889	0.932
Italy	0.975	0.891	0.821	0.925	0.851	0.890	0.943	0.732	0.843
Japan	1	0.885	0.990	0.971	0.925	0.905	0.895	1	0.890
Korea	1	1	0.990	1	0.925	0.902	0.843	0.789	0.987
Latvia	0.987	0.821	0.876	0.897	0.812	0.783	0.432	0.713	0.763
Lithuania	0.786	0.825	0.789	0.987	0.832	0.702	0.678	0.786	0.672
Luxembourg	0.932	0.851	0.843	0.978	0.854	0.890	0.673	0.428	0.690
Mexico	0.943	0.865	0.675	0.998	0.725	0.789	0.854	0.738	0.687
Netherlands	1	0.925	0.904	0.903	0.993	0.942	0.722	0.807	0.888
New Zealand	1	0.854	0.880	0.999	1	0.743	1	0.754	0.803
Norway	1	0.804	0.934	0.994	0.932	0.903	0.789	0.984	0.993
Poland	0.981	0.854	0.890	0.982	0.891	0.875	0.875	0.984	0.943
Portugal	0.943	0.802	0.890	0.765	0.812	0.896	0.733	0.645	0.854
Slovak Republic	0.982	0.775	0.784	0.982	0.775	0.732	0.423	0.644	0.689
Slovenia	0.982	0.801	0.732	0.912	0.876	0.713	0.644	0.728	0.734
Spain	1	0.825	0.840	1	0.821	0.789	0.599	0.627	0.836
Sweden	0.982	1	0.995	0.982	0.811	0.903	1	0.721	0.874
Switzerland	1	1	0.934	1	0.890	0.912	1	0.765	0.943
Turkey	0.789	0.851	0.783	0.894	0.841	0.893	0.707	0.712	0.703
United Kingdom	1	1	0.854	1	1	0.920	0.932	0.902	0.832
United States	0.953	1	0.954	0.903	0.820	0.945	0.764	0.876	0.964

Source: author's calculations

efficiency scores are reported in Table 6. The empirical results reveal an efficiency score higher than 1 (eff. > 1) for Australia, Belgium, Canada, France, Ireland, South Korea, and Switzerland, which suggest that the economies were efficient in the first and middle years of the research period. However, none of the economies demonstrated economy- and transport-oriented health efficiency owing to the global issue. In terms of EHE, only 10 economies performed well in the middle years of the research period, based on their efficiency score of 1. By contrast, only five economies performed well in the first year of the research period, namely, France, South Korea, Spain, Switzerland, and the United Kingdom. We measure the THE scores, and the results indicate that only four economies performed well, based on their efficiency score of 1, namely, Iceland, New Zealand, Sweden, and Switzerland. Meanwhile, only six economies have an efficiency score of 1 in the middle years of the research period, namely, Australia, Belgium, Canada, Denmark, Hungary, and Japan, which suggests that the economies utilized their resources effectively to achieve an optimum level of outputs during the particular years. However, none of the economies performed well in the three efficiency components, namely, ETHE, EHE, and THE, in the last year of the research period. Notably, the lowest efficiency score is 0.450 for Estonia, which indicates that the country was unable to utilize 55% its resources to achieve the optimum level of outputs.

Table 7 reports the DEA–WA efficiency scores. We estimate the efficiency scores for three consecutive years and the moving year. Thus, the efficiency scores are explained in 21 windows, with each window containing the three-year efficiency score. For instance, window 1 contains an average efficiency score of 0.992, which suggests that the economies were unable to utilize their resources efficiently for three consecutive years, on average. The reason behind the outcome may be the effect of macro-level policies on the DMUs as an external factor. Internal shocks can adversely affect specific decisions. Notably, window 10 and window 13 demonstrate efficiency, with an average efficiency score of 1, which indicate that all the economies performed well for three consecutive years, on average. Furthermore, resource utilization strategies can help the economies achieve the optimum level of outputs and secure an efficiency score of 1.

Table 7 Window efficiency analysis

Window	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011		Mean	year
W1	0.978	0.999	1											0.992	W1
W2		0.998	1	0.998										0.999	W2
W3			0.996	0.999	1									0.998	W3
W4				1	0.891	0.827								0.906	W4
W5					0.999	0.898	0.898							0.932	W5
W6						0.798	0.934	1						0.911	W6
W7							0.982	1	1					0.994	W7
W8								0.999	0.783	1				0.927	W8
W9									0.789	0.997	1			0.929	W9
W10										1	1	1		1.000	W10
year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	-	year
W11	0.987	0.999	1											0.995	W11
W12		1	0.738	1										0.913	W12
W13			1	0.999	1									1.000	W13
W14				0.987	1	0.999								0.995	W14
W15					1	0.927	1							0.976	W15
W16						0.999	0.999	1						0.999	W16
W17							1	0.987	1					0.996	W17
W18								0.943	0.9321	1				0.958	W18
W19									0.997	0.993	0.789			0.926	W19
W20										0.943	0.912	0.943		0.933	W20
W21											0.932	0.923	0.954	0.928	W21

Source: author's calculations

We describe the average efficiency score of all decision-making unit (35 economies)

Table 8 Role of health expenditures

Variable	ETHE	EHE	THE
$GOV_{i,t}$	0.023[b]	0.116[b]	0.310[c]
	(0.000)	(0.003)	(0.000)
$MG_{i,t}$	0.125[c]	0.210[c]	0.102[b]
	(0.000)	(0.000)	(0.010)
$PHE_{i,t}$	0.103[a]	0.110[b]	0.100[c]
	(0.016)	(0.012)	(0.000)
$MIF_{i,t}$	0.108[c]	0.010[c]	0.120[c]
	(0.010)	(0.006)	(0.000)
$GDPPC_{i,t}$	0.016[c]	0.115[b]	0.010[c]
	(0.000)	(0.004)	(0.003)
Constant	0.129[c]	0.196[c]	0.141[c]
	(0.000)	(0.000)	(0.000)
Observations	805	805	805

Source: author's calculations

The signs [a], [b], and [c] shows the significance level at 1%, 5% and 10% respectively

Econometric analysis results

The outcomes obtained by the tobit regression econometric technique are reported in Table 8, which show that the coefficient of GOV is positive and statistically significant at the 1% and 5% levels for all three efficiency indicators. A 1% unit change in GOV positively improves ETHE by 2.3%, EHE by 11.6%, and THE by 31.0%. The results suggest that governance can improve transport-oriented health efficiency by improving resources. The coefficient of MG is also positive and statistically significant at the 1% level for ETHE, which suggests that the 12.5% increase is due to the 1% unit change in MG. Meanwhile, a 1% unit change in MG increases EHE by 21% and THE by 10.2%.

The coefficient of PHE has a positive and statistically significant impact on ETHE. The empirical results demonstrate that a 1% unit change in PHE improves ETHE, EHE, and THE by 10.3%, 11%, and 10%, respectively. Moreover, the coefficient of MIF is statistically significant at the 1% level, and the 10.8% increase in ETHE, the 1% increase in EHE, and the 12% increase in THE are due to the 1% unit change in MIF. The results suggest a higher ETHE increment compared with EHE and THE individually. The most important factor for economy- and transport-oriented health efficiency is GDPPC, whose coefficient is statistically significant and positive. Thus, a 1% unit change in GDPPC increases ETHE, EHE, and THE by 1.6%, 11.5%, and 10%, respectively. In addition, we detect an endogeneity issue, and the empirical outcomes suggest that the first-difference and orthogonal approaches yielded statistically significant coefficients. The lag magnitude value of ETHE, EHE, and THE is positive and statistically significant at the 1% level, thereby indicating that the outcomes obtained by the regression models are consistent and stable. We find the turning point values in the first-difference approach, specifically, 8.243, 1.527, and 2.928, rather than in the orthogonal approach, for all the cases.

Discussion

Economy- and transport-oriented health efficiency analyses

This investigation conducts joint and individual efficiency analyses of the OECD economies with regard to their economy- and transport-oriented health efficiency, economy-oriented health efficiency, and transport-oriented health efficiency. This study employs an SBM under the DEA framework (i.e., SBM–DEA approach). The approach can be used to calculate the efficiency scores by incorporating the desirable outputs (i.e., GDP and LXP) and the undesirable outputs (i.e., MRB and MRT) in the current model. The efficiency scores are presented in Table 6, which reveal that 15 economies are efficient (i.e., eff. = 1) with regard to ETHE. The results imply that a 1-unit increase in efficiency leads to improved performance for each of the economies [11, 59, 60].

We use two efficiency models in this study, that is, an input-oriented DEA model and an output-oriented DEA model. The input-oriented model indicates that the minimization of input resources is subject to the same level of outputs or an unproductive unit, which will improve its productivity by lessening the inputs while keeping the outputs at a consistent level. By contrast, the output-oriented model indicates that the maximization of outputs is subject to the constraints of the available input resources or an inefficient unit, which will improve its efficiency by increasing the outputs without changing the available inputs [61, 62]. Economies use the two approaches to achieve the optimum level of outputs. We employ the output-oriented approach in the current model to measure the efficiency scores. The approach used in the model suggests that the economies increase their outputs, such GDP and life expectancy, proportionally based on their available resources [63–65].

Specifically, each economy performs well by utilizing its economic and transport resources to attain the highest level of desirable outputs, namely, GDP and life expectancy. However, the economies also generate undesirable outputs, such as morbidity and mortality (which can reduce health efficiency). The reason behind the results is that the economic and transport inputs of TLF, CEX, TRF, TIF, and HE are converted into GDP and LXP through the provision of manpower (employment), infrastructure, and money for purchasing household and health-related goods (USD millions). However, the inputs also result in undesirable outputs, namely, morbidity and mortality. Long work hours and enormous workloads, irrational or unplanned consumption, poor transport infrastructure quality, and low consumption expenditure can directly or indirectly cause illnesses and health-related conditions, such as depression, anxiety, traffic accidents, cancer, and obesity [66–68]. The input-oriented model can control the undesirable outputs by reducing the available inputs in the current model, namely, TLF, CEX, TRF, and TIF. Thus, the input-oriented model can reduce the inputs and the undesirable outputs while maintaining the level of the desirable outputs.

Hajiagha et al. [20], Lgün et al. [19], and Lefèvre et al. [69] argued that available resources can improve health efficiency by improving allocation within the health entity (e.g., hospital or healthcare unit). The allocation is based on the input-oriented approach, in which the output remains at a consistent level while the inputs are reduced. None of the economies were efficient in 2020 with respect to their economy- and transport-oriented efficiency, which suggests that the countries failed to utilize their economic and transport resources effectively or achieve the highest level of desirable outputs. The reason behind this finding may be the COVID-19 pandemic, which resulted in lockdowns and the poor management of health resources across the globe. The outcomes of the economy-oriented health efficiency measure are reported in columns 4–6 of Table 3. The outcomes indicate that only six economies were economically efficient with respect to health in 2000, namely, France, South Korea, Spain, Switzerland, and the United Kingdom; however, they were not economically efficient in terms of health in 2010.

In addition, none of the economies achieved the highest level of health outputs in 2020, perhaps because of the reallocation of economic resources owing to the insufficient health facilities because of the COVID-19 pandemic and its correlated restrictions, such as nationwide lockdowns. The findings indicate that the countries paid considerable attention to elevating the level of their desirable outputs, such as GDP and life expectancy, by using their available inputs. Economies are concerned about adopting an output-oriented approach to improve the efficiency performance of their health system. The critical situation has created disequilibrium in the markets, which has led to economic instability. Thus, financial resources were not being allocated to health units, which facilitated the emergence of undesirable outputs. Interestingly, Canada, Denmark, Finland, France, Iceland, Japan, South Korea, the Netherlands, Norway, Sweden, Switzerland, the United States, and the United Kingdom have an efficiency score of more than 0.90, which indicates that the countries used 90% of their economic resources to achieve desirable outputs and reduce undesirable outputs, despite having well-established economic and health systems.

We also measure THE to analyze the effect of transportation, which can generate desirable (i.e., GDP) and undesirable (MRB and MRT) outputs. For instance, the transport infrastructure contributes to economic growth by providing facilities to individuals/travelers by generating income [70]. However, poor transport infrastructure (e.g., damaged roads, unplanned routes, subpar vehicles) can cause accidents that may lead to serious injuries or death. Furthermore, traffic congestion may cause depression, anxiety, stress, or other negative emotions, whereas traveling can lead to short- and long-term health problems. The findings suggest that the output-oriented approach can be employed to enhance the desirable outputs and reduce the undesirable outputs. Specifically, economies can use the input-oriented approach to reduce transport-oriented inputs, such as traffic congestion [71–73], which can cause accidents and casualties.

Therefore, the results demonstrate that some of the economies, namely, Iceland, New Zealand, Sweden, and Switzerland, were efficient in THE in the first year of the research period, whereas the other economies were inefficient in the first year and remained inefficient in the middle and last years. Furthermore, none of the economies were efficient in THE in the last year of the research period, possibly because health-oriented restrictions, such as lockdowns, were imposed around the world in 2020 to control the spread of COVID-19. The pandemic also adversely affected the transportation system and restricted access to health units, such as hospitals, and patients. Moreover, the pandemic significantly hindered economic growth and increased mortality and morbidity rates. The findings suggest that the economies can employ input- and output-oriented approaches simultaneously in their transportation and health systems, because transportation can generate dual outcomes, such as the GDP and traffic accident causalities. Therefore, adopting appropriate management strategies is imperative.

We employ the DEA–WA approach to consider the dynamic efficiency scores, because the DEA–SBM approach can calculate only the absolute efficiency scores. The DEA–WA approach can calculate the efficiency scores based on the moving average of each DMU and make comparisons with the previous results of the DMU or with other DMUs [57]. In the current analysis, each window in Table 7 shows the efficiency score for three years based on the moving average. The results suggest that all the economies are efficient in windows

10 and 13. However, the economies are inefficient in the other windows. In contrast to the results of the windows, the economies performed well consistently from 2012 to 2019. The reason behind the finding may be that the economies managed their economic and transport resources effectively in previous years.

Relationship between efficiency and health-oriented factors

We conduct regression analysis after evaluating the health performance of the OECD economies with respect to their economy and transportation system. The DEA approach does not investigate relationships among variables and makes no specific assumptions to measure the efficiency scores. Thus, we employ the tobit regression approach to censor the observations into two different groups. For instance, in the current model, if the efficiency score is greater than 0.90, then it is equal to 1 (estimated as the dependent variable); and 0 otherwise [42, 43]. In addition, we use ETHE, EHE, and THE as the dependent variables to analyze the effect of governance and health expenditure. The outcomes of the tobit regression are reported in Table 8. The results demonstrate that the coefficient of GOV is positive and statistically significant for ETHE, EHE, and THE, which imply that a 1% increase in GOV increases ETHE, EHE, and THE by 2.3%, 11.6%, and 31%, respectively, and the economies practice good governance. Khan et al. [74], Hussain et al. [42, 43, 75], Alvarez et al. [76], and Zhou et al. [44] argued that the six primary factors of governance are negatively correlated with traffic injuries, but some of the factors are related to health.

The coefficient of MG is significant and positive for EHE and THE in the health efficiency analysis; thus, it exerts a remarkable impact on ETHE, EHE, and THE. The findings imply that the 12.5% increase in ETHE is caused by the 1% change in MG Specifically, an increase in the number of medical graduates can reduce the under-5-years-of-age mortality rate and prolong life expectancy at birth by providing health-related facilities, because the number of medical graduates is associated with health-oriented resources. The variable indicates that trained physicians and doctors interact actively with their patients and have the ability to diagnose diseases. At the same time, human health improvements can increase productivity through various resource channels. Thus, economic and transport resources can be allocated effectively to health-related projects/activities, which can increase a county's health efficiency. Moreover, Mohamadi, Efat et al. [77] argued that medical resources can improve health efficiency and suggested that countries can improve their performance by providing health resources to health units.

PHE also has a considerable impact on health efficiency. The coefficient of PHE is positive and statistically significant in the joint and individual efficiency analyses, which implies that the joint efficiency analysis (ETHE) is less affected by PHE compared with the individual efficiency analyses (EHE and THE). Empirical evidence shows that a 1% increase in PHE increases ETHE, EHE, and THE by 16.3%, 33%, and 58.6%, respectively. The reason behind the result may be good governance and the effective utilization of the government health financial resources allocated to pharmaceutical units.

Blankart and Felder [78] and Vogler and Fischer [79] argued that shortages in medicine supply or supply chain interruptions can lead to inaccessible pharmaceutical units. Thus, medicines will remain unavailable in the market. Pharmaceutical units can be enriched with economic and transport (supply chain) resources, and an increase in pharmaceutical expenditure for medicines can improve health efficiency. Specifically, spending on medicines can create economic externalities, such as economic growth, logistics infrastructure (transportation), increase in the household income of pharmaceutical workers, and so on. The factors are indirectly associated with the health-oriented infrastructure and thus can improve the efficiency of economies over time [42, 43, 70, 80].

The medical infrastructure is a fundamental factor for the health sector, because it can provide basic healthcare services to hospitals, pharmaceutical units, healthcare providers, and patients. Thus, the effect of MIF on efficiency should be analyzed. The outcomes show that the coefficient of MIF is positive and significant for ETHE, EHE, and THE, which imply that the 50.8% improvement in ETHE is due to the 1% change in MIF. By contrast, MIF, such as doctors, nurses, employees, and hospital units, cannot effectively improve EHE. The reason behind the result may be that the lack of medical infrastructure may facilitate the improved allocation of economic and health resources.

By contrast, a 1% change in MIF improves THE by 39%, which indicates that the medical infrastructure is associated with transport and health resources. Specifically, health-oriented employees, such as doctors, nurses, and hospital staff, may demand improved transport facilities to reach their destination (hospital) to provide medical services. Thus, such employees will actively use transport resources, which may lead to an efficient health system. The coefficient of GDPPC exerts a drastic impact in the three efficiency analyses. Economy-oriented health efficiency is substantially influenced by GDPPC, which demonstrates a value of 91.5%. This outcome suggests that an increase in GDPPC will stimulate spending for health-related goods, that is, individuals will reallocate their financial resources to health-oriented activities. As a result, economic and health resources will be used effectively, which will improve the country's economic performance.

Table 9 reports the variance inflation factor (VIF) values. The rule of thumb explains that if the VIF is < 3, then the variables have low correlation. Meanwhile, if the VIF is < 5, then the variables have moderate correlation. However, if the VIF is higher than 5 to 10, then the multicollinearity is severe. We estimate the VIF outcomes to be less than 5, which suggest that the correlation among the variables is acceptable.

Table 9 Multicollinearity

	VIF	1/VIF
MIF	4.966	0.201
MG	4.89	0.204
PHE	1.342	0.745
GOV	1.269	0.788
GDPPC	1.203	0.831
Mean VIF	2.734	

Source: author's calculations

VIF indicates variation inflation factor

Endogeneity

We employ the generalized method of moments (GMM) to address the endogenetic issues. Several factors, such as unobserved and error terms, may be correlated with the dependent variable, which will indicate endogeneity in the model. The GMM can be used to address the issue, and the outcomes are reported in Table 10. The upshots explain that the associations between the fundamental variables and efficiency analysis are consistent and can avoid bias in the model. In addition, the first lag of ETHE exerts a considerable impact on the joint efficiency analysis (economy- and transport-oriented efficiency) by 8.4% for the OECD economies in the orthogonal model. By contrast, health efficiency is positively correlated with the lag of EHE and THE. Furthermore, in the first-difference approach, the lowest magnitude value of EHE is around 6.8%. Notably, the square of GHE has a stronger impact

Table 10 Endogeneity

VARIABLES	ETHE		EHE		THE	
	First-differences	Orthogonal	First-differences	Orthogonal	First-differences	Orthogonal
$ETHE_{t-1}$	0.091^{c}	0.084^{c}	-	-	-	-
	(0.024)	(0.006)	-	-	-	-
EHE_{t-1}	-	-	0.076^{c}	0.053^{c}	-	-
	-	-	(0.035)	0.003)	-	-
THE_{t-1}	-	-	-	-	0.068^{c}	0.027^{c}
	-	-	-	-	(0.035)	(0.055)
$GOV_{i,t}$	-0.168	0.143^{a}	9.864^{c}	3.260^{c}	9.792^{c}	3.920^{c}
	(0.354)	(0.123)	(0.514)	(0.650)	(0.514)	(0.65)
$MG_{i,t}$	0.003^{a}	0.0193	1.420^{c}	-1.290^{c}	1.94^{c}	-1.470^{c}
	(2.381)	(0.165)	(0.471)	(0.868)	(0.467)	(0.868)
	(0.042)	(0.010)	(0.032)	(0.010)	(0.021)	(0.031)
$PME_{i,t}$	-0.993	-0.127	-2.16^{c}	-1.68^{c}	-2.17^{c}	-1.67^{c}
	(0.067)	(0.136)	(0.549)	(0.714)	(0.547)	(0.714)
$MIF_{i,t}$	0.405^{b}	0.004^{a}	13.48^{c}	-11.43^{c}	13.48^{c}	-11.57^{c}
	(0.576)	(0.099)	(0.836)	(0.525)	(0.835)	(0.525)
year	-0.068^{c}	0.002	-2.813^{c}	-3.046^{c}	-2.816^{c}	-2.716^{c}
	(0.018)	(0.019)	0.026)	(0.104)	(0.026)	(0.103)
Constant		3.350		6.077^{c}		5.997^{c}
		(0.410)		(0.800)		(0.208)
Sargan stat	547.56		6548.41		342.13	
Turning point	8.243	0.192	1.527	1.348	2.928	1.232
Observations	665	700	665	700	665	700
Number of DMU	35	35	35	35	35	35

Source: author's calculations

The signs [a], [b], and [c] shows the significance level at 1%, 5% and 10% respectively on ETHE by 4.2% in the first-difference approach compared with EHE and THE.

The results further demonstrate that an adjustment in health efficiency can improve ETHE by 90.9% (1–0.91), EHE by 92.4% (1–0.076), and THE by 93.2% (1–0.068). The results suggest that the disparity between the desired and actual health efficiency levels is adjusted over time in the case of the first-difference approach. In the orthogonal approach, the adjustment rates are 91.6% (1–0.084) for ETHE, 94.7% (1–0.053) for EHE, and 97.3% (1–0.027) for THE. The turning point values suggest that the OECD economies must spend USD 842 million on the government general health expenditure to become economy- and transport-oriented health efficient. By contrast, approximately USD 222 million and USD 292 million are required for GHE for the individual health efficiency factors. In the orthogonal model, the economies must spend around USD 292 million to improve their economy- and transport-oriented health efficiency.

Conclusions

In this study, we measure health efficiency with respect to the economy and transportation system by using 5 inputs, 2 desirable outputs, and two undesirable outputs. We employ the DEA–SBM approach and conduct WA to calculate the level of efficiency of each economy. In the second stage, we conduct tobit regression to investigate the effects of other variables on the efficiency level and check the bias in the model. Furthermore, we analyze the impact of governance and health expenditure on health efficiency are 2.3% and 10.3% respectively. The analytical outcomes show that some of the economies were efficient (effi. > 1) because of their economic inputs, such as the total labor force and consumption expenditure, as well as their health expenditure, and thus achieved the highest level of desirable outputs, namely, the GDP and life expectancy. By contrast, all the economies were inefficient (ineffi. < 1) in their economy- and transport-oriented health efficiency in the last year of the research period. The reason for this outcome may be the strict restrictions imposed globally because of COVID-19, which also severely affected the OECD economies.

In addition, the individual assessments show that some of the economies were economically efficient during the middle years but inefficient (effi = 0.90) in the last year of the research period. By contrast, the transport-oriented health efficiency assessment reveals that the economies were unable to perform well owing to the nationwide lockdowns in the last year of the research period. However, the economies were efficient in the first year of the research period. Notably, the joint assessment of the economy- and transport-oriented health efficiency indicates that economic and transport input resources can adversely affect the GDP and life expectancy simultaneously.

In the second stage, the findings of the tobit regression demonstrate that governance has a positive and significant impact on health efficiency. Specifically, good governance can improve about 2.3% health performance of the OECD economies through the effective use of economic and transport resources. In addition, the medical graduates exert a remarkable impact about 12.5% on the joint and individual assessments of health efficiency. Specifically, a 1-unit change in total health expenditures during the research period increased economy-oriented health efficiency by approximately 71% and transport-oriented health efficiency by 58%. Medical infrastructure is significant and positive in the joint and individual health efficiency analyses. The findings of the joint analysis show that economy- and transport-oriented health efficiency is 50.8%, which is relatively larger than the results of the individual efficiency analyses. Notably, the turning point values indicate that the economies must invest at least USD 92.1 million in the health sector to improve their economy- and transport-oriented health efficiency.

This study presents some policy implications based on the empirical findings. First, the OECD economies must improve their economic structure to address their concerns about the utilization of available economic resources. Specifically, the economies should reallocate economic resources approx.82.43% to achieve the highest level of desirable outputs, that is, the GDP and life expectancy, which can lead to improved performance. Second, the sample economies should redesign and shift their consumption expenditure toward health-oriented goods and services, because an increase in consumption expenditure on health goods can significantly improve people's health and prolong their life expectancy. Third, the economies should increase either general health expenditure by approximately USD 4.2 million, on average, to achieve the highest level of desirable outputs and reduce undesirable outputs. Fourth, the economies should continue to raise the governance index value above 7.98 across the six dimensions. Fifth, the economies should improve their medical infrastructure level by at least 0.60 million to improve their health performance. Sixth, pharmaceutical expenditure must be accessible to individuals and not exceed their out-of-pocket costs. Last, the countries should allocate at least 6.3% of their resources to peace measures and national security. Furthermore, the six dimensions of governance should address the health-oriented issues that can cause poor health performance.

Limitations

This study's measurement of health efficiency has some limitations. This study includes economic and transport input variables, because the total labor force, consumption expenditure, traffic, and transportation infrastructure are determinants of economic growth, and their value can be drastically depleted by economic activities, especially, the total labor force. Thus, the total labor force can be directly or indirectly affected by economic activities, which will be reflected in the emergence of severe diseases (morbidity and mortality) and reduced productivity, which may cause inefficiency. To investigate the influencing factors, we incorporate some important factors into the current model, namely, governance, pharmaceutical expenditure, government general health expenditure, and GDP per capita. Specifically, governance can facilitate the creation of a peaceful environment for activities that can improve the health system. Health-oriented factors can also drastically affect healthcare efficiency by improving facilities. In addition, this study identifies directions for future investigations. For instance, future studies may examine mental health, psychological factors, health expenditure per capita, the effect of active transport on physical and mental health, digital technology, biotechnology, macroeconomic management, health policies, the One Belt and One Road countries, developing countries, and emerging economies to broaden health-oriented research.

Abbreviations

OECD	Organisation for Economic Cooperation and Development
DEA	Data envelopment analysis
TLF	Total labor force
CEX	Consumption expenditure
HEX	Health expenditure
TRF	Traffic
TIF	Transport infrastructure
CGDPPC	Gross domestic product per capita
LXP	Life expectancy
MRB	Morbidity
MRT	Mortality
GOV	Governance
MG	Medical graduate
MIF	Medical infrastructure
PHE	Pharmaceutical expenditures
DEA-WA	Data envelopment analysis-window analysis
DEA-SBM	Data envelopment analysis-slack based model
DMU	Decision making unit
GDP	Gross domestic product
CD	Cross-dependence
THE	Transport health efficiency
EHE	Economic health efficiency
HE	Health efficiency
ETHE	Economic and transport health efficiency

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Authors' contributions
ZH develops idea and design theoretical framework. CH implies methodology and calculates the results as well as interpret. AA and WAS write up the whole article and critically analyzed as well as policy recommendations.

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Not applicable.

Data availability
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The authors declare no competing interests.

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