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Three decades in healthcare service efficiency evaluation: a bootstrapping Data Envelopment Analysis (DEA) of Ministry of Health Malaysia

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Abstract

Background One of the most important ways to boost the health system's performance and lower the rising cost of healthcare is to increase its efficiency. The objective of this study is to evaluate the efficiency of the MOH in providing public health services and to gauge the progress of health plans in Malaysia.

Methods Three output variables (number of admissions, number of outpatient attendances, and number of maternal and child health attendances) and six input variables (budget allocation, number of doctors, dentists, pharmacists, nurses, and community nurses) were used in a Data Envelopment Analysis (DEA) Window Analysis. Eight input-output models' bias-corrected efficiency scores were obtained using bootstrapping.

Setting Ministry level in public health service.

Participant 28 Decision making units (DMUs) from 1995 to 2022.

Results Robust performance over the study period was shown by the mean bias-corrected efficiency score of 0.974 (95% CI: 0.907–0.989) under the Variable Returns to Scale (VRS) model. Lower Constant Returns to Scale (CRS) model scores, on the other hand, draw attention to scale-level inefficiencies. During the COVID-19 pandemic, efficiency decreased due to higher input demands and limited outputs.

Conclusions Although MOH has attained a high level of technological efficiency, expanding operations and resolving inequalities in rural areas remain difficult. Targeted tactics including telemedicine adoption, resource redistribution, and a move towards preventive treatment are advised in order to improve fairness and resilience.

Keywords Data Envelopment Analysis, Bootstrapping, Efficiency, Ministry of health, Malaysia

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Introduction

Since the First Malaya Plan (1956–1960) [1], then the First Malaysia Plan (1966 – 197) until recently the Twelfth Malaysia Plan (2021–2025) [2] the government has always sustained the effort to improve, transform and reform healthcare indicating how important healthcare is. It is no wonder that it can be observed that the Total Expenditure on Health of Malaysia in both public and private sector increased progressively in the past three decades [1–4]. Despite all the challenges, issues and obstacles be it internal or external the Malaysian government keep moving forward to ensure subsequent medium- and long-term development plans served as the cornerstones for the country's transition into a developed status especially in the healthcare services [5, 6].

Under Theme 2: Strengthening Security, Wellbeing and Inclusivity in the Twelfth Malaysia Plan, the aim is to revitalize the healthcare system in ensuring a healthy and productive nation. Achieving these aims won't be simple, though, considering the numerous obstacles both inside and outside the healthcare system. First, as the nation's health system works to transform itself and fulfil the 2025 Healthy and Productive Nation agenda, pressure from factors i.e. performance in the health status, the increasing incidence of double burden diseases (Communicable (CDs) and non-communicable diseases (NCDs)), undernutrition among children below five years old, inadequate facilities, mismatch of resources across different levels of healthcare services, unsustainable healthcare financing, inadequate number of health personnel, particularly specialists impede the provision of services to rural and remote areas and changes in environmental are among the factors will persist [5, 7].

The healthcare service provisions in Malaysia can be broadly classified into three sectors: the public sector, the corporate (private) sector, and non-profit organizations. The Ministry of Health Malaysia (MOH) plays a major role in providing healthcare services to the public since the independence of Malaysia [8–10]. As of December 2022, there are 148 Hospital and Special Medical Institution with 45,167 hospital beds under the purview of MOH. Along with 3,121 Health Clinic which includes Health Clinic, Rural Clinic (*Klinik Desa*), Maternal & Child Health Clinic, and Community Clinic. As for dental service there are 1,707 Dental Clinics which either a standalone or part of other centers in the MOH. With over two hundred thousand healthcare workers, assisted by non-healthcare workers the MOH served the populations in term of hospital admission, day care attendance, outpatient and dental health attendance, clinical support service attendance, and maternal & child health attendance [11]. Thus, it is important for the MOH to ensure the financial and human resources allocated are optimized, the services running efficiently and productive, and at the same time strive for improvement in quality and safeguard the affordability of public healthcare services.

Since the World Health Organization (WHO) published the The World Health Report 2000 [12], it has sparked the interest in measuring performance and efficiency of health system from governments all around the world. The question of "How does my X country health system perform against country Y?" began to emerge from politicians, researchers, journalists and the publics [13–16]. Despite the WHO report has many limitations, it has provided a very valuable information and useful conceptual framework for health system performance evaluation.

The study on performance and efficiency is not limited by the method proposed by WHO. The application of Data Envelopment Analysis (DEA) in measuring country healthcare service or health system has been widely used. Several studies have examined the efficiency of health systems across national level [17, 18], among the Organization for Economic Cooperation and Development (OECD) countries [19–21], within the Asian Region countries [22, 23], and even at national/country level [24–28]. Several studies mentioned Malaysia in their analysis. The World Health Report 2000 by WHO used index and score estimation in their evaluation. The report ranked Malaysia's overall health system performance at number 49 out of 191 countries with a score of 0.802 (80.2%) [12, 15]. Another report by WHO ranked Malaysia's overall health system achievement at number 55 out of 191 countries (score = 80.8%) [13]. While report on efficiency of national health systems by WHO on Malaysia was 0.751 (75.1%) (rank 89 from 191 countries) [14]. Some studies have also examined the efficiency of Malaysia healthcare system using DEA. One study reported the efficiency of Malaysia from 180 countries health system under Constant Return to Scale (CRS) was 0.056 and under Variables Return to Scale (VRS) was 1 [29]. While in another study it was observed the efficiency of Malaysia health system was 0.778 (CRS) and 0.927 (VRS) in comparison with 46 Asian countries [22]. A smaller study within ASEAN countries (10), stated the Malaysia healthcare system efficiency was 0.907 (CRS) and 0.991 (VRS) [23]. However, there is a efficiency gap in these analysis in addressing assessing the impact of specific Malaysia Plans on efficiency trends.

Determining the degree of health system efficiency and related elements is a crucial research and policy challenge since efficiency plays a significant role in maximizing the use of current resources and optimizing up the new one. With the aim of "Revitalizing the Healthcare System in Ensuring a Healthy and Productive Nation", it is crucial and important to measure the performance and efficiency of Malaysia health system over the past few decades. The need to efficiently use of both human and financial resources is paramount while at the same time resolve the disproportion between resources and facilities for healthcare services [5]. This study intends to uncover inefficiencies in resource use and give scalable ideas for optimizing healthcare services. DEA Window Analysis provides longitudinal efficiency evaluations, making it perfect for monitoring changes throughout past three decades Malaysia's numerous growth plans.

The remainder of the paper is structured as follows. The research methodology is briefly described in Sect. 2, and the study's findings are highlighted in Sect. 3. Section 4 concludes the paper by discussing the findings and interpretation.

Methodology and data

The two main methodological approaches used to quantify technological efficiency traditionally are parametric and non-parametric tools. Stochastic frontier analysis (SFA) is the most widely used technique for the former, while data envelopment analysis (DEA) is the most widely used strategy for the latter [30, 31]. Although there is a lot of research comparing these two strategies, it is not quite clear which is the better option [32–34]. Despite the known theoretical and methodological limitations of DEA, this study took the advantages of DEA into account and adopted this method. As DEA has the ability to manage a wide range of inputs and outputs; need no prior weighting (as index numbers do); makes no particular assumptions on the functional nature of the relationship between inputs and outputs; and has the ability to integrate DEA with other statistical techniques and methodologies to improve efficiency evaluation [29, 35]. One of the earliest measurements of efficiency that took into account all inputs and outputs was introduced by Farrel in 1957 [36]. It was then further developed by Charnes et al. in 1978 [37]. Till now, for the past over 40 years since the first study in healthcare by Nunamaker in 1983 [38], DEA methodology have been advanced and the application has been extensively applied in many field [39–42]. Taking these advantages and flexibility into consideration, a DEA Window Analysis was adopted in this study.

DEA window analysis

Window Analysis method in DEA, was proposed by Charnes, Clark, Cooper and Golany in measuring the efficiency of maintenance units in the U.S. air force and further evaluated by Klopp [43, 44]. Window analysis is an alternative method for assessing performance over multiple periods. When considering the efficiency of Decision Making Units (DMUs) just within their respective years, window analysis is a simpler method than the Malmquist index. Various periodic averages are then generated to observe general patterns in performance. Within this context, DEA can be carried out gradually, treating each DMU (in this situation the organization) as though it were a "different" DMU at each time interval [39, 45, 46]. In other words, the time period where the data was captured in the organization will be compared with another period within one single organization or multiple organizations (panel data) to evaluated their relative efficiency. The reason for utilising Window Analysis is sound, stressing its capacity to examine efficiency trends over different periods. This temporal analysis adds depth to the evaluation of long-term healthcare system performance.

Model type

The basic DEA models can be described as Radial, Non-Radial and Oriented, Non-Radial and Non-Oriented, and Radial and Non-Radial [40]. Within the Radial DEA framework, the two most commonly employed models are the CCR (Charnes, Cooper, and Rhodes) model and the BCC (Banker, Charnes, and Cooper) model. Overall technical efficiency (TE) is represented by technical efficiency scores that are derived through the use of the CCR model. On the other hand, the BBC model can be used to achieve pure technical efficiency (PTE). The BCC model was selected for this study since it best suits the objective of the study, while also being less restrictive in terms of the DMUs' production criteria, hence making it simpler to implement [47, 48]. The CCR model was also included for references.

Model orientation

Input-oriented or output-oriented DEA models are both possible. When assessing efficiency, orientation shows the direction of the input or output. Put otherwise, the main objective of the evaluation is either output expansion or input decrease. Several considerations or reasoning influence the choice of DEA orientation. Organizations in the healthcare sector generally have less control over their outputs [35, 49]. Nevertheless, the same collection of effective/ineffective decision-making units will be identified by both output and input orientations as both will be estimate at the same frontier [50]. An input-oriented model was adopted in the study due to the desirability of how MOH can minimize inputs in relation to a target output level, the limited control over their outputs and how can MOH estimate the required input for the future.

Return to scale assumption

A key idea in production functions is returns to scale (RTS), which describes the long-term relationships between inputs and outputs. The choice of RTS is influenced by various elements such as the organization's size [51], internal characteristics [52], input-output flow [53], and other relevant aspects. In the application of DEA, there is a shift from Constant Return to Scale (CRS) to Variable Returns to Scale (VRS) assumption [54]. The majority of assessments of healthcare efficiency were conducted with the assumption that economies of scale exist and that not all countries were operating at their optimal scale, implying that there would be economies and diseconomies of scale [55, 56]. While VRS assumes and implies that the outputs of organizations (DMUs) change significantly (increase/decrease) with inputs, CRS assumes that the outputs of their organizations (DMUs) vary (increase/decrease) in a manner similar to that of the inputs. This study chooses input-oriented VRS and CRS assumptions in order to understand the results better [56].

Input and output selection

Selecting suitable inputs and outputs is crucial for a meaningful evaluation. One of the most important tasks is to identify the qualities that best characterize the production or process under investigation (DMUs). There are a number of guidelines, analytical techniques, or concepts that can assist researchers in selecting the most appropriate variables for their study, even though there isn't a defined standard set of input and output in DEA studies [57–60]. It is also important to note that the "n" (number of DMUs) should be greater than the number of inputs (m) and outputs (s) in order to have a sufficient number of degrees of freedom (enough discriminatory power) for the DEA model. As a general rule, researchers advise that "n" should be larger than max {m*s, 3*(m + s)} or (2*m*s) [39, 61, 62]. In this study, the inputs and outputs were prioritised based on their vital importance to MOH hospital operations, internal discussions with MOH stakeholders, and availability.

Based on literature review, availability of data and limited DMU in this study (hence the application of Window DEA), 9 variables were selected. Six input variables and three output variables were measured into 8 models of inputs and outputs variations for the period of 1995 until 2022 (some data for year 2022 were preliminary). Thus the final number of DMUs in the study after considering all the requirement for DEA are 28. The data of MOH were all publicly available data and can be accessed via the MOH official website [63]. Model I was the base model as it provides all the variables for MOH to use for future planning and Model VII and VIII used the same inputs and outputs, but the values of human resources were combined into one and the values of admissions & attendances were also combined. These models serve as a 1 input and 1 output exploratory model to see whether the efficiency score yield a similar result. The model was selected based on internal discussion with MOH after considering all relevant factors. Table 1 shows the significant positive association input with output. The isotonicity property of DEA which requires that an output should not decrease with an increase in an output is not violated. Table 2 provides the description of model specifications, inputs & outputs, also the summary for each model.

Bootstrapping DEA

Conventional DEA models produce biased efficiency scores because they pay less attention to non-discretionary factors influencing the production function and are more susceptible to input and output selection [64–66]. In order to estimate bias-corrected technical efficiency ratings, a bootstrapping DEA model put out by Simar and Wilson was employed [67, 68]. To put into practice, bootstrapping DEA is like running multiple simulations of data many times to estimate how much uncertainty is in the efficiency scores. While bias-corrected efficiency prevents the score from overestimating. Thus, the score of efficiency measured will be more reliable and realistic.

Results

Descriptive statistics

Table 3 provides a detailed summary of this study's variables (inputs & outputs). The MOH yearly financial

Table 1 Pearson correlation matrix of inputs and outputs

Output	Admissions	Outpatient Attendances	Maternal & Child Health Attendances	(Admissions, Outpatient Attendances, Maternal & Child Health Attendances)
Inputs				
MOH Budget Allocation	0.963**	0.897**	0.944**	0.909**
Doctors	0.953**	0.880**	0.940**	0.894**
Dentists	0.917**	0.817**	0.895**	0.833**
Pharmacists	0.945**	0.846**	0.911**	0.860**
Nurses	0.976**	0.931**	0.956**	0.940**
Community Nurses	0.900**	0.914**	0.899**	0.916**
(Doctor, Dentists, Nurses, Community Nurses)	0.978**	0.924**	0.961**	0.935**

** $p < 0.01$

Table 2 Summary of models in the studies

Variables	Model I (base)	Model II	Model II	Model IV	Model V	Model VI	Model VII	Model VIII
Inputs:								
MOH Budget Allocation	X	X	X				X	
Doctors	X	X		X	X			
Dentists	X	X		X	X			
Pharmacists	X		X	X		X		
Nurses	X		X	X		X		
Community Nurses	X		X	X		X		
(Doctor, Dentists, Nurses, Community Nurses)								X
Outputs:								
Admissions	X	X	X	X	X	X		
Outpatient Attendances	X	X	X	X	X	X		
Maternal & Child Health Attendances	X	X	X	X	X	X		
(Admissions, Outpatient Attendances, Maternal & Child Health Attendances)							X	X

Table 3 Summary of statistics of the variables

Variable	Units	Mean	SD	Minimum	Maximum
Inputs:					
MOH Budget Allocation	Malaysia currency (Ringgit Malaysia, RM)	15625406728.21	10562462418.40	2,593,231,000	36,327,000,000
Doctors	Numbers	23109.32	16001.32	4412	52,363
Dentists	Numbers	2670.07	2142.78	738	6944
Pharmacists	Numbers	4030.18	3705.00	353	11,213
Nurses	Numbers	43087.57	19726.56	13,647	71,434
Community Nurses	Numbers	16526.64	7105.93	5495	25,128
Health Human Resources	Numbers	89423.79	47421.17	24,655	164,022
Outputs:					
Admissions	Numbers	2079500.86	436280.69	1,465,861	2,944,808
Outpatient Attendances	Numbers	52028458.00	15988211.06	30,841,158	81,617,298
Maternal & Child Health Attendances	Numbers	12601434.50	2388646.704	9,808,419	17,116,573
Admissions & Attendances	Numbers	66709393.36	18723522.94	42,239,415	101,493,404

allocations includes operating and development budgets. No conversion was done (i.e., Percentage to National Budget) as the study's intention was to measure the exact value in Malaysia currency. The numbers of doctors include Specialists, Medical officers, and House officers as these are the licensed professions qualified to practice medicine in the ministry. As for the outputs, a combined values were used to make sure the number of DMUs were more than the number of inputs and outputs. The admissions consist of admission to MOH Hospitals and Special Medical Institutions. The outpatient attendances include Hospitals, Special Medical Institutions and Public Health Facilities. And the Maternal & Child Health Attendances comprise of Antenatal, Postnatal and Child Attendances.

The outputs were plotted in Fig. 1 showed the trend of admissions and attendances in MOH. This is important as MOH is the main provider of health service in Malaysia. It is an obligation for MOH to provide preventive & curative care, environmental sanitation, use and manufacture of drugs, and control of communicable diseases as described in the Federal Constitution– Ninth (9th) Schedule of Federal Constitution– Article 74, 77– Legislative Lists [10, 69].

Efficiency score estimates for MOH

As mentioned earlier, this study applied DEA Window Analysis to measure the relative efficiency of MOH throughout the period of almost three decades (1995–2022). Each Decision-Making Unit (DMU) is handled as an independent entity across time periods effectively demonstrates the resilience of the approach. This study applied bootstrapping method proposed by Simar and Wilson to correct the estimates of efficiency of random noise [67]. Therefore, a robust efficiency score was computed and robust estimates were consistently lower than the point estimates. Table 4 summarized the average efficiency scores from eight alternate DEA models. The TE score of model VII and model VII were low compare to other model. This can be explained by two main reasons, first because the CRS model assumes that the

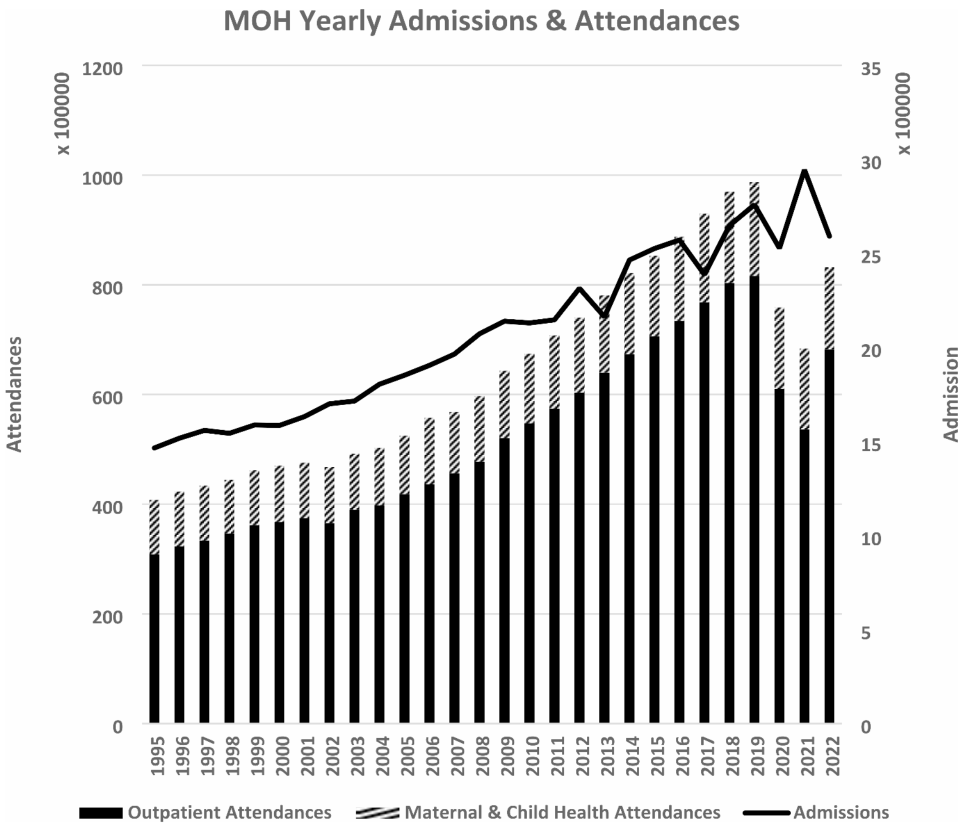

Fig. 1 Trend of admissions and attendances in Ministry of Health, Malaysia

Table 4 Average efficiency scores from eight alternate DEA models

	Technical Efficiency				Pure Technical Efficiency			
	CRS	**Bias corrected**	**Lower bound**	**Upper bound**	**VRS**	**Bias corrected**	**Lower bound**	**Upper bound**
Model I (base)	0.708	0.662	0.584	0.707	0.989	0.974	0.907	0.989
Model II	0.620	0.584	0.528	0.618	0.974	0.956	0.889	0.974
Model III	0.655	0.610	0.538	0.654	0.975	0.955	0.901	0.975
Model IV	0.708	0.663	0.586	0.707	0.989	0.973	0.909	0.988
Model V	0.615	0.583	0.534	0.614	0.967	0.948	0.887	0.966
Model VI	0.655	0.613	0.539	0.654	0.956	0.928	0.869	0.955
Model VII	0.384	0.351	0.294	0.384	0.869	0.845	0.796	0.868
Model VIII	0.526	0.509	0.434	0.526	0.857	0.826	0.773	0.856
Mean	0.609	0.572	0.505	0.608	0.947	0.926	0.866	0.946
Median	0.637	0.597			0.971	0.951		
Minimum	0.384	0.351			0.857	0.826		
Maximum	0.708	0.663			0.989	0.974		

input reduction or output increase is at a constant rate. Second, by only using single input and output the discriminatory power of DEA to identify inefficient DMUs increase. However, by considering the economies of scale VRS model was chosen for this study. Under the VRS, the mean Pure Technical Efficiency of MOH (under 8 models) for the past 28 years was 0.947 (94.7%). The bias corrected score was 0.926 (95% CI 0.866–0.946). This significantly indicates that MOH has been highly efficient in providing public healthcare service to the country. Table 5; Fig. 2 shows the Model I (base model) bootstrapped pure technical efficiency (VRS) score of each of the 28 years with their respective confidence intervals.

Sensitivity of the efficiency scores

Sensitivity analysis was performed under eight models with different combinations of input and outcome variables. The pure technical efficiency (VRS) scores in each of these models ranged from 0.857 to 0.989 on average. The bias corrected score ranges from 0.947 (95% CI

Table 5 Pearson correlation coefficient between VRS efficiency score models

Pearson's correlations	Model I	Model II	Model III	Model IV	Model V	Model VI	Model VII	Model VIII
Model I	1							
Model II	0.935**	1						
Model III	0.773**	0.707**	1					
Model IV	0.997**	0.931**	0.778**	1				
Model V	0.934**	0.982**	0.707**	0.934**	1			
Model VI	0.470*	0.402*	0.798**	0.498**	0.410*	1		
Model VII	0.538**	0.542**	0.451*	0.533**	0.514**	0.116	1	
Model VIII	0.560**	0.530**	0.459*	0.556**	0.512**	0.324	0.857**	1

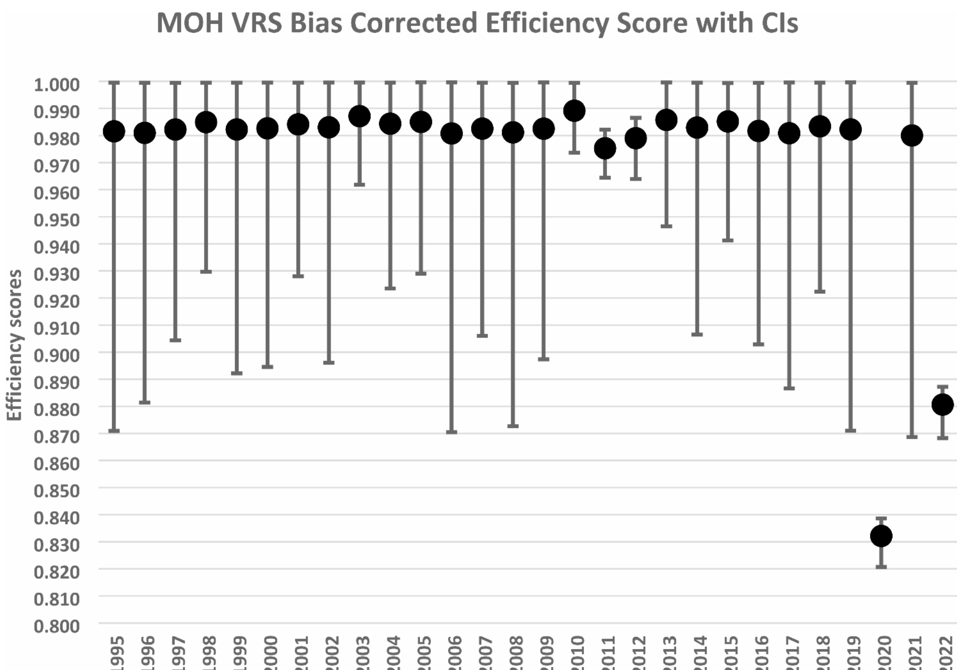

Fig. 2 Bootstrapped pure technical efficiency (VRS) score of Model I

0.909–0.989) to 0.826 (95% CI 0.773–0.856). The most sensitive model was model VI while using the numbers of Pharmacists, Nurses and Community Nurses as the inputs variable. The average bias corrected VRS efficiency score was 0.928 (95% CI 0.869–0.955) as opposed to 0.974 (95% CI 0.907–0.989) for the base model as shown in Fig. 3.

The choices made for inputs and outputs have the potential to misspecify the model (model misspecification). This can manifest as the inclusion of unnecessary variables or the omission of important ones. There is no test to determine whether a specific model definition is appropriate [70]. Thus, Pearson correlation was computed for the Model I (base) to other models following the bootstrapping. The goal is to verify two key points: first, that the selection of inputs, and their combination, does not produce data-specific outcomes; and second, that the use of each of the seven plausible values (other models) as reference output does not change the main findings of the empirical analysis. Table 5 illustrated and confirmed the validity (i.e., robustness) of the baseline (Model I) efficiency score. The coefficients were high and stable in model II, IV, and V. Model VI which was most sensitive, still correlates although it was moderate (0.470). The exploratory 1 input and 1 output models (Model VII & VIII) also had a positive and significant correlation, even though moderate (0.538 & 0.560). With model VII and VIII, DEA technologies were plotted to provide a graphical illustration for MOH efficiency score production function (both non-bootstrapped CRS and VRS) as presented in Fig. 4 Model VII production frontier efficiency score and Fig. 5 Model VIII production frontier efficiency score.

Discussion

This study evaluated the relative technical efficiency of MOH Malaysia as the provider of public healthcare service. The comparison between years using DEA

Table 5 Bootstrapped efficiency score of model I

	Technical Efficiency				Pure Technical Efficiency			
	CRS	**Bias corrected**	**Lower bound**	**Upper bound**	**VRS**	**Bias corrected**	**Lower bound**	**Upper bound**
1995	1.000	0.795	0.677	0.998	1.000	0.982	0.871	1.000
1996	1.000	0.837	0.697	0.999	1.000	0.981	0.881	0.999
1997	1.000	0.899	0.739	0.998	1.000	0.982	0.904	0.999
1998	1.000	0.899	0.758	0.998	1.000	0.985	0.930	1.000
1999	1.000	0.917	0.766	0.998	1.000	0.982	0.892	1.000
2000	1.000	0.919	0.784	0.998	1.000	0.983	0.895	1.000
2001	0.989	0.930	0.803	0.987	1.000	0.984	0.928	1.000
2002	0.918	0.879	0.754	0.917	1.000	0.983	0.896	1.000
2003	0.843	0.805	0.714	0.841	1.000	0.987	0.962	1.000
2004	0.780	0.734	0.637	0.779	1.000	0.984	0.924	1.000
2005	0.716	0.670	0.593	0.714	1.000	0.985	0.929	1.000
2006	0.689	0.652	0.580	0.688	1.000	0.981	0.870	1.000
2007	0.652	0.625	0.559	0.651	1.000	0.983	0.906	1.000
2008	0.566	0.526	0.456	0.565	1.000	0.981	0.873	0.999
2009	0.611	0.598	0.565	0.610	1.000	0.983	0.897	1.000
2010	0.586	0.576	0.546	0.586	1.000	0.989	0.974	0.999
2011	0.532	0.516	0.474	0.531	0.983	0.975	0.964	0.982
2012	0.511	0.495	0.457	0.510	0.987	0.979	0.964	0.987
2013	0.524	0.509	0.465	0.523	1.000	0.986	0.946	1.000
2014	0.503	0.482	0.437	0.502	1.000	0.983	0.907	1.000
2015	0.501	0.482	0.435	0.501	1.000	0.985	0.941	0.999
2016	0.527	0.511	0.466	0.526	1.000	0.982	0.903	0.999
2017	0.571	0.557	0.516	0.571	1.000	0.981	0.887	1.000
2018	0.607	0.595	0.553	0.606	1.000	0.983	0.922	1.000
2019	0.621	0.609	0.570	0.620	1.000	0.982	0.871	1.000
2020	0.488	0.471	0.420	0.488	0.839	0.832	0.821	0.839
2021	0.542	0.515	0.434	0.541	1.000	0.980	0.869	0.999
2022	0.540	0.528	0.490	0.540	0.888	0.881	0.868	0.887
Mean	0.708	0.662	0.584	0.707	0.989	0.974	0.907	0.989
Median	0.616	0.604			1.000			
Minimum	0.488	0.471			0.839			
Maximum	1.000	0.930			1.000			

** $p < 0.01$

provides historical efficiency analysis for MOH. Instead of using other methods such as average, trend over time, or indexes, DEA can give further insight on MOH performance. DEA Window Analysis can capture efficiency patterns over 28 years, providing insights into how healthcare reforms under various Malaysian plans affected resource utilisation.

The key findings of this paper indicate on average that for the past almost three decades the MOH efficiency score was generally high under all models 0.926 (95% CI 0.866–0.946). However, under the CRS evaluation the TE score was 0.572 (95% CI 0.505–0.608) and relatively high scale of efficiency (0.615). The continuously excellent VRS efficiency scores demonstrate that MOH effectively optimizes resource utilization, despite constraints such personnel shortages and geographical inequalities. Thus, taking into consideration of economies of scale the VRS model for estimation for efficiency is more relevant. It was observed under Model I, the efficiency score for MOH throughout the year was generally high with an average of PTE 0.974 (95% CI 0.907–0.989). In 2020 and 2022 the efficiency score was low 0.832 (95% CI 0.821–0.839) and 0.881 (95% CI 0.868–0.887). This condition can be explained due to the COVID-19 global pandemic. In order to address the public health emergency during the imposition of movement restrictions, the government quickly launched a public health response and supplied sufficient medical care [71, 72]. This action may cause increase in (input) MOH expenditure, intake of medical staff, and at the same time rapid increase of patient load and large COVID-19 patient clusters (output) [73, 74] and may impact the efficiency of MOH for certain period. The examination of efficiency over time (1995–2022) is a useful contribution. It reveals how MOH efficiency fluctuated, notably during big events like the COVID-19 pandemic, when scores plummeted in 2020 and 2022.

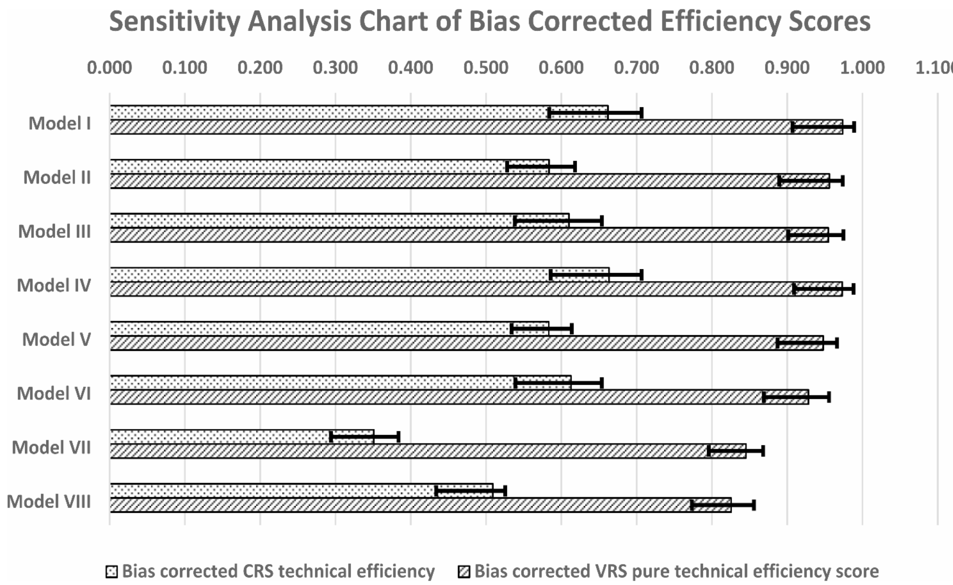

Fig. 3 Sensitivity analysis chart of bias corrected efficiency scores

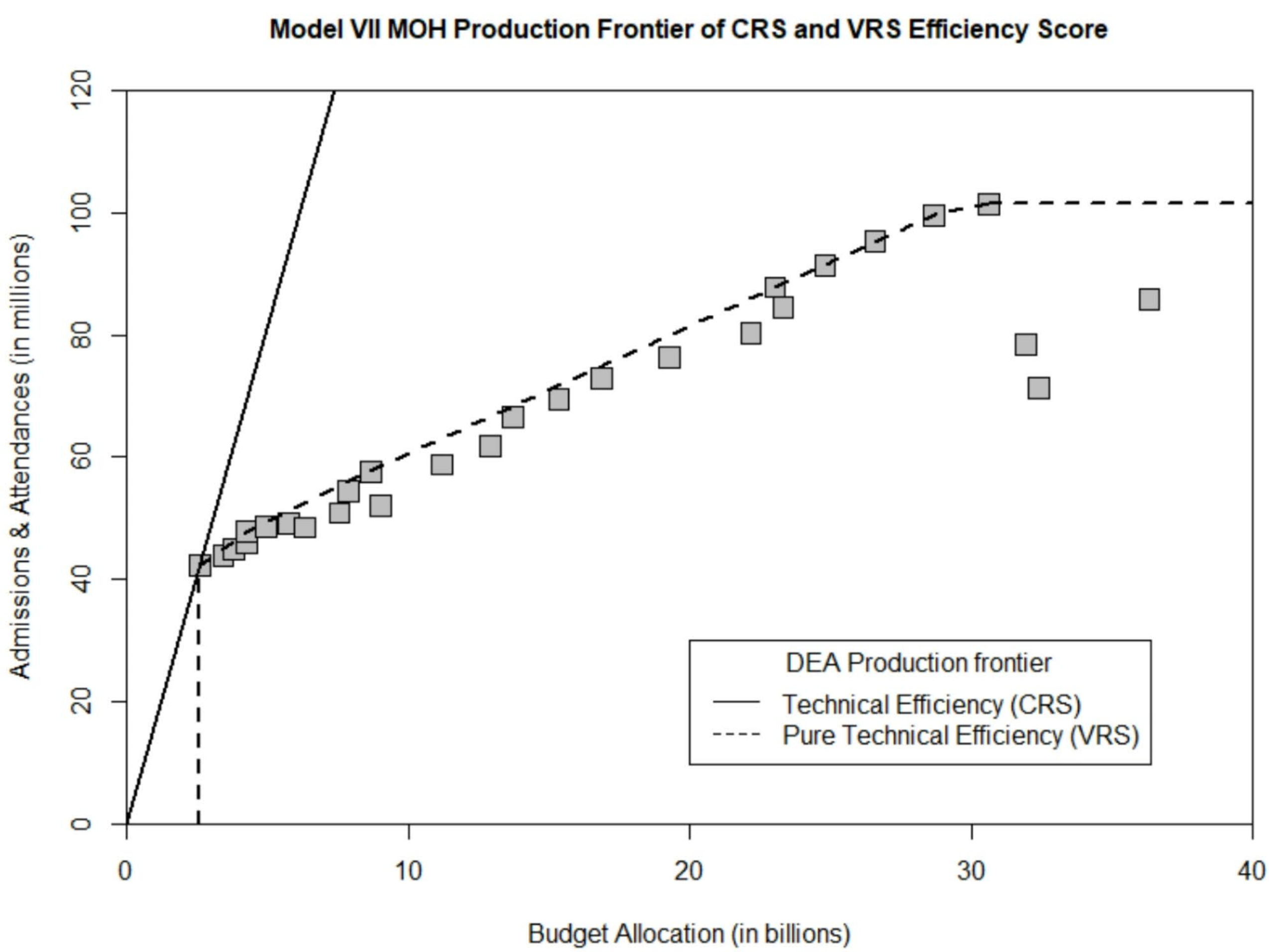

Fig. 4 Model VII production frontier efficiency score

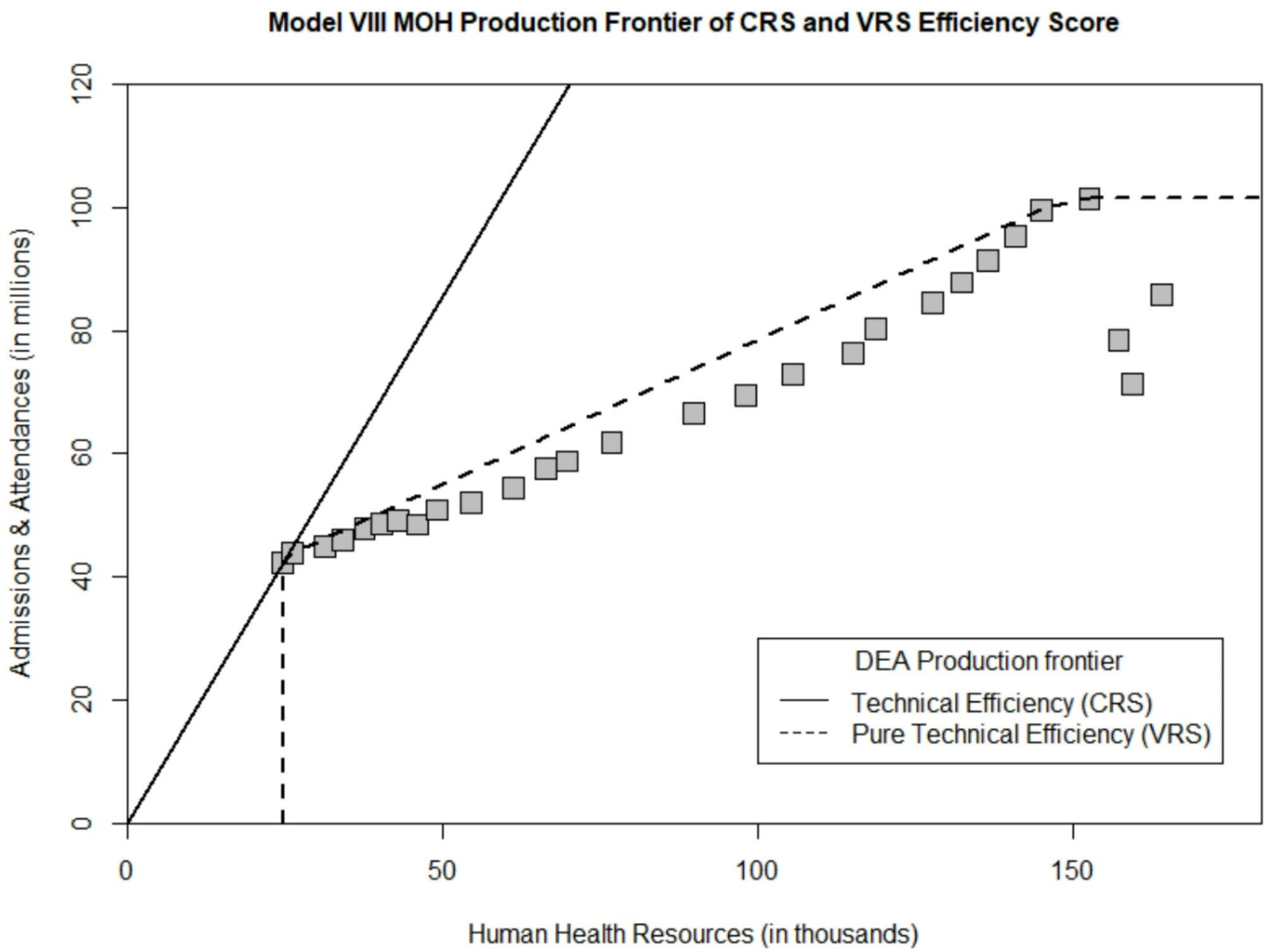

Fig. 5 Model VIII production frontier efficiency score

Model I highlight the fact that MOH relative efficiency (VRS) was characterized by high efficiency. This scores coincide with those of other high-performing ASEAN countries, such as Singapore and Thailand, which also stress resource optimization in public health delivery. The level of efficiency is comparable to other findings albeit under different model or setting [12–15, 22, 23]. Even one study under CRS yield almost similar result [22]. The efficiency score 0.974 (95% CI 0.907–0.989) implied that on average MOH can increase their efficiency by increasing the inputs by about 3%. For instance, the expenditure for year 2022 was RM32.327 (Malaysian Ringgit) billion can be increased to RM33.297 to achieve better efficiency score. While this may be in the past, it can provide MOH with some value for future budgeting. For example, with the assumption that the trend of admissions and outpatient attendances increase proportionally based on previous year. MOH should receive a budget of at least RM34.296. Although this method is very basic but it can provide MOH the foundation to compliment with other methods.

Since the beginning of the period of this study, MOH had already undergone seven Malaysia Plan (RMK 6th–RMK 12th) [1, 2, 6]. Throughout this period the MOH focus public health services on several key agendas.

- expansion of the medical workforce and infrastructure in order to improve the standard and quality of care provided.
- consolidate health care services, improve the development of human resources, and make the best use of available resources (optimization). The commercial sector and NGOs will be more actively involved in the delivery system improvements.
- healthcare transformation to provide universal access and improve quality.

Based on this agenda, this study revealed the relative efficiency of the government health care agenda under MOH. Under Model I VRS, from RMK-6th to RMK-10th the efficiency score remained relatively stable at 0.983, with minor fluctuations. This is the reflection of policies during that period focused on industrialization, privatization, infrastructure development, and economic growth. During RMK-11th there is a slight decline in the efficiency score this is possibly due to economic slowdowns or global trade challenges. There is a major declined in efficiency score during RMK-12th which has been mentioned before because of COVID-19 impacts, affecting the economic and governmental efficiency. Recovery in the efficiency score can be seen afterwards, though not fully returning to the pre-2020 levels. Thus, it can be fairly said that throughout the years the plans had shown good level of efficiency. However, this level of performance was limited to the variables under investigation. While DEA offered reliable efficiency estimates, the use of static input-output data may not adequately capture the dynamic nature of healthcare delivery.

The Model I under CRS, show a downward trend from RMK-6th to RMK-10th. The scale of inefficiencies between VRS and CRS may suggest that the healthcare facilities are either too small to benefit from economies of scale or too large for the population they serve. In general, the policy of Malaysia healthcare system especially in rural areas should shift from a "one-size-fits-all expansion" model to a more flexible, demand-driven system. This includes smaller community-based clinics, larger hospitals for regional healthcare hubs to serve multiple rural areas efficiently and application of telemedicine & mobile clinics to reduce the need for oversized healthcare facilities.

Economically speaking, human resources in public health constitute a highly specialized and short-term irreplaceable factor of production. Since two thirds of the financial resources in both the healthcare system and individual organizations are allocated to labor pay, the public health and healthcare sectors are highly demanding economically. As such, addressing the issues of human resource efficiency is crucial in ensuring long-term viability and advancement of the healthcare industry [75]. Nonetheless, pressure to produce healthcare efficiently is applied both domestically in the MOH and internationally. This pressure is applied both in terms of technical efficiency—that is, an organization's capacity to produce the greatest number of outputs given the volume of inputs and the technologies available—and allocative efficiency—that is, the effectiveness of the use of financial resources within the various healthcare segments. Without doubt MOH, experience this pressure in term of lack of medical personnel, inadequate funding and overcrowding issues [76–78]. Based on Model I, the bias corrected CRS and VRS model indicates that on average the MOH efficiency score were 0.662 (95% CI 0.584–0.707) and 0.974 (95% CI 0.907–0.989) respectively. For MOH to become more efficient, it is possible to increase the number of human resources (on average) by 3% (between 1 and 9%) under VS or 34% (between 29 and 42%) under CS. This value is quite similar to what was stated by the by the Malaysia National Audit Department in the report. Staffing levels at Emergency & Trauma Departments (ETDs) generally short by 11.6–53.1% on average. Emergency specialists (75.6–79.5%) are the most 'in demand', followed by medical officers (41.2–64.6%), assistant medical officers (2.6%), and trained nurses (17.4–67.1%). Even though the audit report was only on ETDs only, the evaluation of DEA provides further insight into the related issues. Improving efficiency necessitates resolving resource inequities. For example, relocating healthcare staff to neglected areas and investing in scalable infrastructure such as mobile clinics, new technology, and telemedicine could improve fairness and efficiency.

As far as the input and output variables are concerned, there are currently no suitable unified variables for the DEA model. Instead, the international literature review and prior empirical research are used to select the input and output variables [57, 58, 62]. In this study, the proposed Model I (input oriented VRS with 6 inputs and 3 outputs) gave a robust and reliable result. The "initial" relative efficiency evaluation under pure technical efficiency ranging from 0.832 to 0.989, shown an almost plateauing trend, indicating that the health expenditure and human resources were used efficiently with the increase of patient load (admissions & outpatient attendances) except during the COVID-19 pandemic period. The bootstrapped efficiency score gave lower bias corrected VRS (average efficiency 0.974 vs. 0.989). Through bootstrap, the DMUs are subject to drawing with replacement from a sample, reproducing the true model's data generation process and generating several estimates that are suitable for statistical inference and allowing to extract the sensitivity of efficiency scores which results from the distribution of (in)efficiency in the sample. Thus, the robustness and reliability of the efficiency measurement was improved.

Limitations and suggestions for future research

This study is not without limitations. First, it used cross-sectional data, solely addressing the efficiency of the health system, and measure the efficiency between years in one country. Future studies can employ a variety of data sources to look at how the nation's efficiency has evolved over time, comparing with other countries, particularly by analyzing how healthcare plan have affected the productivity and efficiency of the health system. Second, this study looked at the variables for efficiency score exclusively. Exogenous or environmental factors should be looked into in the future whereby through exploring the determinants of county health system technical inefficiency, further remedial action can be taken. Third, this study focuses on the secondary care and tertiary care of public health service. Hence, the primary care such as promotion and prevention efforts can be considered as part of variables or exogenous factors in future studies.

Conclusion

As a public health service provider, this analysis offers an empirical picture of the MOH healthcare systems' relative efficiency. The study demonstrates that MOH can be regarded as a highly efficient organization under the VRS assumption. This analysis demonstrates that, under VRS assumptions, MOH Malaysia has attained great operational efficiency, with an average bias-corrected efficiency score of 0.974 (95% CI: 0.907–0.989) for almost three decades. Notwithstanding this achievement, lower CRS scores indicate scale-level inefficiencies that reflect differences in resource distribution that disproportionately impact underprivileged and rural communities. The COVID-19 pandemic's efficiency drop highlights the necessity of flexible approaches to maintain healthcare service in emergency situations. Government health decision makers (MOH, associated government sectors) want information about how successful their organization is in using the resources available to improve the performance of the nation's public health systems. Health policymakers must shift their focus from treating people to preventing diseases and investigate the optimal operation that ensures resource allocation is people-centered, given the pervasive diminishing returns in public health systems; the rise in treatment costs; and the rising trend in disease burden.

Abbreviations

DEA	Data Envelopment Analysis
VRS	Variable return to scale
CRS	Constant return to scale
SFA	Stochastic Frontier Analysis
TE	Technical efficiency
PTE	Pure technical efficiency
CCR	Charnes, Cooper and Rhodes
BCC	Banker, Charnes and Cooper
RTS	Return to scale
MOH	Ministry of Health Malaysia
DMU	Decision making unit
CD	Communicable disease
NCD	Non-communicable disease
WHO	World Health Organization
OECD	Organisation for Economic Co-operation and Development
ASEAN	Association of Southeast Asian Nations
RMK	Malaysia Plan (Rancangan Malaysia)

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Author contributions

M.Z.Z, A.A.N and M.R.A.M: study conception and design. M.Z.Z: acquisition of data. M.Z.Z, A.A.N and M.R.A.M: analysis of collected data. M.Z.Z, A.A.H, M.I.A, M.I.K, M.F.M.R, M.N.M, and N.F: interpreted the data. M.Z.Z, A.A.N, M.R.A.M, A.A.H, M.I.A, M.I.K, M.F.M.R, M.N.M, N.F, A.M.A and S.A.S.S.R: drafted the paper and/or made critical revisions. MZZ: had primary responsibility for the final content. All the authors have read and approved the final manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethical approval and consent to participate

This study was registered at National Medical Research Register, Malaysia: RSCH ID-24-00303-ULH (https://nmrr.gov.my/). Ethical approval and consent are not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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