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Stochastic Frontier Analysis of Curative Medical Consultations in Morocco.

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Abstract

The current research focuses on determining if there is a link across health systems inputs and curative medical consultations through an application of the Cobb-Douglas format to create a stochastic frontier model within Morocco for years 2000-2023. Using descriptive statistics, there was found to be an overall increase in capacity within the health care system as indicated by increases in consultations arising from human resource development as well as increases for infra-structure development through new facilities created. Building upon the results, nurses and primary health care facilities both show a positive, statistically significant relationship with curative consultations while physicians showed a negative, statistically significant relationship suggesting structural or allocation issues may exist. Hospital type facilities operated, as well as bed capacity created, were found to not show a statistically significant relationship given the model. Also of note, the efficiency scores of the sample remained well above 0 of (typical scores being approximately equal to 1), therefore indicating that most of the residual variance of the sample is due to random noise as opposed to technical inefficiencies. Taken together, there are useful implications that reinforce the importance placed upon the utilization of primary health care agencies and nursing resources for generating outpatient medical services within Morocco as well as the conclusion that resources will become limited by availability and structure/organization of the system; therefore, in order for positive performance within the health care system in Morocco it is suggested that organizational structures for allocating urine and blood utilization must change in order for improvements to be made versus only increasing the quantity of resource supplies alone.

Keywords: health system inputs; curative medical consultations; stochastic frontier model; healthcare system efficiency; health economics.

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Résumé

La présente étude vise à déterminer s'il existe un lien entre les intrants des systèmes de santé et les consultations médicales curatives, en appliquant le modèle de Cobb-Douglas afin de créer un modèle de frontière stochastique au Maroc pour la période 2000-2023. L'analyse des statistiques descriptives a révélé une augmentation globale de la capacité du système de santé, comme en témoignent la hausse des consultations résultant du développement des ressources humaines ainsi que l'augmentation des infrastructures grâce à la création de nouveaux établissements. Sur la base de ces résultats, les infirmières et les établissements de soins de santé primaires présentent tous deux une relation positive et statistiquement significative avec les consultations curatives, tandis que les médecins affichent une relation négative et statistiquement significative, ce qui suggère l'existence de problèmes structurels ou d'allocation des ressources. Les établissements de type hospitalier en activité, ainsi que la capacité en lits créée, ne présentent pas de relation statistiquement significative selon le modèle. Il convient également de noter que les scores d'efficacité de l'échantillon sont restés bien supérieurs à 0 (les scores typiques étant approximativement égaux à 1), ce qui indique que la majeure partie de la variance résiduelle de l'échantillon est due au bruit aléatoire plutôt qu'à des inefficacités techniques. Dans l'ensemble, ces résultats ont des implications utiles qui soulignent l'importance accordée à l'utilisation des structures de soins de santé primaires et des ressources infirmières pour la prestation de services médicaux ambulatoires au Maroc, ainsi que la conclusion selon laquelle les ressources seront limitées par leur disponibilité et par la structure/organisation du système ; par conséquent, pour garantir une performance positive du système de santé marocain, il est suggéré de modifier les structures organisationnelles régissant l'utilisation des analyses d'urine et de sang afin d'apporter des améliorations, plutôt que de se contenter d'augmenter la quantité des ressources disponibles.

Mots clés : intrants du système de santé ; consultations médicales curatives ; modèle de frontière stochastique ; efficacité du système de santé ; économie de la santé.

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Introduction

Health system performance relies on various factors. These include the amount of a specific resource available, the method in which that resource is organized, and how that resource turns into a service for use by the public. In the developing world, continued access to health services has relied on improvements to the development of health service delivery systems, the establishment of other health sectors, and the most efficient use of the above resources. In Morocco, the health delivery system has experienced numerous changes within the health area over the last 20 years through increased investment in primary health delivery systems, improvement of hospital facilities, and enhancement of the human resources in that country. Therefore, the evaluation of how the above resources contribute to the provision of health services is important for understanding the overall health delivery system and how these evaluations can help inform policy making at the national level.

This establishes the subject of the present research: analyzing the relationship between health system inputs (human resources and infrastructure) and curative medical consultations in Morocco over the period 2000–2023.

The researchers Idalfahim et al (2025) estimate that Moroccan households allocate a minimum amount of consumption to Health and medical care, which is MAD 5,059.2, and a budget share of 7.9% of their total expenditures. Further, according to their estimates the income elasticity of health and medical care is 0.89 which means that this category of good is considered a necessity due to the fact that demand for health and medical care rises with increasing disposable income but does not rise as fast as the increase in income. Also, the estimated own-price elasticity of -0.99 indicates that the demand for health and medical care is nearly unit elastic with respect to price changes; thus, a 1% increase in price will result in a 0.99% decrease in the quantity demanded (of those items). Lastly, because the cross-price elasticities are equal to zero, it can be concluded that there is no relationship between the price change and quantity demanded of health and medical care and any of the other goods or services consumed by Moroccan households; therefore there cannot be, in general, any significant complementary or substitutionary relationship between health and medical care and any other category of goods consumed by Moroccan households.

A basic aspect of a society is that the healthcare system allows people to get care and helps to stop diseases from spreading or creating other health problems. The way a country organizes its

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healthcare also affects public health as well as economic and social development. There is an increasing number of health challenges that can lead to issues with how the healthcare system is managed, including population growth, the rise of chronic diseases worldwide, pandemics, and disparities in access to healthcare (Bouzit et al., 2024).

Empirical research on health system efficiency has widely used stochastic frontier analysis (SFA) and data envelopment analysis (DEA) to assess how effectively healthcare resources are transformed into health services or outcomes. This literature covers both country-level health systems and healthcare facilities, showing that efficiency varies considerably across contexts depending on resource allocation, institutional organization, and socio-economic conditions. Overall, these studies suggest that efficiency is not determined solely by the quantity of resources, but also by how these resources are managed and distributed within the health system.

At the cross-country level, several studies have highlighted important differences in health system efficiency. Hamidi and Akinci (2016) found that Morocco was among the most efficient countries in the MENA region, while Şenel and Cengiz (2016) reported lower efficiency levels in some OECD countries such as Turkey, Hungary, and the Slovak Republic. Similarly, Kang et al. (2023) showed that inefficiency persists in China and most ASEAN countries, although some lower- and middle-income countries performed better than high-income ones. Ogloblin (2023) further emphasized that health expenditure improves outcomes only up to a certain threshold, suggesting that the effectiveness of spending matters as much as its level.

At the facility level, empirical evidence also points to substantial variation in technical efficiency. Rezaei et al. (2016) found an average efficiency score of 0.67 for university hospitals in Kurdistan, while Qorbani et al. (2017) showed significant provincial disparities in the efficiency of rural primary healthcare in Iran. Jiang and Andrews (2020) reported relatively high technical and cost efficiency in New Zealand public hospitals, whereas Kasa et al. (2021) found a much lower average efficiency level of 51% in Haitian health facilities. In the Moroccan context, Idalfahim and Elouardirhi (2026) estimated regional efficiency scores ranging from 61.2% to 73.4%, with decreasing returns to scale and evidence of resource mis-allocation. Taken together, these findings confirm that improving health system performance requires not only more resources, but also better allocation, stronger primary care organization, and more effective management practices.

The objective of this research is to evaluate health input-service output relationships using stochastic frontier analysis (SFA), which allows for the separation of technical inefficiencies from

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random shocks; hence, SFA is a powerful tool used in conjunction with a Cobb-Douglas stochastic frontier model across a longitudinal data set (2000–2023) for Morocco. The output variable is defined as the number of curative consultations produced; explanatory variables used to measure supply-side dimensions of healthcare include: number of physicians, number of nurses, number of primary healthcare facilities, number of hospitals, and bed capacity. In addition, we also assess each of these explanatory variables for their contribution toward producing healthcare services as well as evaluate the amount of technical efficiency improvement achieved over time.

The structure of this paper is as follows. Section 2 presents the methodology, including the stochastic frontier model specification and the data sources. Section 3 reports the descriptive statistics and empirical results, including the relationship between each input and curative consultations, as well as the efficiency scores. Section 4 discusses the implications of the findings for health policy in Morocco. Section 5 concludes with a summary of the main findings and recommendations for improving resource allocation and organizational structures within the Moroccan healthcare system.

Methodology

There are two general types of methodology for measuring the efficiency of decision-making units in terms of their use of technology: parametric and non-parametric. Data Envelopment Analysis (DEA) is an example of a non-parametric method that uses linear programming techniques to evaluate efficiency. Stochastic Frontier Analysis (SFA) is a parametric method that uses statistical techniques to evaluate efficiency (Assouih et al., 2025). The purpose of this study is to measure the efficiency of the production of curative health care in Morocco using a stochastic frontier function. It will employ annual national statistics for the period 2000-2023, with a total of 24 observations. Stochastic frontier analysis is preferable because it has the capacity to separate random shocks and technical inefficiencies; therefore, it provides a more adequate measure of the performance of the health care system than a conventional production model. The current research uses each of the years between 2000 and 2023 as a separate observation of Morocco's public health care system.

The empirical analysis employs curative medical consultations as the output variable. The volume of outpatient healthcare services provided by the public health system is represented by this indicator. The production frontier contains explanatory variables - physician numbers, nurse

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numbers, number of primary healthcare (PHC) facilities, number of hospitals and the bed capacity of those hospitals - which represent the major human and physical resources used to produce healthcare. While hospitalization days were included in the descriptive statistics, they were not included as part of the baseline frontier model since they refer to inpatient activity and likely indicate how hospitals are used rather than how to produce curative medical consults.

The data used in this study were obtained from the Moroccan Ministry of Health and Social Protection, mainly from the statistical publication Santé en chiffres 2023, which provides official annual information on health resources and service utilization in the public health sector. The dependent variable is the number of curative medical consultations, used as a proxy for outpatient healthcare production. The explanatory variables include the number of physicians, which reflects the availability of medical staff; the number of nurses, capturing paramedical human resources; the number of primary healthcare (PHC) facilities, measuring the territorial availability of first-line healthcare services; the number of hospitals, represent- ing hospital infrastructure; and bed capacity, indicating the volume of available inpatient physical resources. In addition, hospitalization days are reported in the descriptive analysis as an indicator of inpatient activity, although they are not retained in the baseline production frontier because the main output of interest is curative consultations.

To estimate the production relationship, the study adopts a Cobb–Douglas stochastic fron- tier specification in logarithmic form. This functional form is widely used in efficiency anal- ysis because of its relative simplicity, its ease of interpretation, and its suitability for small samples. The estimated model is specified as follows :

$$\ln(\text{Consult}_t) = \beta_0 + \beta_1 \ln(Med_t) + \beta_2 \ln(Inf_t) + \beta_3 \ln(PHC_t) + \beta_4 \ln(Hosp_t) + \beta_5 \ln(Beds_t) + \vartheta_t - \mu_t \quad (1)$$

where Consult_t denotes the number of curative medical consultations in year t, Med_t is the number of physicians, Inf_t is the number of nurses, PHC_t is the number of primary healthcare facilities, $Hosp_t$ is the number of hospitals, and $Beds_t$ is bed capacity. The term ϑ_t captures statistical noise and other random shocks beyond the control of the health system, while $\mu_t \geq 0$ represents technical inefficiency. In the baseline specification, the random error term is assumed to follow a normal distribution, whereas the inefficiency term is assumed to follow a half-normal distribution.

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Results

This section presents the main empirical findings of the study. It first describes the key characteristics of the data through descriptive statistics, then reports the results of the Cobb–Douglas stochastic frontier model and the estimated technical efficiency scores for Morocco over the study period.

Table 1. Descriptive statistics

Variable	Mean	SD	Min	Max
Curative consultations	17,563,639.96	3,336,625.43	10,390,000	**23,356,868**
Number of physicians	9,649.75	2,461.73	5,812	**15,249**
Number of nurses	25,875.08	2,248.05	21,822	**29,738**
Number of PHC facilities	2,703.62	213.44	2,267	**3,053**
Number of hospitals	143.33	16.67	112	**170**
Bed capacity	22,190.50	808.50	20,364	**24,049**
Hospitalization days	**4,523,107.54**	**283,633.68**	**3,875,663**	**4,898,170**

Source: Compiled by the authors

The descriptive statistics indicate substantial variation in curative medical consultations over the study period. On average, Morocco recorded 17.56 million curative consultations per year, with a minimum of 10.39 million and a maximum of 23.36 million, suggesting an overall expansion in service utilization, although with marked fluctuations across years. The average number of physicians was 9,649.75, while the average number of nurses reached 25,875.08, reflecting the importance of human resources in the delivery of healthcare services. Infrastructure indicators also show a progressive strengthening of the health system, with mean values of 2,703.62 PHC facilities, 143.33 hospitals, and 22,190.50 hospital beds. By contrast, hospitalization days averaged 4.52 million, with less dispersion relative to consultations, which may indicate that inpatient activity remained more stable over time than outpatient care. Overall, these descriptive results suggest that Morocco experienced an increase in healthcare capacity and service provision during the period under study, while also facing notable year-to-year variability in output.

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Table 2. Estimation results of the Cobb–Douglas stochastic frontier model

Parameter	Coefficient	Std. Error	z-value	p-value
(Intercept)	-18.279745	3.556072	-5.1404	**0.0000**
log(Nb_med)	-0.845068	0.156082	-5.4143	**0.0000**
log(Nb_inf)	1.256771	0.267368	4.7005	**0.0000**
log(etab_ssb)	4.477477	0.826373	5.4182	**0.0000**
log(etab_hosp)	-0.297270	0.672209	-0.4422	**0.6583**
log(Cap_lit)	-0.398622	0.443345	-0.8991	**0.3686**
σ^2	0.011249	0.003375	3.3327	**0.0009**
γ	0.000117	0.058090	0.0020	**0.9987**
Mean efficiency = 0.999083				

Source: Compiled by the authors

The stochastic frontier estimation based on the Cobb–Douglas specification shows that several explanatory variables are significantly associated with curative medical consultations. Because the model is estimated in logarithmic form, the coefficients can be interpreted as output elasticities. The coefficient for the number of physicians is negative and statistically significant ($\beta = -0.845$, $p < 0.001$), indicating that, all else being equal, a 1% increase in the number of physicians is associated with a 0.85% decrease in curative consultations. Although statistically significant, this negative sign is counterintuitive from a production perspective and may reflect multicollinearity, measurement issues, or structural changes in the health system over time rather than a true negative contribution of physicians to service delivery.

By contrast, the number of nurses has a positive and significant effect on output ($\beta = 1.257$, $p < 0.001$). This implies that a 1% increase in the number of nurses is associated with an approximately 1.26% increase in curative consultations, suggesting that nursing staff play an important role in expanding healthcare utilization. Similarly, the number of PHC facilities exhibits a large positive and highly significant elasticity ($\beta = 4.477$, $p < 0.001$), indicating that primary healthcare infrastructure is strongly associated with the volume of consultations. This result highlights the central importance of territorial healthcare availability and access in explaining outpatient service production in Morocco.

In contrast, the coefficients for the number of hospitals ($\beta = -0.297$, $p = 0.658$) and bed capacity ($\beta = -0.399$, $p = 0.369$) are not statistically significant. This suggests that, within this model, hospital infrastructure does not appear to have a direct and robust effect on curative medical consultations. One possible explanation is that the dependent variable

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mainly reflects outpatient and primary care activity, which is more directly influenced by primary healthcare facilities and human resources than by inpatient hospital capacity.

Regarding the stochastic frontier parameters, the estimated variance parameter is positive and statistically significant ($\sigma^2 = 0.011$, $p = 0.0009$), indicating the presence of residual variation in the model. However, the gamma parameter is extremely close to zero ($\gamma = 0.000117$, $p = 0.998$), showing that almost none of this residual variance is attributable to technical inefficiency. Instead, the unexplained variation appears to arise almost entirely from random noise. Consistent with this result, the mean efficiency score is very high (0.9991), suggesting that the observed production levels are located very close to the estimated frontier throughout the study period.

Overall, these findings imply that the estimated stochastic frontier does not reveal meaningful inefficiency in the Moroccan health system over the period considered. Rather, the model behaves almost like a conventional production function, with differences in curative consultations being explained mainly by observed inputs and random shocks rather than by persistent technical inefficiency. Therefore, the efficiency scores should be interpreted with caution, especially given the use of a single national time series rather than a richer panel dataset across regions or healthcare facilities.

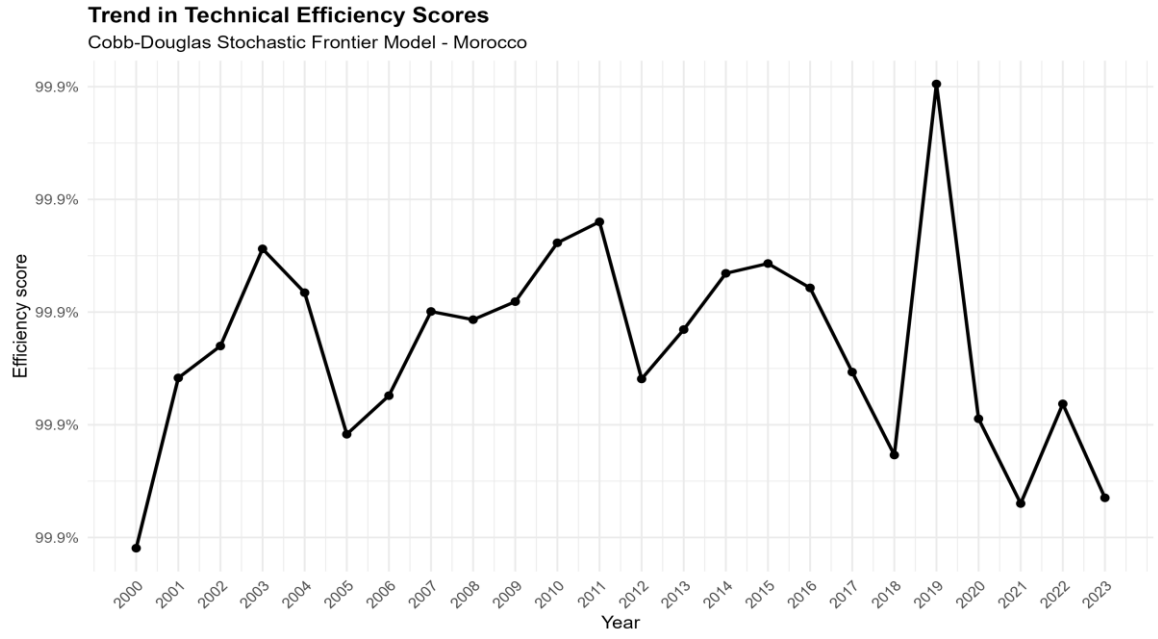

Fig 1. Trend in technical efficiency scores (2000–2023)

The trend in technical efficiency scores shows that Morocco operated consistently very close to the estimated production frontier throughout the study period. Efficiency levels remained extremely high and stable, fluctuating only marginally around 99.9%, which suggests very

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limited variation in technical performance over time. A gradual improvement can be observed from the early 2000s up to around 2010–2011, followed by small year-to-year fluctuations, with a noticeable peak in 2019. After this peak, efficiency declined slightly during 2020–2023, possibly reflecting disruptions in healthcare service delivery, yet the scores remained exceptionally high overall. Taken together, the graph indicates that the Moroccan health system exhibited near-frontier performance during the entire period, with only minor temporary deviations rather than substantial inefficiency.

Discussion

The results highlight an overall expansion in healthcare supply and curative care activity in Morocco over the study period, as reflected in the increase in the average number of consultations, the growth in health workforce levels, and the gradual extension of infrastructure, particularly primary healthcare facilities. The descriptive statistics therefore suggest a long-term strengthening of the Moroccan health system, although this trend was accompanied by significant year-to-year fluctuations. This variability indicates that changes in healthcare output do not depend solely on the accumulation of resources, but also on cyclical, organizational, and institutional factors.

The stochastic frontier estimation confirms that the different components of the health system do not contribute equally to the production of curative medical consultations. The positive and statistically significant effects of the number of nurses and the number of PHC facilities indicate that outpatient care delivery relies heavily on the availability of paramedical staff and on the territorial accessibility of first-line healthcare structures. From an economic perspective, these findings are consistent with the idea that curative consultations are pro- duced in relatively decentralized units, where primary care, patient triage, referral, and continuity of services depend strongly on nursing resources and on the density of basic healthcare facilities. The large coefficient associated with PHC facilities suggests that the expansion of primary care infrastructure likely played a central role in increasing healthcare utilization.

By contrast, the negative coefficient associated with the number of physicians calls for cautious interpretation. From a theoretical standpoint, one would normally expect medical personnel to make a positive contribution to the production of consultations. This counterintuitive sign may reflect several underlying mechanisms. First, it may indicate multicollinearity among supply-side variables, particularly between physicians, nurses, and healthcare infrastructure. Second, it may reflect structural transformations in the

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organization of the health system, in which an increase in the number of physicians does not automatically translate into a proportional increase in consultations, especially if physicians are concentrated in urban ar- eas, hospital-based services, or more specialized activities. Third, this result may point to a mismatch between the quantity of medical resources and their effective allocation. In other words, the policy challenge is not only to recruit more physicians, but also to ensure a better geographical, functional, and institutional distribution of these resources.

The non-significant coefficients of the number of hospitals and bed capacity are also informative. They suggest that curative medical consultations, as measured in this study, are more closely related to outpatient and primary care activity than to hospital capacity itself. From an economic standpoint, this implies that investment in hospital infrastructure does not necessarily have an immediate effect on the volume of curative consultations, particularly when these consultations are mainly delivered through health centers and local facilities. This dissociation between hospital capacity and consultation output underlines the need to distinguish production functions across levels of care: the determinants of outpatient activity are not the same as those of hospital activity, and public policies should avoid applying a uniform logic to segments of the health system that perform very different functions.

From the perspective of efficiency, the results reveal a particular pattern: the mean efficiency score is extremely high, close to 1, and the gamma parameter is nearly zero and statistically insignificant. This means that almost all of the residual variation is attributed to statistical noise rather than to persistent technical inefficiency. In practical terms, the model does not detect substantial inefficiency over the study period. The graph of efficiency scores confirms this interpretation by showing highly stable levels of efficiency that remain consistently close to the frontier. This configuration can be interpreted in two ways. On the one hand, it may suggest that, at the aggregate national level, the Moroccan health system operates relatively close to its observed production frontier. On the other hand, it may also reflect a methodological limitation related to the structure of the dataset used. A national annual aggregated time series provides very little heterogeneity across decision-making units, which greatly reduces the model's ability to identify technical inefficiency.

This methodological limitation is important for the economic discussion of the results. Stochastic frontier analysis is generally more informative when estimated on panel data including several decision-making units, such as regions, provinces, hospitals, or health cen- ters. In the present case, the analysis mainly captures macro-level production relationships

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between supply factors and the volume of consultations, rather than true comparative efficiency differences across producers. In this sense, the findings should be interpreted less as definitive evidence of perfect efficiency and more as an indication that inefficiency cannot be robustly identified in this aggregated dataset.

From a public policy perspective, several implications can be drawn. First, the results support prioritizing the strengthening of primary healthcare, since the expansion of local facilities and the availability of nursing staff appear to be the factors most strongly associated with the production of consultations. Second, they suggest that human resource policy should not be limited to increasing the total number of physicians, but should instead focus on improving the allocation of professionals across territories, strengthening complementarity between physicians and nurses, and enhancing the organization of care pathways. Third, the absence of a significant effect of hospital variables on consultations suggests that investment in hospitals should be designed in coordination with primary care, in order to avoid an excessive concentration of resources in the hospital sector at the expense of basic access to care.

Overall, this study suggests that improving the performance of the Moroccan health system depends less on the simple quantitative accumulation of resources than on a more coherent organization of the healthcare system. The central challenge appears to be the strengthening of first-line care, the effective use of nursing staff, the reduction of territorial disparities, and better coordination between primary and hospital care. Future research based on disaggregated data would make it possible to better identify the real sources of inefficiency, assess performance gaps across territories, and formulate more targeted public policy recommendations.

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Conclusion

Analysis of the technical efficiency of curative healthcare in Morocco was conducted over the timeframe of 2000–2023 with the use of a Cobb-Douglas stochastic frontier model. In addition to a descriptive analysis of healthcare capacity expansion through an increase in the number of curative consultations, health workers and healthcare facilities, the results showed that the production of curative consultations was significantly associated with the number of nurses and the number of primary care facilities, while hospital-related variables had no significant correlation with the delivery of outpatient services.

Moroccan healthcare functioned at peak operational levels for nearly all of the observed time periods in terms of their production processes. The average efficiency score across all measured indicators was extremely high. The gamma parameter showed that residual variation was largely due to randomness rather than technical inefficiencies, which indicates that, at a national aggregate level, variation in healthcare output can be explained primarily by observable inputs and exogenous shocks as opposed to persisting inefficiencies. However, some evidence exists regarding resource allocation and organisational mismatch within the overall healthcare delivery systems, such as an inverse relationship between physician use/number and some infrastructure variables, where little or no significant effect has been established between those variables and total output of the healthcare system.

The findings point to an increased need for improved primary healthcare, greater geographic and functional distribution of the workforce, and improved coordination between outpatient and inpatient settings from a policy perspective. Policymakers should focus on resource quality, rather than solely on increasing resource quantity, efficiency in organizing resources, and complementarity between various levels of care when developing health sector policies. To assist with future health sector reform initiatives in Morocco, researchers should use disaggregated panel datasets at the facility or regional level to identify and measure gaps in efficiency within the primary healthcare system, identify significant variations in resource access across geographic areas as well as develop more specific and accurate recommendations for health sector reform.

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