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Effects of healthcare financing policy tools on health system efficiency: Evidence from sub-Saharan Africa

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ABSTRACT

Background: Evidence shows high levels of catastrophic and impoverishing healthcare expenditure among households in sub-Saharan Africa (SSA). The way healthcare is financed has an impact on how well a health system performs its functions and achieves its objectives. This study aims to examine the effect of healthcare financing policy tools on health system efficiency.
Method: The study classifies 46 sub-Saharan African (SSA) countries into four groups of health systems sharing similar healthcare financing strategies. A two-stage and one-stage stochastic frontier analysis (SFA) and Tobit regression techniques were employed to assess the impact of healthcare financing policy variables on health system efficiency. Data from the selected 46 SSA countries from 2000 to 2019 was investigated.
Results: The results revealed that prepayment healthcare financing arrangements, social health insurance, mixed- and external-financing healthcare systems significantly enhance health system efficiency. Reliance on a single source for financing healthcare, particularly private out-of-pocket payment reduces health system efficiency.
Conclusion: For policy-making purposes, health care systems financed through a mix of financing arrangements comprising social health insurance, private, and public funding improve health system efficiency in delivering better health outcomes as opposed to depending on one major source of financing, particularly, private out-of-pocket payments.

1. Introduction

Many countries around the Sub-Saharan African (SSA) region have undertaken or are considering a fundamental restructuring of their healthcare financing systems to achieve better health outcomes [[1,2]]. The current wave of enthusiasm to secure universal health coverage (UHC), which is inspired by the United Nation's Sustainable Development Goal indicator 3.8, provides a unique opportunity for policymakers to make use of evidence-based academic research in designing the most efficient health systems. The World Health Organization's (WHO) member countries approved Resolution WHA58.33 in 2005, which called for the development of an effective health financing system to hasten the pace to achieve the UHC goal [[3]]. Additionally, in 2006, the 56th WHO Regional Committee for Africa passed Resolution AFR/RC56/10 urging Member States to implement or broaden prepayment schemes. These healthcare financing policy arrangements seek to raise enough money to guarantee access to necessary healthcare services without the risk of financial catastrophe.

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Many countries in the region have implemented or are in the process of implementing sustainable health financing strategies, such as national or social health insurance, community-based health insurance, tax-based financing, private voluntary, and micro health insurance schemes [1,4–6]. Still, other countries are grappling with healthcare financing systems dominated by regressive financing practices such as direct-user fee charges resulting in substantial out-of-pocket expenses [[7]].

Health care spending has increased in all SSA countries over the last two decades, from an average of $47 in 2000 to $125 in 2019. In 2017, health spending absorbed an average of about 6 % of GDP in SSA, ranging from a minimum of 2.5 % in DR Congo to a maximum of 10.9 % in Malawi [[8]]. The annual incidence of catastrophic health expenditure in SSA is estimated at 16.5 % for a threshold of 10 % of total household expenditure. After initially declining in the 2000s, there has been a steady rise in the incidence of catastrophic health expenditure in SSA between 2010 and 2020 [[9]]. Prepayment arrangements and other healthcare financing policies are designed to make health care affordable to all [[8]]. The impact of these policies on the efficiency of the health systems in delivering better health outcomes in SSA, however, has not received much attention in the empirical literature. The few existing health system efficiency studies in SSA focused on the impact of socio-economic and demographic factors on health system efficiency [10–12]. There is no empirical evidence on the effects of healthcare financing policy tools such as social health insurance on health system efficiency in SSA. This study seeks to fill this gap in the literature and examine the effect of healthcare financing policy tools on health system efficiency.

The remainder of this study is structured as follows: Section 2 describes the stochastic frontier methodology and the data used in this study. In Section 3, we discuss the results obtained from the estimations. Section 4 provides concluding observations and policy implications.

2. Methods and materials

2.1. Stochastic frontier analysis

A stochastic frontier analysis (SFA) methodological framework is adopted in this study. The stochastic frontier analysis is an econometric technique that is commonly used in the literature to estimate the potential maximum output level (frontier) given resources (inputs) used. A deviation of the actual output from the estimated potential maximum, after accounting for a random variation, is computed as the level of inefficiency in production. In health production, efficiency is defined as the ratio of the actual health outcome achieved to the potential maximum that could be achieved given the resources used [[13]].

The stochastic frontier analysis (SFA) was developed simultaneously by Aigner et al. [[14]] and Meeusen and van den Broeck [[15]] and has since been applied in a wide range of fields to evaluate the efficiency of decision-making units [[16]]. The SFA framework is used in most studies of health care efficiency, and it models healthcare outcomes as the output of a health production function while considering healthcare inputs, such as healthcare spending and demographic and economic factors that affect population health.

The main alternative to the SFA method is the nonparametric data envelopment analysis (DEA) framework. All observed data points must fall below the frontier because the DEA is a deterministic production frontier approach, and any departures from the frontier are attributed to inefficiency. Thus, the DEA method fails to capture random noise such as measurement errors, unobservable individual characteristics, or macroeconomic level shocks that impact each DMUs differently. All deviations from the estimated frontier are interpreted as being due to inefficiency. This makes the DEA approach to efficiency estimation less attractive, albeit recent development in the DEA minimizes this problem (see [[17]]). The decision to use the SFA approach in the current study is motivated by its ability to distinguish between the stochastic random noises from the inefficiency component of the deviations from the production frontier.

Greene [[18]] introduced the true fixed effect (TFE) model to relax the restriction of a common constant for all DMUs by incorporating several firm-specific dummy variables to distinguish between unobserved heterogeneity and inefficiency. The major challenge with the TFE model is that the inclusion of several country-specific dummies to capture unobserved heterogeneity has the potential to cause over-specification of the model. In resolving this problem, Greene [[18]] further proposed the true random effects (TRE) model by introducing time-invariant and country-specific heterogeneity through the use of simulated maximum likelihood estimation techniques. This study employs all the four time-varying stochastic frontier models for panel data – Kumbhakar [[19]], Battese and Coelli [[20]], Greene's [[18]] true fixed effect (TFE), and true random effect (TRE) – to estimate the health system efficiency of the 46 selected SSA countries and conduct comparative analysis of the efficiency estimates.

The stochastic frontier analysis requires the specification of a production model to capture the relationship between inputs and outputs. Different production models that are usually used in the production literature include: Cobb-Douglas, constant elasticity of substitution (CES), translog, generalized Leontief, normalized quadratic functions and their variants. The Cobb-Douglas specification and the more flexible translog function are the two most commonly utilized functional forms in empirical production literature, including frontier studies. The translog framework has the advantage of being more flexible to accommodate a number of production functional forms without the need for their a priori specification [[16]]. Its major shortcoming is the need to have a large degree of freedom, where the more restricted Cobb-Douglas framework comes in handy since it is more parsimonious in its demand on data. In this paper, the log-linear Cobb-Douglas model is adopted to specify the production relationship between health outcomes and health-system inputs. The choice of the Cobb-Douglas production functional form is motivated by its parsimony and the fact that it has been generally accepted as sufficient for stochastic production functions [11,16,21].

At the macro level, the stochastic production frontier model can be expressed as in Equation (1).

$$y_{it} = \beta' x_{it} + \varphi' c_{it} + v_{it} - u_{it} \quad [1]$$

$$v_{it} \sim N\left[0, \sigma_v^2\right]$$

$$u_{it} \sim N^+\left[0, \sigma_u^2\right]$$

$$\lambda = \frac{\sigma_u}{\sigma_v}$$

where $\boldsymbol{y_{it}}$ is a vector of health outcomes; $\boldsymbol{x_{it}}$ is the vector of health resources; $\boldsymbol{c_{it}}$ is the vector of non-health systems factors that influence the health of the population; v_{it} is the random symmetric component of the deviation which accounts for the idiosyncratic statistical noise; u_{it} denotes a nonsymmetrical deviation component which represents the inefficiency [[22]]; and λ (Lambda) is an asymmetry term which provides an indication of the relative contribution of u and v to the composite error term ($\varepsilon = u + v$). The higher the λ the higher the contribution of σ_u to the error term (ε) relative to the σ_v, an indication that the use of the stochastic production frontier model is justified. We estimated the efficiency scores using Jondrow et al. [[23]] with the JLMS estimator, as defined by Greene [[18]]. Jondrow et al. [[23]] (JLMS) proposed the first method of estimating the inefficiency (u_i) or efficiency (exp ($-u_i$)) of a DMU based on the composite error term of the model ($\varepsilon_i = u_i + v_i$). The conditional mean of u_i given ε_i gives a point estimate of u_i. Greene [[18]] extended the JLMS model by using a group mean residual as a modification in a panel data framework.

2.2. Tobit model

In order to assess the effects of health-system financing policy factors on health system efficiency, a two-stage technique is used in this study. Two-stage models are appropriate since healthcare financing policy factors influence each health system's outcomes [24–26]. In the first stage, as explained in the above section, the SFA is used to estimate the technical efficiency scores for the health systems. Then in the second stage, a regression model is specified to assess the technical efficiency effects. That is, the estimated technical efficiency scores for the health systems are regressed against the observable exogenous variables [[27]], which in this study are the healthcare financing policy variables. A censored regression technique, the Tobit model, is considered a suitable tool to employ since the efficiency scores are censored between 0 and 1 [[28]]. Thus, the Tobit regression model is specified as in Equation [2].

$$\theta_{it} = z_{it}\delta + \varepsilon_{it} \quad [2]$$

where θ_{it} denotes the technical efficiency score for country i observed at time period t, z_{it} is the vector of healthcare financing policy variables, δ represents the vector of parameters to be estimated, and ε_{it} is the error term. The two-stage approach requires that the explanatory variables in Equation [2] and the regressors (i.e. inputs) in Equation [1] are uncorrelated [19,26,27]. A violation of this assumption implies that estimates of β, σ_u, and, σ_v are biased due to the omission of z_{it} from the production function. In this paper, we adopted the two-stage approach because of the low correlation between the input variables in Equation (1) and the healthcare financing policy variables in Equation (2) (see **Appendix A1** for correlation matrix involving all the variables used in this study).

Other efficiency studies adopt a one-stage approach to examine the impact of environmental variables on the efficiency of decision-making units [[29]] so that estimation of the efficiency scores as in Equation (1) and of the parameters of the exogenous variables as in Equation (2) is carried out simultaneously by maximum likelihood estimation (MLE). This is achieved when the truncated-normal distribution of u_{it} is specified in Equation (1) [[20]].

2.3. Empirical strategy

From Equation [1], a stochastic health production function is specified as in Equation (3) for the empirical analysis, where *ln* is the natural logarithm, i and t index countries and time periods, respectively, β and φ denote the vector of coefficients of the health-system inputs and control variables, respectively. Infant survival rate per thousand live births (*ISR*) is used to represent the health outcome of the health system. Health expenditure per capita (*HEPC*) and the square of health expenditure per capita (*HEPCSQ*) are used as the healthcare system inputs. A couple of factors external to the health system but affect the health of the population are controlled for in the model. These are employment (*EMP*), education (*EDU*), and age structure (*AGE*). In order to control for any potential heteroscedasticity or autocorrelation present in the data, a cluster robust standard error estimation approach was used.

$$ln\ ISR_{it} = \alpha_0 + \beta_1 lnHEPC_{it} + \beta_2 lnHEPCSQ_{it} + \varphi_1\ ln\ EMP_{it} + \varphi_2\ ln\ EDU_{it} + \varphi_3 lnAGE_{it} + v_{it} - u_{it} \quad [3]$$

From Equation (2), the empirical Tobit model is specified in Equation (4) to assess the impact of healthcare financing policy variables on health system efficiency. The healthcare financing policy variables which are used as explanatory variables in the efficiency function are compulsory health financing arrangements (*CFA*) funds as a proportion of total health expenditure, domestic general government health expenditure per capita (*GGHE*), out-of-pocket health expenditure per capita (*OOP*), a binary variable that indicates the existence of social health insurance (*SHI*), a categorical variable that describes the predominant source of funding healthcare (*FTYP*) – private, public, external, and mixed (*PRI*, *PUB*, *EXT*, and *MIX*, respectively).

$$\theta_{it} = \delta_0 + \delta_1 lnCFA_{it} + \delta_2 lnGGHE_{it} + \delta_3 lnOOP_{it} + \delta_4 SHI_i + \delta_5 FTYP_i + \varepsilon_{it} \quad [4]$$

in Equation (4), three financing policy variables (*CFA*, *GGHE* and *OOP*) are highly correlated to each other (see **Appendix A1**). To prevent the potential problem of spurious regression results, we estimated three models to which each of these three variables are added one after the other.

Sensitivity analyses are conducted to assess the robustness of the empirical results via one-stage SFA where the parameters of both the production function and the inefficiency function are estimated simultaneously employing the Battese and Coelli [[20]] SFA model. In this setting, since the parameters (δ) show how the healthcare financing policy variables (z) influence the inefficiency term (u_{it}), a positive coefficient implies that the variable increases inefficiency while a negative coefficient shows an inverse relationship between the variable and the inefficiency term.

2.4. Definition of variables

Infant survival rate (ISR), a measure of population health, serves as the dependent variable in the stochastic health production model. Infant mortality rate measures the number of deaths that occur among children aged one year and below per 1000 live births in a country in a year. Infant mortality is considered as a sufficient summary measure of the overall health of the general population [[30, 31]]. Infant mortality rate (IMR) is viewed as an objective health outcome and has been widely used in health production and healthcare system efficiency studies [32–34]. Since the model adopted in this study assumes that outcome variables are isotonic (i.e. increased health outcome increases efficiency), the study follows Afonso and Aubyn [[35]], Hadad et al. [[36]], and Novignon & Lawanson [[11]] to transform the IMR to infant survival rate $\left[ISR = \frac{1000-IMR}{IMR}\right]$ which can be interpreted as the proportion of children aged one year or below who survive as compared to those who died [[34]]. A higher value of ISR indicates better health status.

Following previous studies [11,33,34,37–39], health expenditure per capita (HEPC) is used in this study as the input to the health production function. HEPC is a proxy for the quantity of healthcare services consumed per person [[40]]. Since variations in expenditures across countries better reflect differences in quantity and quality of healthcare services, Andersen [[39]] argues that HEPC is more appropriate than the use of stocks of providers such as the number of physicians, nurses, and beds. HEPC captures the final consumption of health care goods and services including personal health care (curative, rehabilitative, long-term, ancillary services, and medical goods) as well as collective services (public health services and health administration). It is relatively comparable between countries because it is measured in international dollars at purchasing power parity (PPP) rate. Countries with higher levels of healthcare services use are expected to have better health outcomes. Hence, the expected sign of HEPC is positive. The squared term of HEPC captures the non-linear relationship between the HEPC (i.e. health input) and the infant survival rate (i.e. health outcome). It is used to determine whether or not the input variable has a diminishing marginal effect on the outcome variable.

Evidence demonstrates that economic and social factors outside the control of the health system can affect a country's capacity to maximize the impact of a given health spending on its health system's outcomes [25,33,34,36]. To isolate the effect of health spending (HEPC), three socio-economic factors are controlled for in the models: employment (economic factor), education (social factor), and population age structure (demographic factor).

In most studies, income (proxied by GDP per capita) and consumption are used to measure the impact of economic well-being on population health [40–42]. But in the sample, HEPC and these variables had a strong association (pairwise correlation coefficients ranging between 0.820 and 0.903, $p < 0.01$). This suggests that these variables only provide a small amount of information to the models. For these reasons, they have not been included in the analysis.

Therefore, employment (EMP) is used as a proxy for aggregate economic well-being [[11,43]]. Employment is measured as the number of persons aged 15 years and older who are engaged in employment as a share of the total population. Employment status predicts the overall economic well-being of a person [[41]]. While there is a strong evidence of an association between unemployment and poorer health outcomes [44–46], the relationship between employment status and health status has been mixed, with some studies showing positive effect of employment on health [[47]], yet others show no relationship or negative effect [[48]]. Thus, the a priori sign of employment (EMP) is either positive or negative.

The term "level of education" (EDU) refers to the sum of the predicted years of schooling for children and the mean years of schooling for adults, both given as an index and scaled with the corresponding maxima. With higher wages and more stable work as a result of education, families are better able to afford quality healthcare [[49]]. Additionally, studies show that adults who are less educated are more likely to engage in unhealthy practices such as smoking, eating unwholesome diet, and failing to exercise [12,50, 51] found a strong association between education and health system efficiency in producing better health outcomes. Therefore, education (EDU) is expected to have a positive sign.

Population age structure (AGE) is the proportion of the population aged 65 and above. The a priori expectation sign of AGE is largely dependent on the outcome variable. For instance, since health deteriorates with age [[38]], it postulates a negative relationship between AGE and health outcomes such as healthy life expectancy. However, the relationship between AGE and infant survival rate is not direct. On the one hand, countries with a higher proportion of older adults may have better healthcare systems and social support structures, which could benefit infants and improve their chances of survival. On the other hand, a high proportion of older adults in a population may also indicate a demographic shift towards an aging population, which can strain health care and social support systems and potentially negatively impact infant survival rates.

Therefore, the expected sign of AGE can be negative or positive.

Health financing policy variables and characteristics were identified through extensive literature review [21,33,34,37–39] and through a review of the World Health Organization's Global Health Expenditure Database (WHO-GHED). We used compulsory financing arrangement (CFA), domestic general government health expenditure per capita (GGHE), and out-of-pocket health expenditure (OOP). These three time-variant variables were selected based on health financing policy reforms that have taken place in some countries across the SSA region over the last twenty years (from 2000 to 2020) to assess their effects on the efficiency of health systems. GGHE and OOP reflect the prioritization of health in government spending [[52]] while CFA is used as a proxy for pre-payment financing reforms. CFA is the sum of three main sources of healthcare finance1: (i) government health prepayment financing schemes; (ii) compulsory contributory health insurance schemes (i.e. social health insurance and compulsory private health insurance schemes); and (iii) compulsory medical saving accounts (SHA, 2011).

Table 1
Healthcare financing system characteristics[A].

Country	GGHE-D	PVT-D	EXT	HFST	SHI
Angola	52.3	45.1	2.7	Public	No
Benin	23.7	52.0	24.3	Private	Yes
Botswana	62.6	27.7	9.7	Public	No
Burkina Faso	33.0	38.8	28.3	Mixed	Yes
Burundi	26.2	48.3	25.6	Mixed	Yes
Cabo Verde	66.6	26.9	6.5	Public	Yes
Cameroon	14.1	79.0	6.9	Private	No
Central African Rep.	21.0	54.2	24.8	Private	No
Chad	24.7	64.3	11.1	Private	No
Comoros	11.9	77.0	11.1	Private	Yes[a]
Congo (Republic)	37.0	48.4	14.6	Mixed	No
Congo (Dem. Rep.)	9.3	58.5	32.2	Private	Yes[b]
Côte d'Ivoire	16.6	72.9	10.6	Private	Yes
Djibouti	51.3	33.4	15.3	Public	Yes
Equatorial Guinea	19.3	77.2	3.4	Private	Yes
Eswatini (Kingdom of)	46.3	29.4	24.3	Mixed	No
Ethiopia	27.3	45.3	27.4	Mixed	No
Gabon	50.1	48.4	1.4	Public	Yes
Gambia	18.7	20.6	60.7	External	No
Ghana	38.8	47.8	13.4	Mixed	Yes[c]
Guinea	10.8	67.6	21.7	Private	Yes
Guinea-Bissau	22.8	50.5	26.7	Private	No
Kenya	32.8	46.0	21.2	Mixed	Yes
Lesotho	54.4	24.2	21.4	Public	No
Liberia	12.5	62.1	25.4	Private	No
Madagascar	38.5	39.5	22.0	Mixed	No
Malawi	26.3	17.0	56.8	External	No
Mali	22.7	52.3	25.0	Private	Yes
Mauritania	29.0	64.6	6.4	Private	Yes[d]
Mauritius	45.6	53.5	0.9	Private	No
Mozambique	29.6	17.3	53.1	External	No
Namibia	45.6	43.5	10.9	Mixed	No
Niger	27.9	59.7	12.5	Private	Yes
Nigeria	17.9	73.7	8.4	Private	Yes[e]
Rwanda	27.4	26.4	46.2	Mixed	Yes
Sao Tome and Principe	34.1	26.1	39.7	Mixed	Yes[f]
Senegal	32.3	57.8	9.9	Private	Yes
Seychelles	71.1	27.6	1.3	Public	No
Sierra Leone	12.5	64.3	23.2	Private	No
South Africa	48.2	47.2	4.6	Mixed	No
Sudan	29.9	66.8	3.3	Private	Yes
Zambia	34.0	31.4	34.7	Mixed	No
Zimbabwe	26.1	49.9	24.0	Mixed	No

GGHE-D = Domestic General Government Health Expenditure as a percentage of Current Health Expenditure; PVT-D = Domestic Private Health Expenditure as a percentage of Current Health Expenditure; EXT = External Health Expenditure as a percentage of Current Health Expenditure; HFST = Healthcare Financing System Type; SHI = Social Health Insurance.

[A]The healthcare financing characteristics were assessed solely based on data in World Health Organization's Global Health Expenditure Database (GHED). Twenty-year (from 2000 to 2019) averages of the three sources of financing healthcare (*Public*, *Private*, and *External*) were computed for each health system and the source that predominated (i.e. provided 50 % or more) was used to characterize the health system. If none of the three sources predominated (i.e. each source provided less than 50 %) the health system is characterized as *Mixed*. With regard to Social Health Insurance (SHI), '*Yes*' under SHI for a country means that the country had Social Health Insurance as one of the healthcare financing policy tools while '*No*' indicated otherwise.

[a] Since 2012.
[b] Since 2016.
[c] Since 2005.
[d] Since 2007.
[e] Since 2006.
[f] Since 2014.

Health financing systems in the SSA countries are complex institutional constructs that differ between countries. However, for the purpose of classifications it is necessary to reduce the complexity by focusing on the core financing part of each healthcare financing system. To this end, all the studied countries were classified into four types of health systems: public, private, external, and mixed based on which source of funding predominates healthcare financing (see Table 1 for details). According to Kutzin [[52]], health systems are classified by their predominant source of funding. Böhm et al. [[53]] classified 29 OECD countries into five healthcare systems based on which type of actors (state, private, etc.) dominate each core dimension (financing, regulation, and service provision) of the healthcare system. Similarly, Joumard et al. [[54]] classified OECD countries into six health system groups using 20 policy and institutional indicators.

Additionally, the health systems were characterized based on whether social health insurance (SHI) was one of the healthcare financing mechanisms in the country. Social health insurance (SHI) is the organizational mechanism for financing health care services based on risk pooling. SHI pools both the health risks of the insured on one hand, and the contributions of the individuals, enterprises, and the government on the other hand [[55]]. A statutory or national health insurance is SHI mandated by the government.

2.5. Data

The study sourced data from World Health Organization's Global Health Expenditure Database (WHO-GHED) and World Bank's World Development Indicators (WB-WDI) between 2000 and 2019 for 46 SSA countries with a total of 910 observations. The period and countries sampled for the analysis were based on availability of data. The definitions of variables used in the analysis and sources of data are presented on Table 2.

3. Empirical results and discussions

3.1. Descriptive statistics

Table 3 presents the descriptive summary statistics of the selected health outcome, input, control, and health financing policy variables. The results show that on the average infant mortality rate in SSA, between 2000 and 2019, is approximately 60 for every 1000 live births per year. Seychelles, Mauritius, Cabo Verde, and Botswana recorded the lowest values of infant mortality rate while Sierra Leone, Central Africa Republic, Liberia and Angola had the highest values. Infant mortality rate in SSA has decreased from an average of approximately 81 cases in 2000 to 45 cases in 2019 (see **Appendix A2**). Infant mortality rate ranged from a minimum of 11.8 deaths per thousand live births in Seychelles in 2005 to a maximum of 139.5 cases in Sierra Leone in 2000.

The average health expenditure per capita in the SSA, between 2000 and 2019, is $216.14 for all the 46 selected SSA countries in this study. The cross-country variations in the health expenditure per capita is quite dramatic, ranging from a minimum of $6.90 (DR Congo in 2000) to maximum of $1476 (Mauritius in 2019) with a standard deviation of $261. On the average, health expenditure per capita has more than doubled in the SSA, increasing from an approximate value of $134 in the year 2000 to $285 in 2019, registering over 110 % increase over the last two decades (see **Appendix A2**).

Education which is measured on the scale of 0–1 is averaged 0.42 in the SSA while the average of proportion of the population in employment is approximately 36 %, indicating a high dependency ratio across the SSA countries. The age structure of the population shows that an average of just 3.3 % of the total population are 65 years and above, an indication of a very youthful population in SSA.

Table 2
Definitions of variables and data sources.

#	Variable	Definition	Data Source
Health Production Function Variables			
1.	Infant Survival Rate	The proportion of children who survive up to age one per 1000 live births. It is computed from infant mortality rate which measures the proportion of children who die before age one per 1000 live births.	WB-WDI
2.	Health Expenditure per capita (HEPC)	HEPC measures the final consumption of health care goods and services including personal health care (curative, rehabilitative, long-term, ancillary services, and medical goods) and collective services (public health services and health administration). It is measured in international dollars at purchasing power parity (PPP) rate.	WHO-GHED
3.	Employment	Number of persons aged 15 years and above who are engaged in employment as share of the total population.	Penn World Table
4.	Educational Level	Average of mean years of schooling of adults and expected years of schooling of children, both expressed as an index obtained by scaling with the corresponding maxima.	UNDP
5.	Population age structure	The proportion of the population aged 65 years and above.	WB-WDI
Health Financing Policy Variables			
6.	Compulsory health financing	Compulsory financing arrangements as a percentage of total health spending.	WHO-GHED
7.	General government health spending	Domestic general government health expenditure as a percentage of total health spending.	WHO-GHED
8.	Out-of-pocket health expenditure	Health expenditure through out-of-pocket payments measured as a percentage of total health spending.	WHO-GHED

Notes: WHO-GHED = World Health Organization's Global Health Expenditure Database; WB-WDI = World Bank's World Development Indicators; THE = Total health expenditure. [1]Source: WHO-GHED 2021 update based on System of Health Accounts (SHA 2011) methodology.

Table 3
Descriptive summary statistics of variables (2000–2019).

Variable	Obs.	Mean	SD	Min.	Max.
Health Production Function					
Infant mortality (per 1000 live births)	910	60.09	24.33	11.80	139.5
Total health expenditure per capita ($ PPP)	910	216.14	261.45	6.90	1476.0
Employment (% of population)	910	35.87	7.03	22.43	55.45
Educational Level	910	0.42	0.13	0.12	0.74
Aged Population (% of population)	910	3.27	1.21	1.87	12.00
Health Financing variables – time-varying					
Compulsory health financing (% of THE)	910	40.78	16.67	4.50	82.90
Government health spending (% of THE)	910	31.58	16.80	3.40	82.10
Out-of-pocket health spending (% of THE)	910	40.45	20.92	3.00	84.20
Health Financing variables – time-invariant					
Health system financing type: External	60	3 countries			
Mixed	310	16 countries			
Private	400	20 countries			
Public	140	7 countries			
Social health insurance: Yes	400	23 countries			
No	510	23 countries			

Note: PPP is purchasing power rate; THE is total health expenditure.

On the broader healthcare financing typologies, public health systems spent $410 per person per year, which is about 4.9 times that of *external*ly-funded health systems and 2.6 times of *private* health systems (see **Appendix A3**). While 63.3 % of healthcare spending comes from prepayment arrangements in *public* health systems, just 28.9 % of healthcare expenditure of *private* health systems are financed through prepayment arrangements. It also worth noting that out-of-pocket payment constituted as much as 59.15 % of healthcare expenditure of *private* health systems.

3.2. Estimated stochastic frontiers

We selected four time-varying specifications (i.e. Kumbhakar [[19]], Battese and Coelli [[20]], true fixed effects, and true random effects (Greene [[18]]) to estimate the stochastic production frontiers. The parameters were estimated by the maximum likelihood estimation technique. Table 4 reports the results.

The first segment of Table 4 presents the frontier functions for the four models, while the second segment presents the variance decomposition (σ_u σ_v λ θ). The signs of all the estimated coefficients in the production function across the four models are consistent with theory. The statistically significant positive effect of per capita health spending indicates that it is an important determinant of a country's health production outcome. The coefficient of the quadratic term of the per capita health care expenditure is also statistically significant, indicating that the elasticity of ISR with respect to per capita health care expenditure diminishes as the level of per capita

Table 4
Estimated stochastic frontier models (dependent variable: Infant survival rate).

Variable	Kumbhakar (1990)	Battese and Collie (1995)	True Fixed Effects	True Random Effects
Production function				
Health spending	0.0360***	0.0594***	1.7493***	0.0289***
	(0.0109)	(0.0108)	(0.6481)	(0.00573)
Health spending squared	−0.00339***	−0.00482***	−0.1711***	−0.00245***
	(0.000998)	(0.00114)	(0.0638)	(0.000546)
Education	0.0173	0.0211***	−0.1794	0.0584***
	(0.0128)	(0.00582)	(0.11532)	(0.00343)
Employment		0.0271***	0.7684**	0.0446***
		(0.00707)	(0.35816)	(0.00345)
Share of population aged 65+		0.0108	0.0346	−0.0231***
		(0.00666)	(0.0690)	(0.00357)
Constant	6.832***	6.603***	NA	6.680***
	(0.0305)	(0.0395)		(0.0231)
Model parameters				
Sigma u (σ_u)	0.167***	1.515**	2.225***	0.006***
	(0.0383)	(0.8398)	(0.4358)	(0.0009)
Sigma v (σ_v)	0.005***	0.008***	0.091***	0.002***
	(0.0005)	(0.0018)	(0.0072)	(0.0006)
Lambda (λ)	33.95***	189.16***	24.33***	2.570***
	(0.0381)	(0.8393)	(0.6743)	(0.0013)
Theta (θ)	N/A	N/A	N/A	−0.038***
				(0.0015)

Clustered robust standard errors in parentheses; ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

health care expenditure rises. These results are similar to the findings of many other studies [21,37,56–58], but contradict the findings of other studies [59–61].

The significantly positive coefficients of employment and education, as indicators of the overall economic well-being and social factor, respectively, are as expected and in line with Self and Grabowski [[59]] and Ambapour [[12]]. The negative impact of population age structure (in the TRE model) is consistent with previous studies (see Refs. [38,39,62]). This result supports the proposition that older people are higher users of healthcare service which strains healthcare and negatively impact infant survival rates.

The consistency of results in terms of signs and values of the estimated parameters across the four models points to the reliability of the technical efficiency scores generated from each of the four specifications. In order to deal with any potential heteroscedasticity or autocorrelation present in the data, a cluster robust standard error estimation approach was used. It is worth noting that the estimate of λ was statistically significant for all the models, justifying the use of the SFA methodology in this study and the existence of technical inefficiency in the dataset. The value of λ is smallest for the TRE model and highest for the Battese and Coelli and Kumbhakar models. Theta (θ) which represents the component of the variance introduced in the TRE model to control unobserved heterogeneity among the cross-sectional units was statistically significant at 1 % level. This gives an indication that the TRE model was able to disentangle the time-invariant unobserved heterogeneity from inefficiency (u_i).

3.3. Estimated technical efficiency scores

Using the JLMS estimator developed by Jondrow et al. [[23]] as described by Greene [[18]], we calculated the technical efficiency of each health system for the four time-varying models. Based on the average of the estimated efficiency scores from the four models, we ranked each of the 46 SSA nations in the sample. In **Appendix A4**, a summary of the estimated technical efficiency scores and ranks is provided.

From Table 5, the average estimated health system technical efficiency ranges from a minimum of 0.854 (Kumbhakar Model) to a maximum of 0.988 (TRE Model) across the four models. The average of the four models was estimated at 0.942.

The results from **Appendix A4** further show that the average health system efficiency scores and rankings vary across countries. Mauritius, Seychelles, Cape Verde, and Botswana were the top four performers while Liberia, Nigeria, Equatorial Guinea, Angola, and Sierra Leone were among the worst performing countries.

3.4. Healthcare financing policy tools and health system efficiency

In the second-stage, the study examined the effects of health care financing policy variables on health system efficiency by using the technical efficiency scores generated from the Battese and Coelli stochastic frontier model as the dependent variable in the Tobit regression analysis. The choice of the efficiency scores from Battese and Coelli was informed by two major reasons: (i) it has the highest statistically significant λ among the four models used to estimate the efficiency scores (see Table 4); and (ii) it permits us to undertake robustness checks in a one-stage approach where the inefficiency component is modeled as a function of the health care financing policy variables to aid comparison. The outcomes of censored Tobit regression are presented in Table 6.

The findings as shown in Table 6 indicate that health financing types significantly affect the efficiency of health systems. In this regard, the *private* financing type was used as a reference category in the analysis. The results show that *external* and *mixed* financing health systems have positive and statistically significant coefficients across all the three models. This implies that the *external* and *mixed* healthcare financing types perform better in comparison with the *private* financing type in improving health system efficiency. Further analysis of the data shows that the *private* financing health system type had the worst health outcome (an average of 72.14 infant mortality cases per year) compared with the *external* (59.88 cases per year) and *mixed* (50.94 cases per year) financing types (see **Appendix A3**). ANOVA test results indicated that the differences were statistically significant at a 1 % level ($F(3, 906) = [43.79], p = 0.0001$). Also, it is worth noting that out-of-pocket payments on average constitute 59.15 % of the total health expenditure of *private* financing health systems in SSA. These results support other previous empirical studies, which suggest that health care systems that rely heavily on out-of-pocket payments are least efficient [[63,64]].

In the Model 1, the coefficient of *public* financing health system type is negative and statistically significant. The results show that, compared to private financing health systems, public financing health systems were less likely to be efficient. These results suggest that there is poor governance for the utilization of public health resources in some countries in SSA. If there is high prevalence of corruption, public sector resources earmarked for healthcare are used inefficiently, leading to poor health outcomes [[64]]. These results give credence to the findings that indicate that public resources dedicated to the health sector in SSA are inefficiently utilized [[65]]. Indeed, *public* health systems spent an average of $410 per person per year, which is about 2.6 times of *private* health systems (see

Table 5
Summary average efficiency scores (2000–2019).

Model	Mean	Std. Dev.	Minimum	Maximum
Kumbhakar	0.854	0.0436	0.7415	0.9581
Battese & Coelli	0.982	0.0156	0.9081	0.9976
TFE	0.944	0.0313	0.7512	0.9913
TRE	0.988	0.0113	0.9349	0.9990

Table 6
Results of Tobit regression with efficiency as dependent variable.

VARIABLES	Model 1	Model 2	Model 3
Reference: Social health insurance = No			
Social health insurance = Yes	0.00673***	0.00785***	0.00761***
	(0.000942)	(0.000961)	(0.000964)
Reference: Private			
External	0.0139***	0.0189***	0.0165***
	(0.00202)	(0.00199)	(0.00232)
Mixed	0.00909***	0.0128***	0.0134***
	(0.00121)	(0.00111)	(0.00112)
Public	−0.00378**	0.00131	0.00458
	(0.00170)	(0.00165)	(0.00537)
Compulsory financing arrangements	0.00959***		
	(0.00124)		
Government health spending		0.00147***	
		(0.000429)	
Out-of-pocket payment			−0.00104*
			(0.000603)
Constant	0.941***	0.968***	0.977***
	(0.00409)	(0.00156)	(0.00263)
Observations	910	910	910
Number of countries	46	46	46
Log pseudo-likelihood	2629.08	2605.92	2601.58
F(5, 905)	51.00***	54.38***	52.13***

Standard errors in parentheses; ***p < 0.01, **p < 0.05, *p < 0.1.

Appendix A3).

Another possible source of inefficiency associated with public health financing might be as a result of a phemenon widely described as a 'Baumol's disease'. In health economics, health systems that have large decreasing returns (converging to 0) of public healthcare expenditure on health outcomes, such that large health expenditures have limited impact on health status of the population, are described as suffering from 'Baumol's disease' [[66]]. This phenomenon usually comes about when increases in public healthcare expenditures are largely taken up by expensive healthcare services and products which benefit small sub-populations to the detriment of services and products that produce both huge positive externalities and induced increasing returns such as vaccinations against childhood diseases.

The conclusions of some previous studies are partially supported by these results [[67]], though they contradict a priori expectations and previous empirical studies [[68,69]]. In contrast to more fragmented mixed and private financing systems, public-dominated healthcare financing systems are Beveridge-style single-payer tax-funded systems that rely on a small number of revenue sources, financing is concentrated, and private insurance for medical services is limited [[21,68]]. In theory, single-payer systems should have the advantages of lowering administrative costs, a monopsony power that controls provider costs, and limiting consumer choices to control resources devoted to health care [[68,70]]. However, single-payer systems may suffer from low access to healthcare services [[71]] and inefficient utilization of healthcare resources due to poor governance [[56,65]].

The results from Table 6 indicate that, with a given level of health expenditure, countries that offer social health insurance schemes, as compared those that offer alternative schemes, perform better in improving their health system efficiency to achieve better health outcomes. This evidence is pervasive across all the three models. Indeed, further analyses of the data (see **Appendix A5**) reveal that countries with SHI spent far less ($M = \$156, SE = 6.61$) in per capita terms than countries without SHI ($M = \$263, SE = 14.23$), and the difference was statistically significant at 1 % level [$t(908) = 6.26, p < 0.01$]. Nevertheless, health outcomes (measured in terms of infant mortality rate) in countries that adopted SHI to finance healthcare services is better ($M = 59.71, SE = 0.99$) than in those without SHI ($M = 60.39, SE = 1.21$). These results are consistent with previous empirical and theoretical studies [72–74] and thus serve as cross-validation of the previous results. For instance, Green et al. [[72]] noted that SHI improves efficiency of the healthcare system and assists patients to obtain primary health care at less cost. Social health insurance pools both healthcare funds and health risks which enhance cross-subsidization of healthcare costs and thus promote health system efficiency in achieving better health outcomes [[74]].

Furthermore, given that the compulsory financing arrangement has a positive and significant coefficient, more people having prepaid health coverage will result in a more efficient healthcare system. This finding coincides with a priori expectations and the results obtained by Wranik [[21]] and Gerdtham et al. [[75]] who found that health systems that offer insurance coverage to the larger percentage of the population are more efficient. In fact, the data used in this study shows a fairly strong statistically significant correlation ($r = -0.724, p < 0.01$) between percentage of the population in compulsory financing schemes and out-of-pocket payment as percentage of total health expenditure. This suggests that government-subsidized or privately-funded insurance coverage provides financial protection against out-of-pocket payments for the insured and improves the efficiency of health systems in SSA to deliver better health outcomes.

General government health financing significantly has a positive association with efficiency of health systems (see Table 6). This implies that investment by governments in the health sector improves the efficiency of health systems in SSA. In previous studies, government health expenditure was found to have positive association [75–77], negative association [64,65,78], and no association [57,59,69,79] with health system performance. The positive impact of government health expenditure on efficiency favors the Abuja proposition that governments in Africa should invest at least 15 % of their budget in health.

The coefficient of out-of-pocket payment is negative and statistically significant. This implies that out-of-pocket payments for healthcare reduce health system efficiency in SSA. This finding suggests the need for policymakers to design and implement healthcare financing schemes that have the potential to reduce out-pocket-payment to the barest minimum. The negative effect of out-of-pocket payment on health system efficiency is consistent with several past studies [[33,80]]. However, Ogloblin [[63]] found a positive relationship between out-of-pocket spending and health system efficiency, perhaps because out-of-pocket spending constituted a relatively small proportion of total health expenditure in the sample used in the study (which excluded all low-income and war-torn countries).

When one-step stochastic frontier analysis is used, as proposed by Battese and Coelli [[20]], to analyze the sensitivity of the empirical findings, where the production function and inefficiency effects are concurrently evaluated, similar results are obtained (see Table 7). Since the inefficiency scores are used as dependent variable, a negative coefficient of a variable implies that the variable has a negative effect on inefficiency. In other words, an increase in the value of the variable leads to a decrease in the inefficiency score, which is desirable as it indicates that the firm is operating closer to the production frontier.

4. Conclusion and policy implications

In the past two decades, there has been wave of healthcare financing reforms across most countries in the SSA region. This paper

Table 7
One-step results of health production and inefficiency component.

Variables	Model 1	Model 2	Model 3
Health production function			
Health spending	0.0625***	0.0630***	0.0639***
	(0.00405)	(0.00404)	(0.00390)
Health spending squared	−0.00521***	−0.00530***	−0.00526***
	(0.000396)	(0.000396)	(0.000391)
Employment	0.0254***	0.0260***	0.0275***
	(0.00235)	(0.00229)	(0.00225)
Education	0.0209***	0.0205***	0.0195***
	(0.00176)	(0.00179)	(0.00175)
Share of population aged 65+	0.0163***	0.0176***	0.0160***
	(0.00208)	(0.00213)	(0.00223)
Constant	6.596***	6.591***	6.579***
	(0.0159)	(0.0154)	(0.0145)
Inefficiency function			
SHI (Reference: No SHI)	−0.0354***	−0.0547***	−0.0493***
	(0.00831)	(0.0134)	(0.0088)
External (Reference: Private)	−0.169*	−0.279***	−0.3554
	(0.0864)	(0.104)	(0.2346)
Mixed (Reference: Private)	−0.0875***	−0.190***	−0.2043***
	(0.0261)	(0.0538)	(0.0783)
Public (Reference: Private)	0.0102	−0.00517	−0.0228
	(0.00742)	(0.0123)	(0.0886)
Compulsory health financing	−0.0299***		
	(0.00612)		
Government health spending		−0.00822**	
		(0.00360)	
Out-of-pocket health spending			0.0104**
			(0.00405)
Constant	0.117***	0.0248**	−0.0396**
	(0.0168)	(0.0119)	(0.0186)
Model parameters			
Sigma u (σ_u)	0.028***	0.038***	0.133**
	(0.0031)	(0.0046)	(0.0662)
Sigma v (σ_v)	0.009***	0.009***	0.010***
	(0.0006)	(0.0005)	(0.0005)
Lambda (λ)	3.238***	4.159***	13.704***
	(0.0031)	(0.0047)	(0.0663)
Observations	910	910	910
Number of countries	46	46	46
Log-likelihood	2569.76	2550.73	2541.52
Wald chi2	1584.75	1494.14	1748.80
Prob. > χ^2	0.0000	0.0000	0.0000

Robust standard errors in parentheses; **p < 0.01, **p < 0.05, *p < 0.1; SHI: Social Health Insurance.

examines the impact of these reforms on health system efficiency in improving health outcomes. The paper finds evidence that an increase in out-of-pocket payment is associated with decrease in health system efficiency and worsening health outcomes, but increase in compulsory healthcare financing coverage and general government health spending contribute positively in enhancing health system efficiency that results in improved health outcomes. Again, the findings of the paper show that healthcare financing structures influence efficiency of health systems. Health systems that are predominantly financed through public resources (i.e. state-funded health systems) are least efficient relative to the other three types – *external*, *private*, and *mixed*. The paper further provides evidence indicating that social health insurance coverage significantly improves health system efficiency and health outcomes.

This study provides additional policy-relavant analysis of healthcare financing arrangements that contribute to efficiency. The key policy implications of the results of this study are as follows. First, there is evidence that financing healthcare via social health insurance and other compulsory financing mechanisms improve health system efficiency. This finding is also supported in previous empirical and theoretical studies and thus serves as a cross-validation of the previous results. It emphasizes the importance of pooling of funds to finance healthcare.

Second, the evidence that predominantly state-funded healthcare systems are least efficient in the SSA calls for rigorous reappraisal of prioritization of health projects and programs that are undertaken by governments with the view to improve their performance on health outcomes. It also calls for policy designs that will reduce bereaucracy and corruption associated with publicly-funded healthcare programs and projects.

Finally, based on the sign and statistical significance of the healthcare financing system type, donor-funded health systems perform better in improving health system efficiency relative to publicly-funded healthcare systems in the SSA. This finding calls for seriuos retrospection of the consensus reached by members of the Harmonization for Health in Africa, made up of health and finance ministers in Africa, during the 61st session of WHO Regional Committee in Yamousokro, that donor sources of health financing should "only play a catalystic role, and the bulk of funding for health should be mobilized from domestic sources". However, based on this study, domestic sources of funding (at least the general government expenditure component) fails to improve health system efficiency as much as the donor sources of health financing does to significantly improve health outcomes in the SSA. This emphasizes on the earlier points of reappraisal of the prioritization of general government health expenditure and increasing the share of social health insurance in the domestic total health expenditure so that when donor source of health expenditure becomes erratic, the health systems in SSA would not suffer.

This paper, like any other research study, suffers from some limitations which provide opportunity for future studies to refine the outcomes of this current study. First, the empirical results from this study must be interpreted with caution since the stochastic frontier analysis framework was designed to measure association but not to establish causal relationships. Second, the method used to classify health systems is crude as it fails to account for the details and complexities of each healthcare system. It is, therefore, recommended that future studies explore additional features of health systems such as degree of centralization, gatekeeping and cost-sharing arrangements, and methods of payment to primary and specialist physicians.

Again, infant survival rate as the outcome variable of health systems might not be adequate to capture the total contribution of health systems in improving the status of quality of life. It is recommended that future studies explore other variables of health outcomes, such as healthy life expectancy at birth (HALE) and disability adjusted life expectancy (DALE), that measure preventable years lost to both death and to poor quality of life.

Further, limitation exists for availability of high quality data on hospital bed density (capital stock input), physicians density, and nurses and midwives density (labor stock input) for most SSA countries. This makes it difficult to estimate a stochastic frontier production function accurately. This challenge requires that researchers use healthcare expenditure per capita as the main healthare input variable. Future studies should explore the use of these healthcare inputs in the estimation of the SFA production function when high quality data become available.

Despite these limitations, this study presents valuable guiding evidence for policy-making purposes. Evidence from this study support extension of social health insurance and other forms of compulsory healthcare financing coverage and the need to reappraise the prioritization of domestic general government health expenditure.

Data availability statement

The dataset used in this study was obtained from World Health Organization's Global Health Expenditure Database (GHED) available online: https://apps.who.int/nha/database/Select/Indicators/en; World Bank's World Development Indicators (WDI) available online: https://databank.worldbank.org/source/world-development-indicators; and World Bank's Worldwide Governance Indicators (WGI) available online: https://databank.worldbank.org/source/worldwide-governance-indicators.

CRediT authorship contribution statement

Kwadwo Arhin: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Writing – original draft, Writing – review & editing. **Eric Fosu Oteng-Abayie:** Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Supervision, Writing – review & editing. **Jacob Novignon:** Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e20573.

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