Infrastructure and Health System Performance in Africa

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Empirical findings for the effect of infrastructure on health system performance and across a range of infrastructure types in Africa are not common. This is important for ascertaining the infrastructure with more influence on health systems. Findings in this regard are vital in Africa where health systems perform poorly, with fiscal challenges for public provision of health care needs. This paper examined the effect of infrastructure types on health system performance in Africa using data for 54 countries in the region and over the period 2003–2018. Health system performance is captured by population health outcome. Findings are shown using the System GMM estimation technique. The results showed a significant effect of transport and ICT in improving the length of life and reducing under-five mortality. Improvement in ICT reduced maternal deaths. An increase in all infrastructure types (transport, electricity and ICT) significantly reduced infant mortality. From the results, only ICT is associated with improvement in all population health outcome variables used in the study. Findings suggest the key role of infrastructure on health system performance, with ICT shown to have more influence on health systems than other infrastructure types. The provision and use of ICT should therefore be given top priority in the pursuit of better health system performance in Africa.

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Introduction

The African region is characterized by poorly performing health systems resulting in a relatively higher illness burden than other continents on the globe. The region carries about 25% of the world's disease burden with global health expenditures of less than 1%, and manufactures less than 2% of the medicines it consumes (United Nations 2017; World Health Organization 2015). There are clues that the poor state of health system performance in Africa extends beyond poor public sector financing to a shortfall in the level of infrastructural development (UN 2017). This follows from the complementary role of infrastructure in ensuring low input cost, promoting advances in medical research and encouraging innovation and technological advancement (Calderón, Cantú, and Chuhan-Pole 2018).

One of the ways of preventing health workers from migrating, aside from an increase in salaries, is improved working conditions (Chen, Chindarkar, and Xiao 2019). The provision of infrastructure not only improves working conditions but also mitigates the migration of health workers (Chen, Chindarkar, and Xiao 2019). This role is essential given the growing shortage of doctors and nurses for tackling the heavy disease burden in the African region.

There are essentially two broad groupings of infrastructure, which are the soft and hard forms (Zeufack et al. 2020; United Nations n.d.). Examples of hard infrastructure include transport (road, rail, ports and airports) and electricity, as well as Information and Communication Technology (ICT) (Zeufack et al. 2020 2017). Soft forms of infrastructure include health, education, and national defence among others (Zeufack et al. 2020). They are mainly skills that are required to operate technologically and institutionally complex processes (Zeufack et al. 2020; United Nations n.d.). Studies that examined the effect of infrastructure on an outcome variable generally focus on the hard form of infrastructure and the results are often obtained with the use of one type of hard infrastructure (Cole, Watkins, and Kleine 2016; Lenz et al. 2017; Maboshe and Kabinga 2018; Köroglu, Irwin, and Grépin 2019; Chen, Chindarkar, and Xiao 2019; Majeed and Khan 2019; Shobande 2020; Kouton, Bétila, and Lawin 2021). This does not give room for comparison of findings for the effect of infrastructure types on the outcome variable.

In terms of health system performance, hard infrastructure, such as the provision of transport facilities, ensures access to health care by removing distance barriers and facilitating timely use of health services (Lungu et al. 2001; Fiagbe, Asamoah, and Oduro 2012; Syed, Gerber, and Sharp 2013; Broni et al. 2014; Brown et al. 2019; Varela et al. 2019). Poor provision of transport infrastructure and cost of transport are major causes of poor use of healthcare services, particularly where referral care is needed (Broni et al. 2014). Inadequate transport infrastructure is also identified as a major constraint to achieving child and maternal health targets in many developing countries (Babinard and Roberts 2006).

Other forms of hard infrastructure such as electricity also affect health system performance in several ways. At the facility level, electricity provision impacts on the delivery of health care by aiding advanced diagnostics and treatment of poor health conditions (Chen, Chindarkar, and Xiao 2019). It also aids the availability and functioning of medical equipment, night time service provision by health workers, improved data collection at the health facility and proper records of patient information (Chen, Chindarkar, and Xiao 2019). Electricity infrastructure also aids information sharing, networking among medical professionals, increased education and training of medical personnel as well as the provision of safe water for drinking (Palei 2015).

The provision of electricity is also key in improving maternal and child health status (Maboshe and Kabinga 2018). This relates to the use of electricity in health facilities to provide lighting during child delivery, emergency night-time care and refrigeration of essential vaccines and medicines. In developing countries, most healthcare facilities lack access to a stable electricity supply and this is shown to have a negative effect on infant and maternal health (Maboshe and Kabinga 2018).

Using predictors of energy use in a panel study for African countries and with a Generalized Method of Moments (GMM) estimation, findings by Shobande (2020) showed a reduction in infant mortality rate with an increase in energy consumption. Similarly, Chen, Chindarkar, and Xiao (2019) observed increased probability of children receiving vaccinations following an electricity upgrade programme in rural India. Findings also showed an increase in the probability of mothers attending antenatal check-ups during the first trimester due to the electricity upgrade programme. Similar results were obtained by Köroglu, Irwin, and Grépin (2019), showing that frequent power outages induced a fall in the odds of expectant mothers delivering in a healthcare facility in Maharashtra State, India. The results also showed a reduction in the odds of skilled birth attendance due to an increase in power outage frequency and duration. In Rwanda, evidence provided by Lenz et al. (2017), using a mixed-method study, associated improved use of medical equipment, drug storage, sterilization, and administrative duties with electrification.

Adequate power supply is also associated with better dissemination of information regarding health safety measures using mobile phones. This function is vital, especially when there is an outbreak of illness that contributes to high mortality rates such as the Human Immunodeficiency Virus (HIV) and during periods of an epidemic such as the recent COVID-19 pandemic (Suhlrie et al. 2018; Ghosh, Bernstein, and Mersha 2020). Evidence provided by Chen, Chindarkar, and Xiao (2019) in Gujarat, India, showed significant increase in the probability of receiving information about HIV via television and among women due to increased electricity duration and voltage stability. This, in turn, improved health seeking behaviour by educating individuals about the course of treatment of the ailment and the consequences of not seeking care.

Contrary to evidences of the strong impact of electricity supply on the provision of health services, an insignificant effect was observed by Maboshe and Kabinga (2018) in Zambia. Using the data envelope analysis and tobit regression framework, they found a negligible effect of access to electricity on the efficiency of maternal and child service provision at the basic healthcare level in Zambia. This finding is, however, linked to low use of energy dependent technologies or energy-intensive inputs for basic health service provision at the primary health care level.

Infrastructure provision such as ICT also serves as a booster to health system performance in terms of spreading health information to promote efficient disease management and prevention as well as improving communication between the patient and provider of health care (Cole, Watkins, and Kleine 2016; Kouton, Bétila, and Lawin 2021). Among health workers, ICT can be used to improve ordering of medical equipment, minimize stock shortage and facilitate long-distance medical consultations (McConnell 2006; Haluza and Jungwirth 2015; Lee, Liu, and Lio 2016). In Ghana, Abekah-Nkrumah, Guerriero, and Purohit (2014) showed a significant positive effect of ICT on health care use, specifically for maternal health services. Majeed and Khan (2019) examined the effect of ICT on health for a large data set comprising a panel of 184 countries and with use of the GMM, and the fixed and random effects techniques. The evidence showed improvement in population health, specifically life expectancy at birth and infant mortality rates, with development in ICT. Findings by Kouton, Bétila, and Lawin (2021) showed similar results for a panel study of 35 African countries and with use of the GMM estimation. The results showed a reduction in infant deaths with development in ICT.

The use of ICT can, however, be linked with poor health outcomes. In this case, high usage of ICT induces irregular food intake, mental distress and less physical activity (Booth et al. 2001; Rosell et al. 2007; Kim et al. 2010). Findings by Rana, Alam, and Gow (2018) showed negative effects of ICT use on public health measured using an index of health outcome in a panel study for 20 countries in the Organization for Economic Cooperation and Development (OECD). Adverse effects of ICT on health outcome are also connected to misleading or misinterpreted information online that can cause unnecessary anxiety, unrequired visits to physicians and even mortality (Murray et al. 2003; Tanis, Hartmann, and Te Poel 2016).

By 2050, Africa's population is projected to reach one quarter of the world's total, increasing from 17% of the global population in 2018 to 26% in 2050 (OECD/ACET 2020). Interestingly, the recent COVID-19 pandemic that has slowed down population growth in most parts of the world had relatively minimal effect on mortality in the African region (Ghosh, Bernstein, and Mersha 2020). The projected rise in population in the African region will further strain existing poor health systems, leading to more adverse health conditions than are currently observed. Empirical findings for the determinants of health system performance in Africa are mainly in terms of the role of funding, environmental pollution and poor governance (Novignon and Lawanson 2017; Boachie, Ramu, and Põlajeva 2018; Osakede 2018; Osakede and Ajayi 2019; Osakede 2020). Not many studies have focused on the role of infrastructure. The few existing findings that associate health system performance with infrastructure examined the effect of a single form of infrastructure (Cole, Watkins, and Kleine 2016; Lenz et al. 2017; Maboshe and Kabinga 2018; Köroglu, Irwin, and Grépin 2019; Chen, Chindarkar, and Xiao 2019; Majeed and Khan 2019; Shobande 2020; Kouton, Bétila, and Lawin 2021). There is, therefore, a dearth of findings for the effect of several infrastructure types in terms of their relative effect on health system performance. This research is necessary to ascertain the infrastructure type that should be considered top priority in addressing improvement in health systems. In addition, findings for the effect of infrastructure on health system performance captured using population health outcome have mainly focused only on one or two indicators of population health (Maboshe and Kabinga 2018; Kouton, Bétila, and Lawin 2021; Shobande 2020). A focus on the effect of a range of infrastructure types on several indicators of population health will be more distinct and informative in the pursuit of better health system performance.

This paper provides findings for the effect of hard infrastructure on health system performance in Africa using data for 54 countries in the region, over the period 2003 to 2018. The effect of transport, electricity, ICT and an overall composite measure of infrastructure on health system performance are examined, captured using measures of population health: life expectancy at birth, and infant, under-five and maternal mortality rates. The focus on hard infrastructure follows from data availability as there are challenges with data for soft forms of infrastructure.

The contribution of the study to the literature is as follows. First, this paper adds to literature findings on the determinants of health care system performance in Africa with a focus on the role of infrastructure. Second, unlike most existing research, it provides empirical findings for the effect of infrastructure on health system performance across a range of infrastructures to ascertain the type of infrastructure that exerts a stronger influence on health systems in the region and hence should attract more policy attention. Third, the study differs from existing findings in this regard with its focus on more indicators of population health outcome as a measure of health system performance than is observed in the extant literature. Findings in this regard are also not common in Africa and will be more informative in guiding policy initiatives in promoting health system performance in the region.

Methodology

MODEL SPECIFICATION AND ESTIMATION TECHNIQUE

The World Health Organisation has identified three broad goals of health systems (World Health Organization 2000). These are to improve the health of the population, respond to the reasonable expectations of the population and collect funds in a fair way (World Health Organization 2000). The performance of health systems is hence captured by the extent of achievement of these goals. The achievement of the goals of health systems is connected to its key dimensions, namely accessibility, quality, and efficiency of health care (Mackillop, Hanna, and Brundage 2016). Smith et al. (2010) provide several ways in which health system performance can be measured. This includes the use of population health indicators such as life expectancy, disability adjusted life years and years of life lost. Others are the use of clinical quality and appropriateness of care with outcome measures such as specific post-operative readmission and mortality rates. Additional proposed measures are the responsiveness of health systems in terms of patient experience and satisfaction, and equity in the access and use of health care. Some other measures are the productivity of health-care organizations and individual practitioners in terms of the use of cost-effective methods, and allocative and technical efficiency in the delivery of health care.

In examining health system performance, measures that capture population health are often preferred, particularly for macro-related studies, due to challenges with data availability for other measures (Olafsdottir et al. 2011). As noted by Rechel and Karanikolos (2014), a key challenge in the assessment of health systems is the lack of reliable and high-quality data. Population health indicators are a reflection of the dimensions of health care systems in terms of timely access to care when it is needed, the quality of care, the effectiveness and efficiency of health care (Smith et al. 2010). Based on data availability for a macro study of this type, health system performance is captured using measures of population health outcome, specifically life expectancy at birth, and infant, under-five and maternal mortality. These indicators are widely accepted to measure population health (Boachie, Ramu, and Põlajeva 2018). Moreover, infrastructure, which is the main predictor variable in this study, is identified to have strong association with infant, under-five and maternal health condition as well as length of life. The general assumption is that countries with healthy populations have good health systems and will have low mortality and higher life expectancy (Boachie, Ramu, and Põlajeva 2018).

In specifying the empirical relationship between the selected population health outcome variables and the predictor variables, this study adopts the theoretical foundation of the health production function in line with the Grossman (1972) modelling strategy for health care demand. According to Grossman (1972), individuals can produce health based on inputs that influence health condition such as their behaviour or lifestyle, medical care consumption or expenditure on health, literacy rate and income. In line with the supposition by Grossman, the individual's health production function can be represented as:

$$H_i = f(hinpts_i), \tag{1}$$

where H is the health output for individual i and *hinpt* represent inputs or factors that determine the individual's health.

This model presents the health production function at the individual level. At the macro level, the health production function captures population health and the inputs are reorganized into three categories: social, economic and environmental factors (Fayissa and Gutema 2005). For simplicity, this study categorizes health inputs at the macro level into social economic and environmental factors. So, equation (1) can be restated in the panel form as:

$$H_{it} = f(Se_{it}, Env_{it}), i = 1, 2, \dots, n, \text{ and } t = 2003, \dots, 2018, \tag{2}$$

where *H* represents population health outcome. Se captures social economic factors and Env represents the environmental condition. Based on available data, socioeconomic factors considered in this study include macroeconomic income measured using per capita Gross Domestic Product (GDP), government spending on health and education, and labour force participation (Majeed and Khan 2019; Osakede 2020). Environmental condition is measured using carbon dioxide emission (Majeed and Khan 2019; Osakede and Ajayi 2019). In this study, the role of governance quality is also considered as a determinant of population health (Novignon and Lawanson 2017; Boachie, Ramu, and Põlajeva 2018; Osakede 2020). Governance quality is measured using the control of corruption. This is because other forms of governance quality are often a reflection of the extent of corruption in a society. To capture the role of infrastructure, the index for transportation, electricity, ICT and a composite infrastructure index are included in the health production function.

Similar to the techniques used by macro studies of this type, the model for the effect of infrastructure on health systems is estimated using the GMM technique. This is the most appropriate methodology for panel data study of this type because it is mainly applied to models with large cross section and small time dimension. The approach makes it possible to predict the dynamic nature of the human condition (Shobande 2020). Choice of this technique is also based on its wide application in controlling potential endogeneity due to the omission of country-specific explanatory variables in panel data models (Majeed and Khan 2019; Shobande 2020; Kouton, Bétila, and Lawin 2021). In the GMM estimation, lagged values of the dependent variables are used as instruments to control for endogeneity (Roodman 2009). The GMM estimates can be derived using the one-step (first difference) or two-step (second difference) transformation. However, the two-step GMM is often preferred because it provides more efficient and consistent estimates, particularly if a variable's recent value is missing (Roodman 2009; Arellano and Bover 1995). The GMM estimate can be derived using the Arrelano and Bond (1991) Difference GMM (DGMM) or the Blundell and Bond (1998) system GMM (SGMM). Oftentimes the SGMM is preferred to the DGMM because it provides more efficient estimates than the DGMM and circumvents the finite sample bias with small time periods that is often observed with the DGMM (Alonso-Borrego and Arellano 1999; Heid, Langer, and Larch 2011).

The general model of the data-generating process for the GMM model specification in this study is stated as:

$$H_{it}^{j} = H_{i,t-1}^{j} + X'_{i,t}\beta + \varepsilon_{i,t}, \tag{3}$$

where $H_{i,t}^{j}$ is health outcome j for country i at time t. Four health outcome variables are considered in this study: life expectancy at birth (years), infant mortality per 1,000 live births, under-five mortality per 1,000 live births, and maternal mortality per 100,000 live births. $H_{i,t-1}^{j}$ is health outcome j for country i at time t-1. $X'_{i,t}$ is a vector of control variables. The control variables are the natural logarithmic value for per capita Gross Domestic Income at constant USD, labour force participation as a percentage of total population ages 15 and above, government spending on health in constant USD and government spending on education in constant USD. Others include carbon dioxide emission in metric tons per capita, the control of corruption and the natural logarithmic value for infrastructure variables.

The disturbance term $\varepsilon_{i,t}$ has two orthogonal components: the fixed effects, μ_i, and the idiosyncratic shocks $\upsilon_{i,t}$. That is,

$$\varepsilon_{i,t} = \mu_i + \upsilon_{i,t}, \tag{4}$$

where $E(\mu_i) = 0$ and $E(\upsilon_i) = 0$, so that $E(\mu_i \upsilon_{i,t} = 0)$.

It is expected that:

- The initial value of the dependent variable will be positively related to its current value.
- A rise in per capita income will translate to better health outcomes as higher income ensures financial access to health care when needed and is also an indication of increased welfare such as better nutrition and housing (Majeed and Gillani 2017).
- Similarly, increased labour force participation can lead to better health outcome, especially where the nature of employment is with minimal work hazards. Moreover, with improved economic empowerment, individuals are able to purchase more baskets of goods that raise welfare and health conditions. In addition, revenue generated from income taxes can serve as a booster to government spending on basic needs in the society that can improve health conditions.
- Increased government spending on health and education are also expected to have a positive impact on health. Higher public health spending is an indication of better provision of health care services for the populace and hence should raise health conditions. Similarly,

improved public spending on education should raise literacy rates that in turn improves the effectiveness and efficiency of the use of health care. This in turn raises health outcomes.

- Carbon dioxide is a form of environmental pollution and constitutes unhealthy changes in the atmosphere that harms the health of present and future generations. Increase in carbon dioxide emission is expected to have negative effects on population health and hence dampen efforts geared towards improving health systems. However, increased carbon emission can be due to higher industrial sector activities, suggesting a rise in income. In this case, negative effects may be dampened by a rise in wellbeing.
- Improvements in the index of governance are expected to induce positive effects on health outcome due to its influence on the effective use of public funds (Osakede 2020). The governance indicator is measured using the control of corruption based on suggestions of a strong effect on health system performance. Countries with high corruption are generally characterized by poor institutions and low governance quality. They are also associated with low investment in social welfare and poor population health (Gupta, Davoodi, and Tiongson 2000; Kaufmann, Kraay, and Mastruzzi 2004). Estimates for governance indicators range from approximately −2.5 (weak) to 2.5 (strong) governance performance.
- In terms of infrastructure provision, it is expected that improved infrastructure supply will enhance health system performance, reflected in improved health outcome. This follows from the role of infrastructure in promoting quality and effective delivery of health care services, better response to emergencies, improved data collection and databases for better implementation of health care intervention (van Schalkwyk and Mindell 2018; Brown et al. 2019; Chen, Chindarkar, and Xiao 2019; Varela et al. 2019; Shobande 2020; Kouton, Bétila, and Lawin 2021).

DATA SOURCES

The data for infrastructure used for the study were sourced from the Africa Infrastructure Development Index provided by the African Development Bank (2018). Data for the control of corruption was obtained from the World Governance Indicators provided by the World Bank (https://databank.worldbank.org). Data for the other variables used in

TABLE 1 Descriptive Statistics

Variables and Measurement	Mean	SD	Min	Max
Life expectancy (total in years)	59.65	7.71	42.42	76.69
Infant mortality (per 1000 live births)	55.42	24.11	10.20	134.30
Under-5 mortality (per 1000 live births)	83.69	41.29	12.00	216.80
Maternal mortality (per 100,000 live births)	504.40	330.10	37.00	1,960.00
Real GDP per capita (constant 2010 USD)	2,558.00	3,312.00	194.90	20,513.00
Labour force participation total (% of total population ages 15 years and above)	65.31	12.61	41.15	89.05
Domestic government health expenditure (% of total government expenditure)	7.01	3.47	0.65	18.29
Government spending on education (% of total government expenditure)	16.89	5.76	0.88	37.52
CO_2 emission (metric tons per capita)	1.19	2.07	0.02	1.00
Control of corruption	−0.66	0.60	−1.87	1.22
Transport infrastructure index	10.84	12.20	0.00	56.59
Electricity infrastructure index	9.18	16.85	0.00	100.00
Information and communication technology infrastructure index	6.15	10.01	0.00	67.39
Composite infrastructure index	20.88	18.44	0.01	94.97

NOTES Based on data from from World Bank (https://databank.worldbank.org) and African Development Bank (2018).

the study were obtained from the World Development Indicators provided by the World Bank (https://databank.worldbank.org). Data used covered 54 countries in the African region. Based on constraints for the availability of infrastructure data, the time frame for the study spans from 2003 to 2018.

Results and Discussion of Findings

The results for the descriptive statistics of the variables used in the study are shown in table 1. Average life expectancy in the African region and over the period of the study is approximately 60 years with a maximum value of about 77 years. The standard deviation of life expectancy of approximately 7 years shows that the figures are not very distant from its mean value. On average, infant deaths are approximately 55 per 1,000 live births. At maximum, the value is as high as 134 infant deaths per 1,000 live births. This is quite high when compared to global average figures of 39 per 1,000 live births in 2017 and also far from the Sustainable Development Goal (SDG) of 25 deaths per 1,000 live births (UNICEF, WHO, World Bank Group and United Nations 2018). The mean value for under-5 mortality is approximately 84 per 1,000 live births. This is also high relative to global estimates of 39 deaths per 1,000 live births in 2017 and far from the SDG of 25 deaths per 1,000 live births (UNICEF, WHO, World Bank Group and United Nations 2018). On average, maternal mortality rates are about 504 per 100,000 live births. This, again, is far from the SDG of 70 per 100,000 live births (World Health Organization 2019). The statistics suggest the need for countries in the African region to accelerate progress to meet the SDG for infant, under-five and maternal mortality.

The average value of real GDP per capita is 2,558 USD. The standard deviation of real per capita GDP is 3,312 USD. This is quite high and may be due to the heterogeneous nature of country cross sections. Approximately 65% of individuals aged 15 years and above are actively engaged in the labour force, suggesting that less than half of the individuals aged 15 and above are unemployed. However, most employment types in African economies are in the informal sector and this creates a low tax base for the government (International Labour Organisation 2020). Domestic government health expenditure as a percentage of total government expenditure is approximately 7% with a maximum value of 18%. The indication is that for the time period of the study, governments in the African region allocated 7% of budgetary provision to health. This suggests low domestic health prioritization in terms of budgetary allocation to health and less financial protection, especially for persons who are poor (World Health Organization 2018). Government spending on education as a percentage of total government expenditure is approximately 17% on average with a maximum value of 38%. The indication is that governments in the region allocate more funds to education than health. The education and health sectors are important in achieving sustainable growth and development and each complements the other in achieving this objective. With higher budgetary allocation to education than health, individuals may not be able to harness the reward of education due to poor health following from low provision of health care needs.

CO_2 emission is approximately 1 metric ton per capita on average. Carbon emission is oftentimes associated with increase in economic output yet negative effects are noticeable on health condition as it generally promotes poor air quality (Farooq et al. 2019; Osakede and Ajayi 2019; Olubusoye and Musa 2020). On average, the index for the control of corruption is –0.664. The negative sign suggests the prevalence of poor control of corruption in the region.

The average value for infrastructure suggests better provision of transport infrastructure than other forms of infrastructure considered in the study. Transport infrastructure is shown to have an index value of 11 on average while electricity infrastructure has an average index value of 9. ICT is shown to have an average index value of 6. The figures clearly show that the African region is characterized by less ICT infrastructure than other forms of infrastructure. On average, the composite index of infrastructure is shown to have a value of 21. The minimum value of the composite infrastructure index is approximately zero, showing that some countries in the region do not have records of any form of infrastructure.

Table 2 presents the estimates of the SGMM regression results for the effect of infrastructure on life expectancy.

Findings show positive effect of past values of the dependent variable on its current value. Findings also show that macroeconomic income positively impacts the average length of life in the region. The result showed that a 1%-point increase in per capita income implies a rise in life expectancy by approximately 0.305 years. This is not surprising as higher income enables financial access to health care and better living conditions that should ordinarily increase the length of life. Similarly, findings showed that a rise in the labour force participation rate raises life expectancy. A 1%-point increase in the labour force participation rate implies a rise in life expectancy by approximately 0.018 years. As individuals get some form of economic empowerment, they are able to afford basic needs and better living conditions that should promote health status.

An increase in government spending on education is also found to raise life expectancy. A 1%-point increase in government spending on education as a percentage of total government spending would raise life expectancy by approximately 0.006 years. Increase in carbon emission is found to reduce life expectancy in the region. A 1-unit rise in CO_2 emission in metric tons per capita induces a fall in the length of life by approximately 0.112 years. This is in line with expected findings as carbon emission is associated with several chronic illnesses and hence detrimental to health and wellbeing (Ebenstein et al. 2017; Liu, Xu, and Yang 2018). As expected, the index for the control of corruption is shown to have negative effects on life expectancy. A 1-unit rise in the index for the control of corruption implies a fall in life expectancy by approximately 0.050 years.

Findings for the effect of infrastructure on life expectancy showed that

TABLE 2 SGMM Regression Results: Dependent Variable Life Expectancy

Variables		(1)	(2)
Initial life expectancy		0.9360***	0.0034
Log of per capita GDP		0.3050***	0.0191
Labour force participation		0.0176***	0.0017
Domestic general government health expenditure		0.0014	0.0017
Total government expenditure on education		0.0059***	0.0012
CO_2 emission		−0.1120***	0.0074
Control of corruption		−0.0503**	0.0219
Log of transport infrastructure index		0.1360***	0.0189
Log of electricity infrastructure index		−0.0096	0.0071
Log of ICT infrastructure index		0.0466***	0.0054
Log of Composite infrastructure index		0.3830***	0.0397
Observations			320
Number of ID			47
Hansen_test			39.5800
H0: over-identifying restrictions are valid	Hansen Prob		0.9690
	AR(1)_test		1.4000
H0: no first order autocorrelation	AR(1)_*P*-value		0.1620
	AR(2)_test		1.6780
H0: no second order autocorrelation	AR(2)_*P*-value		0.0933
	No. of instruments		66

NOTES Column headings are as follows: (1) coefficients, (2) standard errors. *** $p < 0.01$, ** $p < 0.05$, * $p < 0$.

transport, ICT and the composite infrastructure index induce a significant effect on life expectancy. The results suggest stronger influence of transport infrastructure in raising the length of life than other forms of infrastructure. Findings show that a 1-unit rise in the index of transport infrastructure would increase life expectancy by about 0.136 years. Similarly, a 1-unit increase in the index of ICT infrastructure would raise life expectancy by approximately 0.047 years while that for the composite index for infrastructure would raise life expectancy by approximately 0.383 years. The result for the composite index of infrastructure induced a larger effect on health outcome as it comprises more infrastructure components. As noted in most studies, the provision of transport facilities can improve population health as it removes distance barriers to the use

TABLE 3 SGMM Regression results: Dependent Variable Log of Infant Mortality

Variables		(1)	(2)
Initial infant mortality		0.9890***	0.0009
Log of per capita GDP		0.0090***	0.0009
Labour force participation		−0.0002***	0.0000
Domestic general government health expenditure		−0.0007***	0.0000
Total government expenditure on education		−0.00001	0.0000
CO_2 emission		−0.0002	0.0002
Control of corruption		−0.0030***	0.0009
Log of transport infrastructure index		−0.0057***	0.0009
Log of electricity infrastructure index		−0.0018***	0.0004
Log of ICT infrastructure index		−0.0007***	0.0000
Log of Composite infrastructure index		−0.0134***	0.0013
Observations			320
Number of ID			47
Hansen_test			40.1300
HO: over-identifying restrictions are valid	Hansen Prob		0.9920
	AR(1)_test		0.4780
HO: no first order autocorrelation	AR(1)_*P*-value		0.6330
	AR(2)_test		2.1990
HO: no second order autocorrelation	AR(2)_*P*-value		0.0279
	No. of instruments		76

NOTES Column headings are as follows: (1) coefficients, (2) standard errors. *** $p < 0.01$, ** $p < 0.05$, * $p < 0$.

of health care and facilitates timely use of health services (Lungu et al. 2001; Broni et al. 2014; Brown et al. 2019;). Similarly, the provision of ICT improves health system performance in several ways, one of which is promoting efficient disease management and prevention (McConnell 2006; Haluza and Jungwirth 2015; Cole, Watkins, and Kleine 2016; Lee, Liu, and Lio 2016; Kouton, Bétila, and Lawin 2021).

Findings for the effect of infrastructure on infant mortality are shown in table 3.

The results show that past values of infant mortality rate significantly explain the current value. Contrary to a priori expectation, findings suggest that an increase in per capita income does not translate to a reduction in infant deaths. With a 1%-point increase in per capita income, infant deaths rise by approximately 0.009%. This can be associated with high income inequality in most African countries. Evidence from the literature shows that the region is characterized by unequal income distribution (UNDP Regional Bureau for Africa 2016). The high uneven spread in income implies that the majority of the populace in the region are still poor even with the statistics showing high per capita income. Recent estimates show that 85% of Africans are still categorized as poor (Castaneda Aguilar et al. 2019). In this case, there can be some possibility of experiencing an increase in infant mortality with a rise in per capita income as the rise in per capita income relates to few individuals in the region. Infants and children are more likely to experience negative impacts of inequality in income relative to the adult population due to low health capital stock as shown by Grossman (1972). In line with expected results, findings show that increase in the proportion of individuals participating in the labour force reduces the number of infant deaths, but by a very small magnitude.

The result also showed that an increase in government allocation to health induces better infant health. For every 1%-point increase in government allocation to health as a percentage of total government spending, infant deaths would fall by approximately 0.001%. The index for the control of corruption also showed an expected negative effect on infant health. With 1 unit increase in the index for the control of corruption, infant deaths fall by approximately 0.003%. This suggests that improvement in institutional quality promotes infant health.

Findings for the effect of infrastructure showed that all forms of infrastructure used in the study improve infant health, with slightly higher effect of transport over other forms of infrastructure. A 1%-point increase in the index of transport infrastructure induces a fall in infant mortality by approximately 0.006%. With a 1%-point increase in the index of electricity infrastructure, infant mortality would fall by approximately 0.002%. A 1%-point increase in ICT infrastructure index would reduce infant deaths by about 0.001%. Findings for the composite infrastructure index further strengthen evidence for the strong role of infrastructure on infant health. Findings show that a 1%-point increase in the composite infrastructure index induces a fall in infant deaths by approximately 0.013%. The results suggest the strong effect of not only electricity and ICT in promoting infant health as shown in the extant literature but also transport infrastructure (Lenz et al. 2017; Chen, Chindarkar, and Xiao 2019; Köroglu, Irwin, and Grépin 2019; Shobande 2020; Kouton, Bétila, and Lawin 2021).

TABLE 4 SGMM Regression Results: Dependent Variable Log of Under-Five Mortality

Variables		(1)	(2)
Initial under-five mortality		0.9850***	0.0011
Log of per capita GDP		0.0120***	0.0014
Labour force participation		−0.0002***	0.0000
Domestic general government health expenditure		−0.0010***	0.0001
Total government expenditure on education		−0.0002***	0.0000
CO_2 emission		−0.0020***	0.0004
Control of corruption		−0.0073***	0.0011
Log of transport infrastructure index		−0.0075***	0.0001
Log of electricity infrastructure index		−0.0009	0.0006
Log of ICT infrastructure index		−0.0017***	0.0002
Log of Composite infrastructure index		−0.0156***	0.0024
Observations			320
Number of ID			47
Hansen_test			36.8000
HO: over-identifying restrictions are valid	Hansen Prob		0.9970
	AR(1)_test		1.8530
HO: first second order autocorrelation	AR(1)_*P*-value		0.0639
	AR(2)_test		1.7370
HO: no second order autocorrelation	AR(2)_*P*-value		0.0825
	No. of instruments		75

NOTES Column headings are as follows: (1) coefficients, (2) standard errors. *** $p < 0.01$, ** $p < 0.05$, * $p < 0$.

Findings for the effect of infrastructure on under-five mortality are shown in table 4.

The results again showed that past values of under-five mortality rate significantly explain the current value. Findings also showed that increase in per capita income does not translate to a fall in under-five mortality. A 1%-point increase in per capita income raises under-five deaths by approximately 0.012 %. This is against expectation and can be related to high income inequality as stated earlier.

In line with expected results, findings showed that an increase in the labour force participation rate reduces under-five mortality but with a very small magnitude. Similarly, an increase in government spending on health and education translates to a reduction in under-five deaths. With a 1%-point rise in government spending on health, under-five mortality falls by approximately 0.001%. In terms of magnitude, government spending on education showed very little effect on under-five health; however, the results suggest that investment in human capital in terms of education and health are important in improving child health outcomes.

Surprisingly, findings showed a negative effect of a rise in carbon emission on under-five deaths. With a 1-unit increase in carbon emission, under-five deaths fall by 0.002%. This result is against expectation but can be explained by the fact that increase in carbon emission can be associated with industrialization and hence suggests more labour employment and empowerment that can provide better financial access to health care needs (Olubusoye and Musa 2020). As previously seen, a rise in the control of corruption reduces under-five mortality. With a 1-unit increase in the index for the control of corruption, under-five mortality falls by approximately 0.007%. The result suggests that improvement in institutional quality is vital for achieving a fall in under-five mortality rate.

Findings for infrastructure show that only transport, ICT and the composite infrastructure index have significant effect on under-five health outcomes. The results showed that with a 1%-point increase in transport infrastructure index, under-five mortality falls by approximately 0.008%. And with a 1%-point increase in the ICT infrastructure index, under-five mortality decreases by approximately 0.002%. As mentioned earlier, the result suggests that timely use of health services, associated with transport infrastructure and obtaining health information that is often associated with ICT infrastructure, is important in promoting under-five health (Lungu et al. 2001; Broni et al. 2014; Mimbi and Bankole 2015; Brown et al. 2019). As expected, the results show stronger effect of a rise in the composite index of infrastructure in reducing under-five deaths than other forms of infrastructure. Findings show that with a 1%-point increase in the composite infrastructure index, under-five deaths fall by approximately 0.016%. This result again strengthens the role of infrastructure in promoting health outcomes.

Findings for the effect of infrastructure on maternal mortality are shown in table 5.

The results again show that past values of maternal mortality rate significantly explain the current value. As expected, findings also showed that increase in the labour force participation rate reduces maternal mortality rate, but with small magnitude. The small magnitude of effect can be associated with high informal sector employment. Informal employment

TABLE 5 SGMM Regression Results: Dependent Variable Log of Maternal Mortality

Variables		(1)	(2)
Initial maternal mortality		0.9970***	0.0001
Log of per capita GDP		−0.0008	0.0009
Labour force participation		−0.0003***	0.0000
Domestic general government health expenditure		−0.0006***	0.0002
Total government expenditure on education		0.0002	0.0001
CO_2 emission		−0.0002	0.0001
Control of corruption		−0.0047**	0.0023
Log of transport infrastructure index		0.0025	0.0018
Log of electricity infrastructure index		−0.0004	0.0014
Log of ICT infrastructure index		−0.0041***	0.0004
Log of Composite infrastructure index		−0.0611***	0.0050
Observations			320
Number of ID			47
Hansen_test			40.3300
HO: over-identifying restrictions are valid	Hansen Prob		0.9930
	AR(1)_test		−0.1150
HO: no first order autocorrelation	AR(1)_*P*-value		0.9090
	AR(2)_test		1.6530
HO: no second order autocorrelation	AR(2)_*P*-value		0.0983
	No. of instruments		73

NOTES Column headings are as follows: (1) coefficients, (2) standard errors. *** $p < 0.01$, ** $p < 0.05$, * $p < 0$.

generally requires low skill and hence low labour productivity and income (Guven and Karlen 2020; International Labour Organisation 2015). As expected, increase in government spending on health reduces maternal deaths. With a 1%-point increase in government health expenditure, maternal deaths fall by approximately 0.001%. Findings also associate a significant effect of the control of corruption on maternal health. With a 1-unit increase in the index for the control of corruption, maternal mortality falls by about 0.005%.

The result for infrastructure index suggests that only ICT and the composite infrastructure index induce improvement on maternal health. Findings showed that a 1%-point increase in ICT infrastructure index is associated with a fall in maternal deaths by about 0.004%. With a 1%-

point increase in the composite infrastructure index, maternal deaths fall by about 0.061%. The insignificant effect of electricity on maternal health is consistent with empirical results by Maboshe and Kabinga (2018) that found negligible effect of access to electricity on the efficiency of maternal and child health service provision in Zambia. Findings for improvement in maternal health due to a rise in ICT infrastructure are consistent with the evidence provided by Abekah-Nkrumah, Guerriero, and Purohit (2014) in Ghana suggesting that ICT promotes maternal health by increasing the use of maternal health care services.

Conclusion

This paper provides findings for the effect of infrastructure on health system performance using a panel of 54 countries in Africa and over the period 2003 to 2018. In line with previous literature, health system performance is measured using population health outcome, specifically life expectancy, infant and under-five mortality as well as maternal mortality rate. Based on data availability, the study made use of hard forms of infrastructure, namely transport, electricity, ICT and the composite infrastructure index. The empirical models applied in the study follow the theoretical foundation of the health production function as presented by Grossman.

Findings are derived using the system GMM estimator based on a large number of cross sections relative to the time span used in the study. Findings validate the role of infrastructure in promoting health system performance. The result for each infrastructure type suggests the significant effect of transport and ICT infrastructure in promoting the length of life and in reducing under-five mortality rate, while all forms of infrastructure exert significant effects in reducing infant mortality. The result further suggests the key role of ICT in promoting maternal health in the African region. Findings hence highlight the fundamental role of ICT in promoting population health based on the significant effect in improving all forms of population health outcome. Interestingly, the index for ICT is shown to have the lowest value across all forms of hard infrastructure used in the study. A more effective way to improve health system performance in Africa in terms of population health is to promote infrastructure improvement with investment in ICT as key. Findings for other control variables that are consistent across population health outcome suggest that a rise in labour force participation and government health care spending improve population health. These variables should also be given strong consideration in the effort to raise health system performance in the African region.

This study is limited in the sense that the measure of health system performance used is not exhaustive. Other measures, as shown in the literature, could not be explored due to missing time series observation for countries in Africa. While this limitation may be the basis for future research, it does not undermine the findings of this current study as population health outcome is well documented in the literature as a measure of health system performance.

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