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Infrastructure Matters

Complementarities with the Quality of Health Service Delivery in Kenya

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Abstract

In many low- and middle-income countries, the lack of access to essential infrastructure such as roads, electricity, and information and communications technology may hinder the provision of many critical services such as health care. For instance, scarce and deficient roads might limit the patients' access to health facilities, restrict the supply of qualified staff, and constrict access to key inputs such as medicines and vaccines. Likewise, lack of reliable electricity and internet connection may limit the ability of health facilities to power essential equipment, have better access to information, potentially serve more patients, and manage their supply chain efficiently. This paper combines exhaustive health facility surveys with geospatial data to study the extent to which better access to infrastructure in Kenya might improve the functioning of health care facilities and the quality of their services. First, the paper documents the gap in access to infrastructure in the health care sector in Kenya and reviews the literature on this topic. Then, using a novel data set, it finds that access to electricity and good quality roads is associated with more accurate provider diagnostics for both general illnesses and those primarily affecting children and pregnant women. Additionally, access to electricity is associated with (i) higher availability of vaccines for children—mostly by making it possible to have a working fridge, which is essential to store most vaccines; and (ii) higher availability of essential and priority medicines, by facilitating the use of information and communications technology for supply chain management. Finally, access to good quality roads, electricity and use of information and communications technology for supply management are positively related to the availability of antenatal care tests for pregnant women. Overall, the results suggest that increased investment in infrastructure and communications technologies may improve health service provision in Kenya.

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Infrastructure Matters: Complementarities with the Quality of Health Service Delivery in Kenya[1]

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1. Introduction

Health is an essential component of human capital formation, especially in the early years of the lifecycle.[2] Inadequate infrastructure affects both demand for health care services as well as supply. On the demand side, many people in low- and middle-income countries face barriers that prevent or limit their access to the health care services they need. Excessive travel times to reach facilities, lack of information, and limited health care resources impact remote and vulnerable populations the most. On the supply side, inadequate infrastructure hampers the functioning of health care facilities and the quality of their services. These barriers not only affect access to health services but also the quality of services people receive. Therefore, policies to improve access to health services should also focus on improving the quality of provided services.[3]

While many dimensions that affect the quality of health service delivery have been documented in the literature, access to infrastructure remains understudied, especially on the supply side. Investments to improve access to infrastructure such as roads, electricity, and information and communications technology (ICT) hold the potential to enhance the quality of health service provision. This is particularly true in low- and middle-income countries, where access to quality infrastructure remains a challenge in rural and hard-to-reach areas. Not only do more and better roads facilitate the access of patients to health facilities, but they may also allow facilities to attract more staff and ease the supply of key inputs such as medicines and vaccines. Likewise, lack of reliable electricity may compromise health care provision as electricity enables lifesaving interventions, the maintenance and use of essential equipment, and the ability of health facilities to operate for extended hours, particularly at night. Similarly, access to the internet allows facilities to have better information, reach more patients, and better manage their supply chains. This paper aims to contribute to the literature by exploring the extent to which more and better infrastructure might improve the quality of health services provision in low- and middle-income countries by studying the Kenyan context.

Kenya has made great progress in increasing the availability of health care services in the last decade, but much remains to be done (WHO, 2017). A child born today in Kenya is likely to only achieve 55% of her/his potential according to the latest update of the Human Capital Index (World Bank, 2020), which includes measures of child and adult survival rates, stunting and access to and quality of schooling. While Kenyan county governments have prioritized investments in the health sector, especially in the construction of new health facilities and purchase of medical equipment and ambulances, not many efforts have been made to ensure that health facilities have access to reliable infrastructure (Mugo, et al., 2018).[4] According to the latest 2018 Service Delivery Indicators (SDI) report, only 56% of primary-level health care facilities have access to stable electricity and only 15% of health facilities use ICT for supply chain management.

Improving the access and quality of infrastructure remains a challenge in Kenya. Despite an increase in access to energy by 50 percentage points over the past ten years, which has translated into 70% nationwide coverage, 30% of the population still has limited access to reliable electricity (World Bank, 2021). The latest Rural Access Index in Kenya shows that 56.8% or about 13.4 million rural residents are still unconnected to

[2] See Bleakley, 2010; Case, Fertig, & Paxson, 2005; Conti, Heckman, & Urzua, 2010; Knudsen, Heckman, Cameron, & Shonkoff, 2006.

[3] Within Millennium Development Goals (MDGs), from 2000 to 2015, there was an increase in health coverage in low- and middle-income countries (LMICs). But health outcomes did not improve at the same rate for every country or everyone within each country. Despite the increase in the coverage achieved, low quality of services persists in many LMICs and high maternal and child mortality rates continue to be of serious concern. In this context, quality health services are essential to better human capital and healthier economies (WHO, 2018). There are many well-documented factors that affect the quality of health service delivery (Di Giorgio, et al., 2020; Gatti R. , et al., 2021; Mosadeghrad, 2014). For instance, providers' effort and knowledge in primary care vary according to institutional settings (private or public, with their cost structure), and medical training -where the relationship is not strictly positive (Das, Holla, Mohpal, & Muralidharan, 2016; Das, et al., 2012).

[4] The right to access quality health care is a basic human right guaranteed by the 2010 constitution of Kenya. In line with the law, the national government has made investments in interventions geared towards accelerating UHC for all Kenyans. In 2013, Kenya devolved health services to 47 semi-autonomous counties established in response to the new constitution of 2010, increasing local autonomy for managing health services (Achoki, et al., 2019).

roads in fair condition (Iimi, et al., 2016). Finally, mobile subscriptions had a penetration close to 100% in 2018, but only 23% of the population in Kenya had access to internet services in 2019 (World Bank, 2021). Given these gaps, improving the access and quality of infrastructure has a potentially important role for improving health service provision in Kenya.

This paper focuses on specific dimensions of infrastructure with data availability and for which we found prior suggestive evidence on their link to the quality of health service delivery. In particular, we study access to and quality of electricity (using stability of the connection as a proxy for quality), road quality and accessibility, cellphone, and internet connectivity (2G and 3G), and use of ICT. Likewise, in this paper we are restricted to study only certain aspects related to the quality of health services for which we have data. While we understand that quality of health service delivery is multi-dimensional and complex to measure, we use level of health services' readiness (i.e., availability of key medicines, vaccines for children, and ANC tests) and health providers' medical knowledge to treat certain conditions (i.e., diagnostic accuracy) as proxies of quality of health service delivery. For this analysis, we combine geo-referenced survey data collected at the health facility level with geospatial data on infrastructure and location characteristics in order to document some of the cross-sectoral drivers of the quality of health.

We first find that access to electricity and quality of roads are associated with more accurate provider diagnostics for general illnesses and for those affecting primarily the early development of children and threatening the life of pregnant women. We also find that access to electricity is associated with (i) higher availability of vaccines for children, mostly by making it possible to have a working fridge, which is essential to store most vaccines; and (ii) higher availability of essential and priority medicines for children and pregnant women, partially through the use of ICT for supply chain management. Finally, access to electricity and ICT use for supply management are positively related to the availability of antenatal care (ANC) tests for pregnant women. Test availability also decreases when facilities are further away from fair or good quality roads. Overall, our results suggest that investments in infrastructure and technology may play an important role in improving the quality of health service delivery, including early childhood and maternal health.

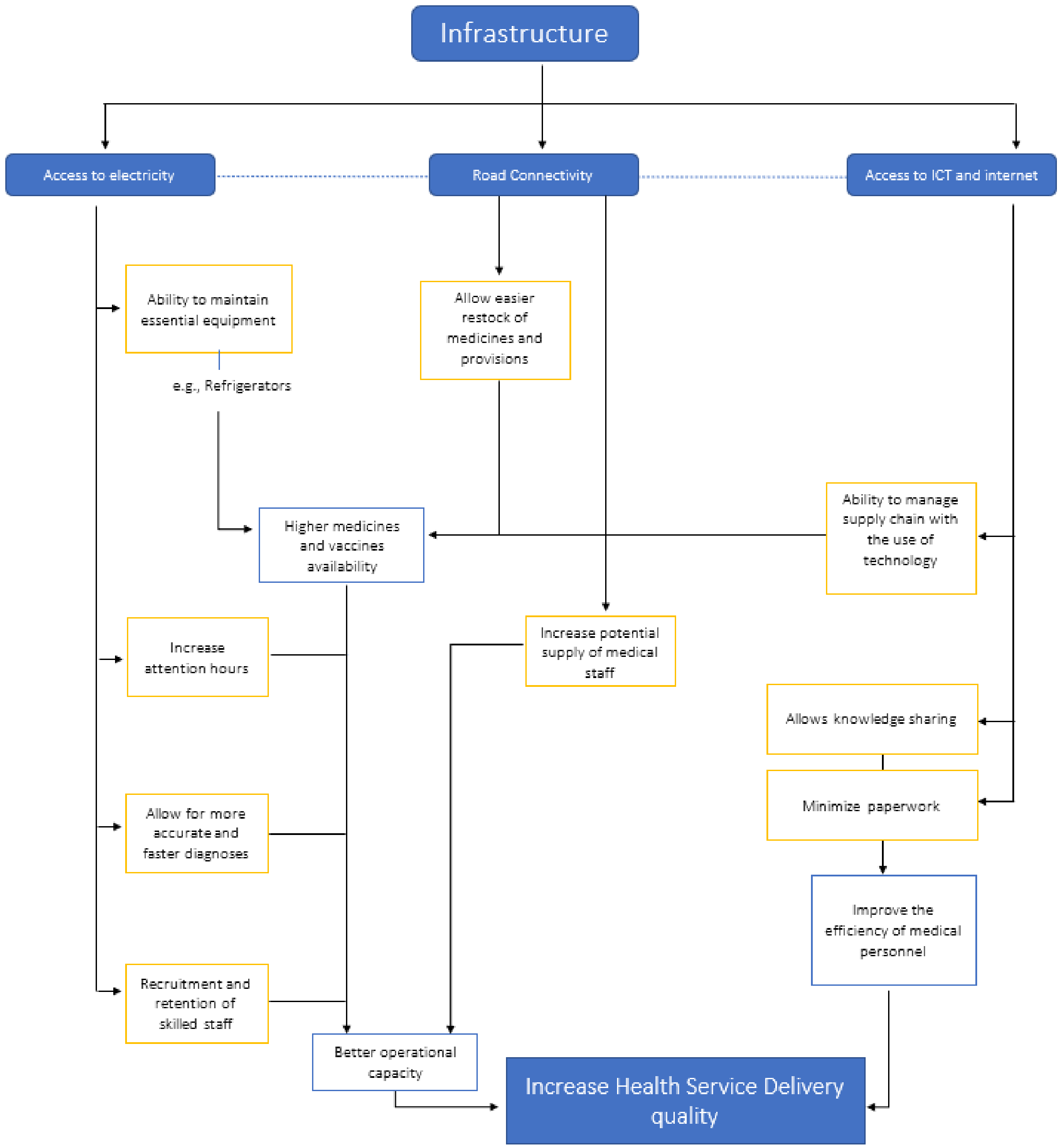
Our contributions to the literature are three. First, we focus on the potential impact of access to infrastructure (i.e., electricity, road quality, cellphone and internet coverage, and use of ICT) on the quality of health service provision in a lower-middle-income setting. This is different from the current literature in that (a) we focus on the supply side while most papers focus on the demand side; (b) we use novel data by merging geospatial data with high-quality health service delivery indicators survey data from different sectors; and (c) while our data does not allow to identify causal impacts, we document the initial gaps in access to infrastructure and control for a wide set of characteristics in our correlational analysis to quantify the potential effect of infrastructure on health service provision. Furthermore, we provide insights for the provision of general health services, as well as for early childhood care and pregnant women. Second, we take advantage of the rich set of questions in the health service delivery indicators survey to provide suggestive evidence of the possible channels through which infrastructure affects the quality of health service delivery. Third, we lay the groundwork for future cross-sectoral studies by reviewing the literature and proposing a simple analytical framework on the channels through which infrastructure affects the quality of health service delivery.

The rest of the paper continues as follows. Section 2 summarizes some of the main findings from the literature around a simple framework. Section 3 describes the sources of data used, the construction of the indicators analyzed, and the methodology for the proposed analysis. Section 4 presents the results and policy implications of our findings.

2. Conceptual Framework and Literature Review

Most of the literature on health service sector has focused on the demand side, such as access to health services, while much less has been done on the supply side, and even fewer papers document the channels through which different infrastructure contributes to enhancing or limiting the provision of services. In this paper, we focus on evidence looking at access to electricity, roads, ICT, cellphone coverage, and the internet as key infrastructure measures. Based on this literature, Figure 1 presents a framework that identifies three channels of interest: better operational capacity, higher medicine and vaccine availability, and improved efficiency of medical personnel. We summarize the evidence related to each below.

Figure 1. Health Service Delivery and Access to Infrastructure Framework



Access to reliable electricity has been identified as critical for health care facilities. Without it, many life-saving interventions cannot be undertaken (WHO, 2014). Having electricity also allows the maintenance of essential equipment for medical tasks, such as sterilizers, refrigerators, and equipment to maintain the cold chain of medicines and vaccines. These practices are related to the quality of the services provided and might reduce mortality (Chen, Chindarkar, & Xiao, 2019; Irwin, Hozha, & Grepin, 2019; World Bank, 2008). Besides the well-functioning of essential equipment, electricity allows facilities to have laboratories and implement reliable tests that impact diagnostic quality (Irwin, Hozha, & Grepin, 2019). Access to electricity has been related to the ability to attract better-skilled providers, which results in better health outcomes such as improved survival rates, particularly for children and pregnant women (Kruk, et al., 2018; Irwin, Hozha, & Grepin, 2019; Lenz, Munyhirwe, Peters, & Sievert, 2016; Chaindhury & Hammer, 2003). Finally, extended hours of operation are only feasible if facilities have access to a source of energy, which contributes to the continuous provision of services as these should be available beyond the daylight hours (WHO, 2014). Extended hours also increase the number of patients that come into facilities and their perceived quality of health service delivery (Chen, Chindarkar, & Xiao, 2019; Irwin, Hozha, & Grepin, 2019).

Long travel times to health facilities as well as transportation restrictions are also significant barriers to health care access, especially for low-income populations. Large distances, the lack of transport availability, and deficient road conditions inevitably delay medical attention, which threatens the lives of people who need it, especially for urgent care (Syed, Gerber, & Sharp, 2014; Kaibung, Mavole, & Okuku, 2017). For instance, pregnant women in remote areas are less likely to receive medical attention, and several maternal deaths might be prevented if access to emergency childbirth care was ensured (Babinard & Roberts, 2006). Remote areas might also face lower availability and retention of medical providers (Ojakaa, Olango, & Jarvis, 2014). In addition, lack of transportation or poor road quality conditions might negatively influence the availability of medicines. Without accessibility, meeting the demands for medicines could be more complicated and, therefore, medicines might be restocked less frequently, affecting the availability of drugs in the health centers (Hall, Radebe, & Roberts, 2006; Kaibung, Mavole, & Okuku, 2017).

Finally, having access to the internet and ICT improves access to medical knowledge, to other peers and experts, and access to patients. Connectivity and mobile and internet infrastructure have been proven pivotal in the COVID-19 context, enabling medical services even at a distance through telemedicine. Furthermore, ICT and internet access also allow facilities to access worldwide information that can be used, from learning opportunities to external consultations to discussing diagnostics with experts (Bukachi & Pakenhan-Walsh, 2007). Finally, given its massification power, ICT also enables the broadcasting of information on a large scale, which can be valuable for health promotion (Dutta, Gupta, & Sengupta, 2019).

ICT might also be beneficial for increasing the efficiency of facilities when used for administrative tasks. For example, using ICT may help to reduce drug stock-out, time spent on paperwork, and patients' waiting time (Achampong, 2012; Nilseng, et al., 2014; Githinji, et al., 2013; Kaibung, Mavole, & Okuku, 2017). Access to ICT and the internet might then improve the efficiency of medical personnel by ensuring a better supply of needed inputs such as medicines or vaccines, enhancing their knowledge by having access to information and freeing up time previously spent on manual tasks.

The quality of care comprises a large variety of inputs, processes, and outputs. For this work, we focus our attention on the dimensions for which we have data to test our hypotheses, as access to infrastructure and ICT. We acknowledge this scope omits other dimensions of quality that might be equally relevant but expect that future research can explore this further once the data to do so becomes available.

3. Data and Methodology

This section describes the data used in the paper and the construction of the main variables of interest. It then provides summary statistics and discusses some data limitations.

3.1. Data Sources

We combined high-quality georeferenced facility survey data with geospatial data on infrastructure and location-specific characteristics for this analysis, including:

Service Delivery Indicators Data

The Service Delivery Indicators (SDI) initiative gathers comparable international information on service delivery for education and health around the world. These data help to identify gaps, track changes over time, benchmark progress, stimulate evidence-based debate, and ultimately, influence how countries design policies and interventions to accelerate progress in human capital outcomes. Even when service coverage has been shown to have increased in many countries, the quality remains uneven, and the investments in expansion and access have not been matched with human development outcomes (World Bank, 2021). The SDI surveys develop a set of critical indicators that benchmark service delivery performance to provide valuable inputs for direction and policy making, increase public accountability, track progress over time and improve quality and human capital accumulation across countries (World Bank, 2018). Launched by the World Bank in partnership with the African Economic Research Consortium and the African Development Bank in 2010, the SDIs for health and education were piloted in 2010 in Senegal and Tanzania, implemented in Kenya in 2012. Since then, they have been scaled up to cover more than 15 African countries and adapted outside Africa, like in Iraq, Indonesia, Bhutan, and Moldova, where work is ongoing (Gatti R., et al., 2021).

The SDIs are nationally representative surveys that involve three dimensions of health care service provision: (i) providers' knowledge, (ii) providers' effort, and (iii) providers' inputs to work. SDI surveys allow for assessing how these elements come together to produce quality health services in the same facility. Data collection is undertaken by enumerators visiting selected medical facilities in announced and unannounced visits and observing providers' performance, the availability of inputs, and the infrastructure in place.

For this analysis, we rely on the SDI health survey implemented in Kenya in 2018, the largest to date, for which 3,094 facilities, of which 1,718 public and 1,313 private facilities, were visited between March and July 2018. The survey is representative of each of the 47 counties, the location of facilities (i.e., urban or rural), facility ownership (i.e., public or private), and facility level (i.e., hospital, health center, or dispensary and clinic).

Data on service delivery performance, including the availability of inputs and medical providers' knowledge, are aggregated at the facility level. We focus on questions related to the availability of resources, such as medicines and vaccines, and providers' knowledge, focusing on early childhood and maternal health. For the former, enumerators verify firsthand the availability of non-expired medicines and vaccines from a list of essential pharmaceuticals and maternal and reproductive products. For the latter, Patient Case Simulations (PSC, also called vignettes) are performed to assess the providers' diagnostic and treatment accuracy for specific illnesses of wide prevalence in the country. A random sample of staff is selected in each facility[5] with one of the enumerators presenting different cases of a sick patient to each health provider while the other acts as an observer. Section 3.2 describes the variables built based on SDI questions.

[5] Up to ten medical personnel from those who regularly treated patients.

Geospatial data sources

Master List of health facilities in Kenya

The most up-to-date health facility roster in Kenya has been constructed by the health unit research of KEMRI-Wellcome Trust Research Programme. The list contains 11,544 public and private facilities, of which 10,131 have GPS coordinates. It includes information on geopolitical divisions (i.e., County, Sub-County and Ward), as well as basic information on each facility, such as name, type, ownership, and operational status. This list of facilities allows us to verify information collected during the 2018 SDI. This data source approximates the universe of health facilities in Kenya.

Access to electricity

The Global Electrification Platform (GEP) is a platform and a set of tools designed to allow users to explore least-cost electrification solutions.[6] The tool enables users to navigate several scenarios for electrification investment. For this study, the 2018 baseline was used to assess the electrification status at the facilities. The information is calculated at the settlement level, and all health facilities are attributed to their respective settlement's electrification status. Figure 2 shows the electrification status of all the facilities included in the Master List of health facilities in Kenya.

Internet Connectivity (GSMA data)

Figure 2: Access to electricity for health facilities using the Global Electrification Platform

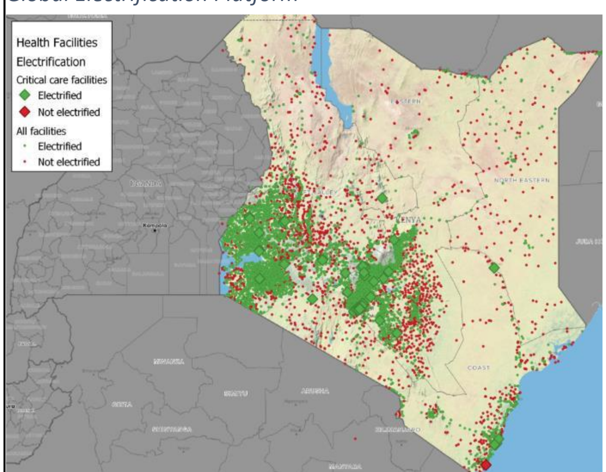
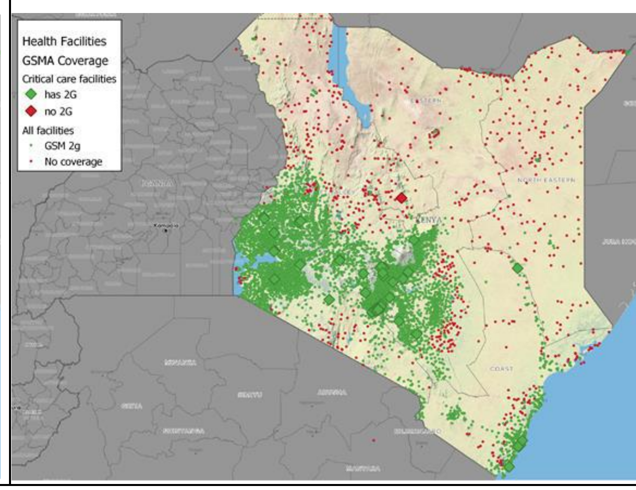


Figure 3: Access to 2G coverage



Note: The maps show connectivity status for all facilities as listed and referenced in the Master List.
Source: Global Electrification Platform and GSMA

Global System for Mobile Communications (GMSA) provides a data set of coverage of second- and third-generation cellular networks (i.e., 2G and 3G). The primary difference between 2G and 3G networks for mobile subscribers is that they can access faster internet browsing and data downloading on 3G. The information is generated through a combination of operator-submitted data and coverage from the open database OpenCellID. We combine these data with our georeferenced facility layers to assess whether each facility is disconnected from the network or has access to any mobile internet connectivity options. Figure 3 shows 2G coverage for all the facilities listed in the Master List, where 20.22% of facilities were not in an electrified settlement as reported by the GEP, 8.56% lacked 2G coverage following GSMA, and 6.48%

[6] https://electrifynow.energydata.info/

of facilities lacked both services. Figures 2 and 3 demonstrate the evidence of the gap in access to infrastructure for health facilities in Kenya, with some rural facilities far from the most populated cities lacking electricity and internet connectivity.

Road connectivity

We use two sources of road data: the Global Friction Surface 2015 and georeferenced road network data from government sources (Kenya Road Fund 2018). The Global Friction Surface 2015 enumerates land-based travel speed for all land pixels between 85 degrees north and 60 degrees south for a nominal year 2015.[7] It was produced through a collaboration between the University of Oxford Malaria Atlas Project (MAP), Google, the European Union Joint Research Centre (JRC), and the University of Twente, Netherlands. The underlying data sets used to produce the map include roads (comprising all Open Street Map and Google roads data sets), railways, rivers, lakes, oceans, topographic conditions (slope and elevation), landcover types, and national borders. A speed of travel in terms of time to cross is allocated to each pixel. The final map represents the travel speed from this allocation process, expressed in units of minutes required to travel one meter. We also use a road network from the Kenya Road Board for 2018 that relies at least partially on actual road surveys. The road network data set features surface type and road conditions.

We use the Global Friction Surface 2015 to calculate the catchment area of population for each health facility, which represents the number of people that can be reached in a certain amount of time given the time allocated on the Global Friction Surface. We use the road network to calculate the orthogonal distance of each facility to the nearest fair- or good-quality road.[8]

Socioeconomic factors

We use local estimates of deprivation scores, a proxy for poverty, calculated by the Poverty Global Practice at the World Bank. These calculations were done in small areas for the whole country, providing helpful information for comparisons within counties in Kenya. The methodology used and leveraged the "Small Area Estimation of Poverty under Structural Change" by Lange, Pape, & Putz, 2018. Poverty is estimated for each sub-location in two stages by estimating household consumption using census data.[9] In the first one, a consumption model is developed using survey data[10] but including non-variable household characteristics from the census. In the second stage, the estimated parameters are applied to census data, providing estimates for welfare at the sub-location level. In Kenya, 7,110 sub-locations were used in the analysis; on average, each had 120 households. The measure of poverty is included in the analysis as a control and proxy for the facility's resources.

3.2. Key Variables and Summary Statistics

We first merge the SDI data set and the Master List of facilities which results in a subset of 2,578 facilities. This means that 15% of the 2018 SDI facilities could not be found in Kenya's Master List of facilities. This final sample was complemented with information on road, electricity, and cellphone internet access, with additional data described in the previous subsection.[11]

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[7] D.J. Weiss, A. Nelson, H.S. Gibson, W. Temperley, S. Peedell, A. Lieber, M. Hancher, E. Poyart, S. Belchior, N. Fullman, B. Mappin, U. Dalrymple, J. Rozier, T.C.D. Lucas, R.E. Howes, L.S. Tusting, S.Y. Kang, E. Cameron, D. Bisanzio, K.E. Battle, S. Bhatt, and P.W. Gething. A global map of travel time to cities to assess inequalities in accessibility in 2015. (2018). Nature. doi:10.1038/nature25181.

[8] For quality road we followed the definition of the Rural Access Index: "*Good roads are paved roads that look dark and are not eroded. Fair roads are either paved roads in fair condition or good gravel roads that are motorable*" (Iimi, et al., 2016).

[9] 10% of the Kenya Population and Housing Census (KPHC), randomly selected.

[10] The Kenya Integrated Household Budget Survey (KIHBS) conducted between 2015 and 2016.

[11] The restricted sample works with the facilities that merges with the reviewed Master List. Moreover, an initial inclusion of "Distance to the nearest Facility" made it necessary to work with facilities in the 10,131 list.

We focus on four indicators of quality for health service delivery: (i) provider's knowledge, (ii) availability of vaccines for children, (iii) availability of essential medicines; and (iv) availability of antenatal care (ANC) tests. All service delivery variables are calculated from the SDI data. Providers' knowledge is measured using the diagnostic accuracy rate aggregated at the facility level for general illnesses and diseases of children and pregnant women. Availability of vaccines is the percentage of vaccines available at the facility as a proportion of the seven essential vaccines asked in the survey: Rubella, Polio (OPV/IPV), Rotavirus, Pentavalent, Pneumonia, Bacille Calmette-Guerin (BCG), and Vitamin A. Likewise, availability of medicines is defined as the proportion of medicines available at the time of the survey in relation to the 19 essential medicines asked in the survey according to the standards of the World Health Organization (WHO). Finally, ANC tests refer to the number of the type tests available at the facility out of four test types (see Appendix for complete list of medicines and ANC tests).

Access to infrastructure is captured by five variables at the facility level: (i) access to electricity, differentiated by stable and unstable access,[12] (ii) the use of ICT for supply management, (iii) the availability of fridges for vaccine storage, (iv) distance to a primary or secondary road of at least fair quality[13] and (v) cellphone internet access (2G or 3G). Extensive description of the construction of the variables is provided in the Appendix. To refer to the specific questions used to construct the indicators, see Table A4.

Table 1 presents descriptive statistics for the main variables used, indicating the source of each of them (whether SDI or Geospatial information). A large fraction of health facilities is located in rural areas (76%), and over half of the sample are public institutions (63%). Most facilities have access to electricity (89%), mainly because of their connection to the national grid. Still, there is variation regarding the connection quality: only 55% of facilities have stable access to electricity. Likewise, most facilities have access to improved sources of water and sanitation as defined by the WHO,[14] and have basic medical equipment[15] (83%). There is variation in poverty levels, catchment areas, and access to other services (e.g., 2G/3G) for health facilities in Kenya.

[12] Stable access to electricity: without interruptions in the last three months, or with interruption but access to a secondary source. Unstable access to electricity: with interruptions in the last three months and without access to a secondary source.

[13] Several distance and quality variables were analyzed, and "Distance from a health facility to at least "fair" quality Primary Road (Trunk) or Secondary Road (Km)" was the best fitted variable.

[14] https://www.who.int/water_sanitation_health/monitoring/jmp04_2.pdf

[15] Basic equipment is a dummy variable indicating whether the facility has a thermometer, a stethoscope, a sphygmomanometer, and a weighing scale.

Table 1. Descriptive statistics

Variable	SDI	GEO	Mean	Std. Dev.	Min.	Max.	N
General Diagnostic accuracy	x		65.739	20.055	0	100	2578
Children and mothers' cases diagnostic accuracy	x		67.471	19.984	0	100	2575
%Medicine Availability	x		44.686	23.547	0	94.737	2578
%Vaccine Availability	x		89.641	25.608	0	100	2023
ANC tests available for pregnant women	x		2.08	1.595	0	4	2230
Access to electricity	x		0.893	0.31	0	1	2578
Stable Access to electricity	x		0.555	0.497	0	1	2301
Unstable Access to electricity	x		0.445	0.497	0	1	2301
Access to improved sources of water	x		0.888	0.315	0	1	2578
Access to improved sources of sanitation	x		0.718	0.45	0	1	2578
Having a working fridge	x		0.925	0.264	0	1	1826
Having basic equipment	x		0.831	0.375	0	1	2578
Use ICT for supply management	x		0.147	0.354	0	1	2569
Access to 2G network		x	0.877	0.328	0	1	2578
Access to 3G network		x	0.173	0.379	0	1	2578
Catchment population area (x 100,000 inhabitants)		x	7.089	12.482	0	62.601	2577
Distance to at least "fair" quality Primary Road or Secondary Road (Km)		x	1.982	5.415	0	95.213	2578
Public	x		0.63	0.483	0	1	2578
Rural	x		0.766	0.423	0	1	2578
Deprivation score		x	38.179	17.378	1.388	92.915	2549

3.3. Methodology

To analyze the relationship between quality of health services and infrastructure variables, we use linear regressions controlling for characteristics at the facility-level. Fixed effects at the county level are included in the specifications as Kenya devolved health services to its 47 semiautonomous counties in 2013. Equation 1 describes the model used in the analysis:

$$Quality_{fac} = \beta_0 + \sum_{t=1}^{T} \beta_t INF_{fac} + \sum_{i=T+1} \beta_i \, Controls_{fac} + \alpha_{county} + \varepsilon_i \quad (1)$$

Where $Quality_{fac}$ are the health service quality variables at facility level (i.e., provider's knowledge or medicines/inputs availability), and INF_{fac} are the infrastructure access variables (i.e., electricity, distance to a fair/good quality road, access to internet/cellphone coverage, or ICT use). $Controls_{fac}$ are control variables at the facility level, including rural/urban, public/private, facility-level (hospital, health center, or dispensary), and a proxy for poverty small-area estimations. Finally, α_{county} are county fix effects and ε_i is the random error term. In general, the large set of controls at the facility level that measure surrounding their characteristics allow us to clean our correlations between quality of health service delivery and infrastructure variables to some extent.[16]

3.4. Limitations of the Study

This section describes the limitations of the proposed approach for the analysis and each data source used and the discrepancies found between different sources.

[16] Interactions between infrastructure variables (i.e., road connectivity and electricity access) were considered but the results did not explain the relationships better than the proposed model. Future research can explore this interdependencies more deeply.

Restricted dimensions of quality of health care and infrastructure

The analysis is restricted to the relationship between health services quality and infrastructure dimensions for which we have data. As health care quality is a multidimensional concept, we are not able to explain all its variability with the proposed approach and the available data sets. However, our approach allows us to explore the associations between the variables of interest and provide suggestive evidence on the relevance of the access to infrastructure to the quality of health services in Kenya. We based our discussion and recommendations acknowledging these limitations of the methodology.

Longitudinal and cross-sectoral dimensions of SDI

Despite SDI surveys being a rich source of information, these data did not allow us to pursue a causal analysis due to lack of an exogeneity source. Therefore, this study only presents correlations between access to infrastructure and health service quality. These are still useful benchmarks for illustrating the potential that investments in infrastructure might have for improving the quality of health service delivery.[17]

Infrastructure is a cross-sectoral and typically long-term investment that might influence services simultaneously in multiple sectors over many years. Ideally, the education SDI data would also have been exploited in this paper, but the 2012 education data was several years more outdated and done at a smaller scale (i.e., only representative at the country level, not at the county level). Moreover, it was impossible to perform an intertemporal analysis using the 2012 and 2018 health SDI data sets due to several methodological changes that made data not fully comparable over the years (e.g., different sample methodologies, different facilities, and different levels of representativeness).

Finally, as mentioned before, the last SDI data set for Kenya is from 2018. Although it is not completely outdated, in the past years, Kenya has made important improvements both in infrastructure and health service delivery, which might not be captured by the present analysis. Nevertheless, for the purpose of the analysis, we use the most up-to-date data available.

Limitations of geospatial data

The main limitation of geospatial data is that the information is not as granular as for the SDI data set. For example, the Master Facility List, although the most updated list of health centers in Kenya, contains very limited information about each facility (i.e., level of the facility and ownership). Additionally, the calculations for other geospatial data are often predictions for small areas based on multiple data sources, and in some cases the calculations based on sources like MAP might be challenging because of the geospatial coverage range capacity. This makes it less precise for the analysis as compared to SDI data collected directly from health facilities and more susceptible to capture other geographical aspects such as urban/rural status. Also, the information estimated with geospatial data is less specific than SDI data; for instance, it is only possible to study access to electricity (a dummy variable) instead of the quality of the connection at this stage.

[17] Other dimensions of quality of health service delivery were also considered but not included in this paper. For instance, one attractive aspect of the 2018 SDI is that it included an exit interview for users, capturing the supply side of the services and the perceptions of the demand. Nevertheless, the sample of users is small (up to five patients per facility, with many facilities having only one patient interviewed), questions were only asked about family planning services, and there is no variation in the inpatients' perceptions of quality.

systemic differences were discovered during the analysis. We carry out a more nuanced comparison between the type of information each data source provides, as well as the magnitude of these differences and their causes in Appendix II. Due to the granularity of SDI, which includes information on source and quality of electricity, as well as differences in definitions and on expected accuracy from direct observations versus small-area estimations, this paper favors the use of SDI data on access to electricity. Nonetheless, we note that the GEP data might still provide useful information for other studies when no first-hand data is available, particularly when using electrification as a control that might also capture other socioeconomic variables.

4. Results

This section presents and discusses the main results for each quality indicator. All specifications include controls at the facility level and county fixed effects.

4.1. Provider's Knowledge

Diagnostic errors are a source of avoidable illness and death, now more than ever since many previously incurable conditions now have a treatment (Khullar, Jha, & Jena, 2015). We explore here two indicators for diagnostic accuracy, one related to children and adults' illnesses and another one focusing on children and pregnant women-related ailments. As shown in Table 2, access to a stable electricity connection is positively related to diagnostic accuracy at the facility level, while longer distance to the nearest at least fair quality road is negatively related with this measure of provider's knowledge.

Column 1 in Table 2 displays the results for general cases (diarrhea with dehydration, pneumonia, diabetes, and tuberculosis). Here, access to electricity service is related to an increase of 4.20 percentage points in the diagnostic accuracy compared to facilities without access to electricity. Even though unstable access to electricity is also positively related to diagnostic accuracy, the relationship is not significant. Column 2 shows diagnostic accuracy for childhood and pregnant women cases (diarrhea with dehydration, pneumonia, post-partum hemorrhage, and neonatal asphyxia); the results follow the same logic, with a positive and significant relationship between access to a stable electricity connection and diagnostic accuracy of 5.03 percentage points.

The specification includes controls for a comprehensive set of facility-level covariates, including access to improved sources of water or sanitation and small area poverty and population density estimations to control for possible sorting. Given the broad set of controls used, the results suggest that facilities with better infrastructure might attract and/or retain better-skilled providers, which is in line with evidence from Lenz, L. et al., 2016, where mainly for rural areas, access to grid electricity facilitates recruiting trained staff in Rwanda.

On the other hand, increasing distance to at least a fair quality primary or secondary road is negatively related to provider's diagnostic accuracy at facility level. Using the quantile distribution of this geospatial variable by distance, it is seen that the further the facility is from fair or good quality roads, the worse the results of provider knowledge. While there seems not to be any significant differences between quintiles one and two, facilities in the third quintile of the distance variable have 3.7 and 2.5 percentage points lower diagnostic accuracy than at the facilities which are in the first quantile - the closest to the fair or good quality roads. This relationship intensifies with distance, and the farthest facilities are estimated to have 4.9 and 4 percentage points lower diagnostic accuracy than those closest to fair or good quality roads.

Our results may indicate that, despite the country's efforts to make hard-to-reach areas more attractive to health workers (Ministry of Health, 2009; Ministry of Health, 2015), health centers in remote areas still face transportation barriers for the recruitment and retention of top-performance medical providers, as documented in Ojakaa, Olango, & Jarvis, 2014 for Kenya. The findings on the relationship between providers' knowledge and the access to electricity and distance to the nearest fair or good quality road highlight the importance of facilities' infrastructure quality for health provider retention (Ojakaa, Olango, & Jarvis, 2014; Rockers, et al., 2012; Rowe, de Savigny, FLanata, & Victora, 2005; WHO, 2010; Lenz, Munyhirwe, Peters, & Sievert, 2016).

Table 2. Linear regression for diagnostic accuracy

	(1) Diagnostic Accuracy	(2) Children and mother illness Diag. Accuracy
Stable Electricity vs No Access	4.20***	5.03***
	(1.44)	(1.50)
Unstable Electricity vs No Access	2.04	1.88
	(1.43)	(1.47)
2G vs No Access	2.66	-2.08
	(1.83)	(1.86)
3G vs No Access	2.19	-2.22
	(2.42)	(2.45)
Second quantile road distance	-1.76	-0.89
	(1.13)	(1.15)
Third quantile road distance	-3.71***	-2.51**
	(1.16)	(1.21)
Fourth quantile road distance	-4.93***	-4.05***
	(1.20)	(1.24)
Public	3.70***	5.46***
	(1.01)	(1.00)
Rural	-2.14*	-1.69
	(1.28)	(1.28)
Deprivation Score	-0.09*	-0.06
	(0.05)	(0.05)
Catchment pop.	-0.03	0.01
	(0.08)	(0.07)
Hospital vs Dispensary	2.94**	0.62
	(1.28)	(1.45)
Health Center vs Dispensary	2.49**	-0.97
	(0.97)	(1.07)
% of Male-Facility	2.33*	1.41
	(1.32)	(1.34)
Average providers age -Facility	-0.14***	-0.23***
	(0.05)	(0.05)
% Post-secondary education-Facility	10.63***	7.37***
	(1.62)	(1.47)
Constant	58.00***	66.09***
	(4.42)	(4.36)
Observations	2,548	2,545
R-squared	0.17	0.15
Controls	Yes	Yes
Fixed Effects	County	County
Mean	65.74	67.47

Robust standard errors in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$

4.2. Availability of Vaccines

Vaccines are pivotal and cost-effective solutions for individual and collective well-being (Owais, Hanif, Siddiqui, Agha, & Zaidi, 2011; Ramalingaswami, 1989; Schuchat, 2011). In Kenya, more than one out of seven children die before the age of five, largely from causes related to preventable diseases for which the best response is to promote immunization (CDC Kenya, 2017). From our sample, 78.45% of the facilities provide vaccination services, and only these are asked about the availability of vaccines. The survey also gathered information about whether the vaccines were stored at the facility and whether the center used a fridge for storing vaccines.[18] All the vaccines mentioned in the survey questions require refrigeration (i.e., Rubella, Polio (OPV/IPV), Rotavirus, Pentavalent, Pneumonia, Bacille Calmette-Guerin (BCG), and Vitamin A). The relationship between the percentage of available vaccines and access to electricity and fridge is expected to be positive and significant, and it is indeed the case.

Table 3. Linear regression for vaccines availability

	(1) % Vaccines	(2) % Vaccines	(3) % Vaccines
Stable Electricity vs No Access	10.47***	1.18	1.07
	(2.63)	(1.32)	(1.25)
Unstable Electricity vs No Access	11.21***	0.98	0.90
	(2.66)	(1.30)	(1.23)
Having a fridge		5.46**	
		(2.70)	
Having a working fridge			10.93***
			(2.71)
Uses ICT for supply chain		0.01	0.01
		(1.21)	(1.22)
Second quantile road distance	5.52***	1.56	1.61
	(1.75)	(1.17)	(1.18)
Third quantile road distance	4.80**	1.57	1.55
	(1.88)	(1.15)	(1.14)
Fourth quantile road distance	3.09	1.32	1.35
	(1.96)	(1.14)	(1.13)
# Outpatient last 3 months	0.00**	0.00**	0.00**
	(0.00)	(0.00)	(0.00)
Catchment pop.	0.09	0.03	0.03
	(0.06)	(0.04)	(0.04)
Constant	71.60***	88.67***	84.53***
	(7.05)	(4.19)	(4.54)
Observations	1,994	1,794	1,794
R-squared	0.11	0.09	0.12
Controls	Yes	Yes	Yes
Fixed Effects	County	County	County
Mean	89.64	95.67	95.67

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Column 1 in Table 3 shows the importance of access to electricity for the availability of vaccines. Having access to electricity is associated with an increase of 10 to more than 11 percentage points in the percentage

[18] A description of the scheme of questions is in the appendix, Figure A1 .

of types of vaccines available at the facility. Note that already 89% of facilities in Column 1 have vaccines available. Column 2 shows the results when the variable for having a fridge (working or not) is included. Here, the relation of electricity and the availability of vaccines is captured through the use of a refrigerator for storage with an associated increase of 5.46 percentage points in the percentage of vaccines available. Moreover, when only a working fridge is included in the specification, the association is higher, stating that a functioning refrigerator is associated with the full availability of vaccines.

On the supply side, the availability of the vaccines *in situ* is key for achieving higher immunization levels. Ensuring a reliable connection to electricity, and the necessary equipment for storage in all facilities might then increase the coverage of vaccination plans. Here, it is relevant to highlight that vaccine coverage might also depend on factors like financial autonomy of vaccine programs and supply chain capacity, but our results indicate infrastructure *in situ* is also associated with the availability of vaccines at facility level. Finally, it is relevant to mention that in reducing infant mortality related to preventable diseases, motivating the demand side is also relevant, especially after the COVID-19 crisis has interrupted the vaccination schemes of many children around the world.

4.3. Availability of Medicines

Medicines are essential components of patient care, and their availability is commonly cited as one of the most crucial elements of quality by health care consumers (Ministery of Health, 2013). Therefore, medicines are critical for the health service provision and pivotal to attend to the population's health care needs (WHO, 2010). Here we analyze two sets of medicines: (i) the list of 19 tracer medicines for children and pregnant women identified by the WHO, and (ii) the list of 10 medicines fundamental for health care systems also identified by the WHO. Results for both lists of medicines are consistent, so here we focus on (i) and present the results for (ii) in Table A5 in the Appendix.

Table 4 shows the results for the list of medicines for children and pregnant women. A stable connection to electricity is related to an increase of 4.5 percentage points in availability of medicines. Furthermore, ICT use for supply management is also positively related to the availability of medicines with a magnitude of 6.79 percentage points. Our transport variable, the distance of the facility to a primary or secondary road in at least fair condition seems not to be correlated with the medicines stock. While a significant difference arises between the first two quintiles of the variable, there is no significant difference in the availability of the selected essential medicines from the closest and further facilities. On the other hand, access to cellphone internet is negatively associated with the percentage of essential drugs in the facilities. While the latter result is surprising, we interpret the cellphone internet access as a proxy for the degree of rural/urban, suggesting the most remote facilities have more medicine availability.

This group of essential medicines need to be available at all facilities to meet the basic health care needs of the population, and there is room for improvement. Only 15% of our sample of facilities use ICT for supply management and, even when almost 90% of the facilities have access to electricity, only half of them have a stable connection. Therefore, as stable electricity and ICT for supply management are positively related to the availability of essential drugs, these two might be leveraged to effectively manage the stock of medical supplies and increase its availability for patients.

Table 4. Linear regression for essential medicines for children and pregnant women availability

	(1) % Medicine available	(2) % Medicine available	(3) % Medicine available
Stable Electricity vs No Access	4.88***		4.50***
	(1.34)		(1.33)
Unstable Electricity vs No Access	0.55		0.76
	(1.29)		(1.29)
Uses ICT for supply chain		7.33***	6.75***
		(1.56)	(1.55)
# Outpatient last 3 months	0.00***	0.00***	0.00***
	(0.00)	(0.00)	(0.00)
Second quantile road distance	2.93**	2.98**	2.91**
	(1.26)	(1.24)	(1.24)
Third quantile road distance	0.58	0.61	0.76
	(1.26)	(1.26)	(1.25)
Fourth quantile road distance	0.81	0.98	0.93
	(1.21)	(1.20)	(1.20)
2G vs No Access	-5.32***	-5.61***	-5.37***
	(1.62)	(1.61)	(1.61)
3G vs No	-11.97***	-11.97***	-12.07***
	(2.51)	(2.49)	(2.50)
Catchment pop.	0.18**	0.18**	0.18**
	(0.09)	(0.09)	(0.09)
Constant	45.63***	45.71***	42.76***
	(4.75)	(4.62)	(4.69)
Observations	2,539	2,530	2,530
R-squared	0.40	0.41	0.41
Controls	Yes	Yes	Yes
Fixed Effects	County	County	County
Mean	44.69	44.69	44.69

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

4.4. Availability of Antenatal Care Tests

Promptly detecting potential risks to children's health in utero and/or pregnant women is essential to avoid fatal consequences. In Kenya, Maternal Mortality Ratio (MMR) is 362 maternal deaths per 100,000 live births (DHS Program, 2014),[19] and the stillbirth rate is between 18.32 and 21.09 per 1,000 births according to UNICEF estimates (UNICEF, 2020). Although the indicators have indeed improved in the last decade, they remain far from their targets, which are 147 and 12, respectively for maternal deaths per 100,000 live births and stillbirth rate per 1,000 births (Lang'at, Mwanri, & Temmerman, 2019). Antenatal care (ANC) tests are essential to diagnose possible complications that require special attention during pregnancy, which is critical to attain those goals. Therefore, facilities must provide ANC tests to pregnant women and have them readily available.

[19] The latest available data is from 2014.

This analysis involves four ANC tests in line with Kenyan national guidelines: HIV, Urinalysis, Hemoglobin, and Syphilis. Table 5 displays the results for the number of tests provided at the facility, the variable being ANC test between 0 and 4. Similar to what has been found before, electricity service is positively related to the provision of tests, but in this case, the relationship is significant for both stable and unstable connections. The use of ICT for supply management is also positively correlated with the number of tests provided, which might be explained by the need for inputs to perform the rapid tests (strips, containers, etc.). Farther distance to the nearest road of fair or good quality is negatively related to the number of ANC tests provided for the farthest facilities compared to the ones at the facilities with the closest distance to the nearest fair or good quality toad; this might indicate that farther the facilities, more barriers they face in getting the needed inputs. It is worth noting that better infrastructure might also increase the demand for medical services. This may be the underlying reason for the statistically significant relationships between ANC tests and infrastructure variables such as electricity.

Table 5. Linear regression for Antenatal Care test availability

	(1) ANC test	(2) ANC test	(3) ANC test
Stable Electricity vs No Access	0.56***		0.55***
	(0.09)		(0.09)
Unstable Electricity vs No Access	0.49***		0.50***
	(0.09)		(0.09)
Uses ICT for supply chain		0.27**	0.26**
		(0.11)	(0.11)
Second quantile road distance	0.14	0.14	0.13
	(0.09)	(0.09)	(0.09)
Third quantile road distance	-0.16*	-0.18*	-0.15
	(0.09)	(0.09)	(0.09)
Fourth quantile road distance	-0.25**	-0.27***	-0.25**
	(0.10)	(0.10)	(0.10)
# Outpatient last 3 months	0.00***	0.00**	0.00**
	(0.00)	(0.00)	(0.00)
2G vs No Access	0.27**	0.26**	0.26**
	(0.13)	(0.13)	(0.13)
3G vs No Access	0.23	0.24	0.22
	(0.20)	(0.20)	(0.20)
Catchment pop.	0.01**	0.01**	0.01**
	(0.01)	(0.01)	(0.01)
Constant	2.45***	2.78***	2.33***
	(0.36)	(0.35)	(0.36)
Observations	2,201	2,193	2,193
R-squared	0.34	0.33	0.34
Controls	Yes	Yes	Yes
Fixed Effects	Yes	Yes	Yes
Mean	2.080	2.080	2.080

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

5. Discussion

Overall, while this study does not present causal inferences, it does document the evidence of existing correlations between different infrastructure variables and the quality of health services provided in Kenya after controlling for a wide set of other characteristics. These results are supported with and complement other existing literature to study possible channels and/or corroborate findings.

In determining the quality of health services, many factors come into play. We acknowledge that health care quality and infrastructure have several dimensions that cannot be covered by the available data or the scope of this work, which might have influenced the variability or quality of the variables explained by our model. Nonetheless, with the existent information we have relevant evidence to positively associate infrastructure access to our analyzed dimensions of health quality. For the case of Kenya, this study finds suggestive evidence that infrastructure matters, and that investments in infrastructure and technology may play an important role in improving the quality of health service provision, including the services for early childhood and maternal health. These results contribute to the understanding of quality in the health services from a supply side, by exploring dimensions of infrastructure to which it might be related and providing evidence on the relevance of the relationship. More work is needed to explore the quality of health services from a demand side perspective and, for both sides, more frequent and up to date data is needed to perform relevant and timely evaluations of the service and its components.

In terms of policy recommendations, in order to ensure that everyone, especially households in poorer and more isolated areas, has access to high-quality basic health services, it is important to prioritize electrifying the facilities that do not have access to electricity. While most facilities have access to electricity (89%), half do not have stable access, which is crucial for delivering health services, even in a broader scope than those analyzed here. In addition to the shown relationship between access to electricity and provider's knowledge, the availability of drugs, vaccines and medical inputs, a stable electricity connection is also key to perform tests (e.g., laboratory test), treat patients (e.g., use ventilators), be able to perform medical procedures from the simplest to surgeries, among others. Therefore, providing the health facilities with a nationwide access to stable electricity access remains a priority to be addressed in Kenya. Needless to say, this would be an investment that would benefit many other sectors and households directly.

Likewise, it is equally important to invest in and improve the accessibility to roads and enhance their quality. Our findings suggest that more and better roads might help facilities eliminate access barriers that allow health facilities to access inputs, patients, and providers with more ease. Making facilities more accessible, however, may not contribute to addressing these issues if other complementary measures are not put into place. For instance, the 2018 SDI data suggests that urban-based health care workers had similar levels of diagnostic accuracy scores as their rural counterparts. Therefore, just increasing access will not necessarily translate into better providers if the pool of qualified providers is not large enough.

Moreover, the evidence presented suggests that ICT may be a valuable ally for improving the efficiency of supply chains and distribution of inputs to their end users. Enabling facilities to access and use ICT may positively impact the availability of medicines and inputs and also save time and resources. There is a substantial potential to increase the use of ICT for supply chain management in Kenya since only 15% of the facilities reported using it for this purpose.

Overall, these results show that investments in infrastructure might have significant positive effects for the quality of health service delivery and might be a relevant factor for improving health (and possibly many other) outcomes in the population as a whole.

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Appendix

I. Definition of health and infrastructure indicators

Provider Knowledge: Diagnostic Accuracy

The selection of illnesses was based on the burden of the diseases among Kenya's population and its suitability to be simulated with the PSC method. Four conditions were evaluated for the general population, including two children's conditions (severe dehydration and pneumonia) and two adult illnesses (pulmonary tuberculosis and type I diabetes). The measure of diagnostic accuracy is the percentage of cases correctly diagnosed by the provider, and the variable analyzed here is the average diagnostic accuracy at the facility level.

A variable only related to children's and pregnant mothers' illnesses was also developed to be studied. This indicator includes the two conditions for children described before, plus post-partum hemorrhage and neonatal asphyxia, the most common causes of maternal and neonatal death during birth, respectively. Equation A1 illustrates the formula for the provider's knowledge variable applicable to each indicator (general and children and mothers related):

$$Provider's\ knowledge\colon \ \frac{\#\ cases\ correctly\ dignosed}{4} \qquad (A1)$$

Availability of vaccines

The SDI survey asked for seven vaccines for children: Rubella, Polio (OPV/IPV), Rotavirus, Pentavalent, Pneumonia, Bacille Calmette-Guerin (BCG), and Vitamin A. Information on vaccine availability is conditional on facilities offering vaccination services. Of our 2,578 facilities, 2,023 offered vaccination services. The vaccines availability indicator is the percentage of vaccines available that are observed by the enumerator, in stock and non-expired, as shown in Equation A2:

$$Vaccine\ availability : \ \frac{\#\ Vaccines\ in\ stock\ and\ unexpired}{7} \qquad (A2)$$

Availability of medicines

Two measures of the availability of medicines were developed for this analysis. One measure refers to drugs for general use, and the other one considers essential medicines for mothers and children. The first indicator is based on the percentage of 10 essential medicines available and in stock at the time of the SDI survey; these medicines are included in the World Health Organization's (WHO) list of essential medicines.[20] The medicines included under this measure are shown in Table A1. To assess the availability of drugs at the facility, the enumerator needed to observe the drug *in situ* and to verify that the facility had at least one not

[20] From the original list of fourteen medicines selected for the construction of medicines availability, four were not asked in the Kenya SDI. Therefore, the indicator presented only works with ten medicines.

expired item of each medicine on the day of the visit.

Table A1. List of WHO Medicines asked in Kenya's SDI

	WHO list-Kenya SDI	Function
1	Amitriptyline	Anti-depressant
2	Amoxicillin	Antibiotic
3	Atenolol	Beta blocker
4	Cefixime	Antibiotic
5	Ciprofloxacin	Antibiotic
6	Cotrimoxazole	Antibiotic
7	Diazepam	Anti-seizure
8	Glibenclamide	Anti-diabetic
9	Paracetamol	Analgesic
10	Salbutamol	Bronchodilator

The second measure includes essential medicines for children and mothers. A total of nineteen drugs were considered for this indicator:

Table A2. List of essential medicines for children and mothers. SDI,2018

Target	Medicine
Mothers	Oxytocin (injectable),
	Misoprostol (cap/tab),
	Sodium chloride (saline solution) (injectable solution)
	Azithromycin (cap/tab or oral liquid)
	Calcium gluconate (injectable),
	Cefixime (cap/tab)
	Magnesium sulfate (injectable)
	Benzathine benzylpenicillin powder (for injection)
	Ampicillin powder (for injection)
	Betamethasone or dexamethasone (injectable),
	Gentamicin (injectable)
	Nifedipine (cap/tab)
	Metronidazole (injectable),
	Medroxyprogesterone acetate (Depo- Provera) (injectable)
	Iron supplements
Children	Amoxicillin (syrup/suspension),
	Oral rehydration salts (ORS sachets)
	Artemisinin combination therapy (ACT)

	Artesunate (rectal or injectable)

Equation A3 shows the calculation of the availability of medicines at the facility level for both indicators, where *X* takes the value of ten for the general indicator based on the WHO list and nineteen for the second indicator of medicines for mothers and children.

$$Medicine\ availbaility:\ \frac{\#\ Medicines\ in\ stock\ and\ unexpired}{X} \qquad (A3)$$

Availability of Antenatal Care Tests

In Module I, the SDI survey asked whether providers at the facility level offered four tests to pregnant women:

- HIV rapid diagnostic test
- Urinalysis
- Any rapid test for hemoglobin
- Syphilis Rapid Diagnostic

The enumerator had to verify the availability of each test. The ANC test indicator points out the number of tests available on the day of visit at the facility level.[21]

Access to electricity

Module I of the SDI had a section dedicated to exploring the infrastructure of each of the facilities. The survey explored access sources to electricity and power -primary and secondary-, contemplating a connection to the national grid, solar panels, generators, and batteries. Beyond that, the questionnaire explored the stability of the service of primary sources, asking if the facility had service interruptions in the past three months from the survey and whether it had a secondary source of access. With information about the connection and reliability of the service, we build a categorical variable to describe the access to electricity and its quality. The variable takes the value of zero if the facility reported not having access to electricity (base category), one if the connection was stable (no interruptions in the previous three months or interruptions but access to a secondary source); and two if the connection was not stable (disruptions in the service).

ICT use

SDI also included information about the use of Information and Technology (ICT) use. From Module 1, we used a variable that asked about particular uses for ICT within the facilities. Several options were contemplated in this question, as shown in Table A3. For this study, we used information related to ICT use for supply chain management.

Table A3. Question of use of Information Communication Technology in the SDI

USE OF INFORMATION COMMUNICATION TECHNOLOGY (ICT)	
Does this facility use ICT for the following purposes?	Yes/No
A. Patient registration	|___|
B. Facility record keeping	|___|

[21] Information on ANC is only available for 2,312 facilities.

C. Individual patient records/Electronic Medical Record	|___|
D. Health Insurance Claims and Reimbursement System	|___|
E. Mobile money cash transfers and payments	|___|
F. Routine communication	|___|
G. Awareness and demand creation activities	|___|
H. Supply chain management/stock control	|___|
I. Health worker training	|___|
J. Clinical consultation (long-distance communication with experts)	|___|
K. Other (specify)	|___|

Table A4. Questions used to formulate Health Service Delivery Indicators

Indicator	Source	Module/Section	Question
Provider Knowledge	SDI	Module 3	Case scenarios were presented to the provider. Diagnostic was asked after the History taking and the Physical examination.
Medicines Availability	SDI	Module 1 Section E, Module 1 Section K	Are any of the following medicines available in the facility/location today? For each of the maternal/reproductive health medicines that I mention, please tell me if they are currently available in this facility.
Vaccines Availability	SDI	Module 1, section B	Are the following vaccines available in this service site today?
ANC test availability	SDI	Module 1, section B	Do ANC providers in this facility provide any of the following tests from this site to pregnant women as part of ANC?

Figure A1 Vaccine, storage ang equipment structure of questions

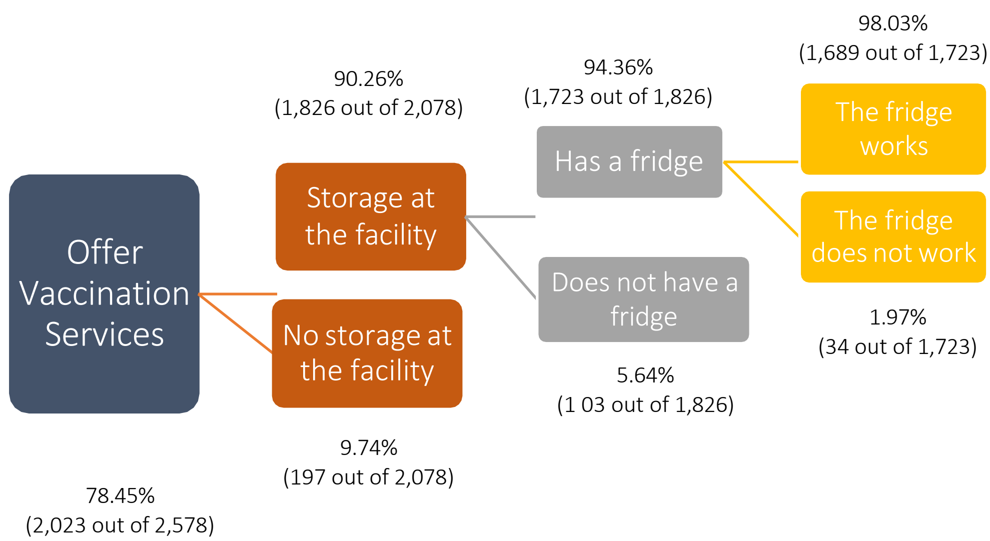

Table A5. Linear regression for ten essential medicines – WHO

	(1) % Medicine available WHO	(2) % Medicine available WHO	(3) % Medicine available WHO
Stable Electricity vs No Access	0.16		-0.07
	(0.99)		(0.99)
Unstable Electricity vs No Access	-1.56		-1.47
	(0.97)		(0.97)
Uses ICT for supply chain		3.80***	3.60***
		(1.08)	(1.09)
# Outpatient last 3 months	0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)
Second quantile road distance	-1.19	-1.19	-1.21
	(0.93)	(0.93)	(0.93)
Third quantile road distance	-2.64***	-2.52***	-2.55***
	(0.91)	(0.91)	(0.91)
Fourth quantile road distance	-1.70*	-1.60*	-1.71*
	(0.94)	(0.94)	(0.94)
2G vs No Access	0.89	0.60	0.69
	(1.43)	(1.43)	(1.42)
3G vs No Access	0.68	0.55	0.55
	(1.96)	(1.96)	(1.96)
Catchment pop.	0.05	0.05	0.05
	(0.06)	(0.06)	(0.06)
Constant	78.82***	77.04***	77.47***
	(3.56)	(3.51)	(3.61)
Observations	2,539	2,530	2,530
R-squared	0.31	0.32	0.32
Controls	Yes	Yes	Yes
Fixed Effects	County	County	County
Mean	69.09	69.09	69.09

II. Validating data on electricity between SDI and GEP data

This section describes the type of information each data source provides, as well as the magnitude of these differences and their causes.

Access to electricity based on SDI survey: Module I of the Kenya SDI has a section on infrastructure (Section C), in which the heads of each facility are asked about access, sources, and interruptions in the electricity service. This section contains detailed information on whether the facility has access to electricity, what the primary source of electricity is (i.e., national grid, generator, batteries, and solar, among others), interruptions in the service and their length, and whether or not the facility counts with a second source of electricity and its type. While the SDI data set contains detailed information on access and usage of electricity, it is restricted to the sample of health facilities surveyed; nevertheless, the sample is representative at the county level.

Access to electricity based on the Global Electrification Platform (GEP): The Global Electrification Platform is designed to allow users to explore electrification investment scenarios. We use the baseline data, which includes estimations of current electrification from the year 2018. The information is calculated at the settlement level; all health facilities are attributed with the settlement's electrification status. This data set cannot identify or assess individual facility stats, such as batteries or solar panels, but it is mainly based on access to the national grid. Nonetheless, the estimations incorporate variables on infrastructure (as high or medium voltage lines, road network, etc.), energy resources, socioeconomic distributions, and other features such as light through nighttime lights. In addition, the GEP data is available for all settlements in the country, allowing for a potential match with the universe of health facilities in Kenya. However, this analysis is restricted to the SDI sample to assess the validity of the data. Finally, due to geocoordinates measured with some noise in the SDI sample, around 5% of SDI facilities fall outside any of the settlements in the GEP.

Given the nature of the data sources and their construction, differences across them are found. For instance, 61% of the facilities that have no access to any source of electricity based on SDI data are located in electrified settlements based on GEP data. This is not necessarily contradictory since the GEP data only reports being in an electrified settlement, and that does not guarantee access to electricity at the facility level. Likewise, 22% of the facilities classified as having access to the electricity in the SDI are located in an unelectrified settlement as per GEP data (Table 6). Differences across these two data sources can potentially be explained by their definition, including the type of electricity source they capture and the geographical level at which the GEP is aggregated.

Table 6. Differences in access to electricity between GEP and SDI data (total percentage by row)

		GEP Electrified Settlement		
		No	Yes	Total
SDI Access to Any Source of Electricity	No	107 38.6%	170 **61.4%**	277 100%
	Yes	508 **22.1%**	1,793 77.9%	2,301 100%
	Total	615 23.9%	1,963 76.1%	2,578 100%

Facilities that appear not to be connected to electricity at GEP data, but that have access to electricity following the SDI are mostly grid-connected. At the same time, and even when GEP mainly captures connection to the national grid, some facilities with electricity in GEP have other sources of main access to electricity, like solar panels (Table 7).

Table 7. Distribution of GEP's missing between SDI's source of access (total percentage by column)

		GEP		
		No Access	Access	Total
Sources of access to electricity SDI	No access	107 17.40%	170 9.00%	277 11.00%
	National Grid	**274** **44.55%**	1656 84.36%	1930 74.86%
	Generator	6 0.98%	8 0.41%	14 0.54%
	Batteries (car)	0 0.00%	1 0.05%	1 0.04%
	Solar panel	221 35.93%	120 6.11%	341 13.23%
	Other (specify)	7 1.14%	8 0.41%	15 0.58%
	Total	615 100%	1963 100%	2578 100%

Due to the data issues mentioned above, we decided to use the SDI access to electricity information. Two points are essential to support this decision: First, SDI data allows to analyze access to electricity beyond being located in an electrified geographical unit. In particular, SDI information also enables the analysis of the quality of the connection by providing information about interruptions to the service and access to backup sources. Using this information, we construct a categorical variable that captures both access and service stability in three categories: (i) no access, (ii) unstable access, (iii) stable access, which includes access to electricity without interruptions AND access with interruptions but with a second source. On the other hand, the GEP electrification status variable only provides information on whether a facility is in an electrified settlement or not. Although settlements are a small geographic area, there are 388,631 settlements in Kenya with an average area of 1.5 km^2, making it possible for electricity access to fluctuate within settlements.[22] Therefore, the fact that a facility is within an electrified settlement does not guarantee access to electricity or reflects that the service is available in theory but not in practice because it could also be unstable or almost non-functional.

[22] This was estimated by dividing the total area of Kenya by the number of settlements.

The second reason for choosing SDI information is that while GEP captures settlement information from geospatial data available and estimated for small areas, SDI data is gathered at the facility level collecting information directly from health providers. This makes the data far more accurate and best suited for this study. Nonetheless, the GEP data might still provide useful information when no first-hand data is available, particularly when using electrification as a control that might also capture other socioeconomic variables.