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Infrastructure quality and firm productivity in Africa

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Abstract

Purpose – The World Bank (2017) ranks poor infrastructure, particularly electricity, as the second topmost obstacle (after access to finance) affecting enterprises in Sub-Saharan Africa. The purpose of this paper is to investigate the effect of infrastructure quality on firm productivity in Africa.

Design/methodology/approach – The author used the World Bank Enterprise Survey (WBES) for 26 African countries and employed both descriptive and ordinary least squares techniques during the analysis. The author circumvents the endogeneity of infrastructure in the productivity model by using firm-level measures of infrastructure quality rather than the stock of infrastructural capital.

Findings – On an average, 80 percent of manufacturing firms in Africa reported having experienced electricity outages in the financial year preceding the survey. Power outages are negatively associated with the productivity of small, medium, young, domestically owned firms and non-exporters. On the other hand, the author observes a substitution effect of generators for the unreliable power from the public grid and this effect positively influences the productivity of large, old, foreign-owned and exporting firms.

Practical implications – The author argues that in addition to infrastructure capital at an aggregate level, dealing with quality issues at firm level is required to enhance productivity. More attention needs to be put to the elimination of power outages so as to improve the productivity of all firms particularly those that cannot afford to use generators in the place of electricity from the public grid.

Originality/value – The author notes that there exists scanty empirical literature on the effect of infrastructure quality on productivity for the case of Africa despite the existence of WBES for at least two waves for both developed and developing countries. The uniqueness of this paper in comparison to the previous literature is that the author undertakes the analysis according to some important firm categories: size, age, ownership and export status. Additionally, the author uses the infrastructure quality to understand its effect on firm-level efficiency levels rather than the stock of infrastructural capital. The use of aggregate indicators of infrastructure introduces an endogeneity problem which the author circumvents in this study.

Keywords Infrastructure, Quality, Productivity

Paper type Research paper

1. Motivation

Good-quality infrastructure is crucial for enlisting efficiency gains at firm level which is very important for fueling overall economic growth (Escribano *et al.*, 2010; World Bank, 1994). Good-quality infrastructure not only "greases" the production space at firm level but also enhances the participation of firms in the global trading arena by lowering transaction or logistical costs (Helpman and Krugman, 1985; Escribano *et al.*, 2010; Holl, 2006; Roller and Waverman, 2001) as well as fostering access bigger labor markets (Duranton and Turner, 2012). Reinikka and Svensson (2002) designate infrastructure capital as complementary capital because it offers support services necessary for the operation of productive private capital. On the other hand, poor quality infrastructure and lack of connectivity partly accounts for the low competitiveness of many products from developing countries in the global markets as well as the low competitiveness of rural producers in the urban markets leading to low returns per unit hence dampening the speed of growth and poverty reduction (Escribano *et al.*, 2010; Mitra *et al.*, 2016). From an indirect viewpoint, infrastructure is argued to promote agglomeration of enterprises and businesses with productivity enhancing effects from technology spillovers and utilization of a common pool of resources including specialized labor (Wan and Zhang, 2017; Fujita and Thisse, 2013).

World Journal of Entrepreneurship, Management and Sustainable Development
Vol. 14 No. 4, 2018
pp. 367-384
© Emerald Publishing Limited
2042-5961
DOI 10.1108/WJEMSD-11-2017-0091

Indeed, early studies using aggregate data found that infrastructure such as electricity, water, roads and telecommunications were important drivers of economic growth not only in Sub-Saharan Africa but also elsewhere like in USA and India (Aschauer 1989a, b; Easterly and Rebelo, 1993; Easterly and Levine, 1997; Munnell, 1992; Loayza *et al.*, 2002; Mitra *et al.*, 2002; Estache *et al.*, 2005). These studies sought to understand the degree of responsiveness of economic growth to changes in the infrastructure capital of countries. The path-breaking works of Aschauer found that infrastructure capital stock had positive and significant efficiency effects in the USA and other developed countries as early as the 1950s and 1960s while Mitra *et al.* (2002) found a similar effect in India. Easterly and Levine (1997) used telephones per worker rather than spending to proxy infrastructure constraints and found that infrastructure drives growth. Additionally, Bougheas *et al.* (1999) and Röller and Waverman (2001) found that transport infrastructure greatly dampened trade cost in the European Union and in 21 Organisation for Economic Co-operation and Development countries, respectively. Li and Li (2013) agreed with previous authors by providing evidence that a dollar in road investment saved two cents in inventory costs in the manufacturing sector. However, all these authors did not pay particular attention to the quality of infrastructure probably because of lack of data that could provide a good measure of quality.

Another strand of literature using firm-level data assessed the impact of infrastructure on firm-level productivity (Reinikka and Svensson, 2002; Deichmann *et al.*, 2002; Escribano *et al.*, 2010; Commander *et al.*, 2011; Shiferaw *et al.*, 2012; Bertschek *et al.*, 2013; Bogetić and Olusi, 2013; Moyo, 2013; Velde, 2015; Mitra *et al.*, 2016; Wan and Zhang, 2017). Reinikka and Svensson (2002) used data on 243 Ugandan firms surveyed in 1998 where information on infrastructure services and private investment were collected. They provide evidence that poor complementary public capital significantly reduces private investment and that firms substituted for deficient public services by investing in complementary capital themselves. Deichmann *et al.* (2002) used firm-level data from the Mexican manufacturing sector and used external characteristics such as infrastructure quality and regulatory environment in explaining productivity differentials. They find that access to markets through improvements in transport infrastructure linking urban areas have significant efficiency gains at firm level.

Escribano *et al.* (2010) provided an empirical assessment of the impact of infrastructure quality on the total factor productivity (TFP) of African manufacturing firms using Investment Climate Surveys from 1999 to 2005. The authors find mixed results according to the income class of countries considered. For example, poor quality electricity provision affects mainly poor countries, whereas problems dealing with customs while importing or exporting affect mainly faster growing countries. Commander *et al.* (2011) use data on manufacturing firms in both Brazil and India to estimate the effect of ICT on productivity. The authors find a strong positive association between ICT capital and productivity in both countries. Shiferaw *et al.* (2012) combined GIS-based panel data on the road accessibility of towns with a unique panel of Ethiopian manufacturing firms for the period 1996-2009. They find that better road access significantly increases a town's attractiveness for manufacturing firms.

Bertschek *et al.* (2013) sought to provide empirical evidence for the causal impact of broadband internet on firms' labor productivity and process and product innovations. They find no support for the broadband internet and firm productivity linkage. However, they show that broadband internet drives innovation activity. Bogetić and Olusi (2013) used a rich Amadeus database as well as the recent EBRD/World Bank Business Enterprise and Performance surveys to study drivers of firm-level productivity in the Russian manufacturing sector for the period 2003-2008. They find

that infrastructure quality gaps reduce firm productivity with water supply gaps having the largest impact which is quite surprising for a high-income country like Russia that should not have water problems. Moyo (2013) analyzed the quality of power infrastructure in relation to firm-level productivity of Africa's manufacturing firms. The study found that number of hours of power outage per day and the percentage of output lost due to power outages negatively and significantly influenced productivity.

Velde (2015) study the impact of regional infrastructure on firm-level productivity encompassing the effects of trade for Sub-Saharan Africa. They observe that border crossing costs vary by firms for the same gateway, suggesting there is more to regional infrastructure than hard infrastructure. Mitra *et al.* (2016) studied the role of infrastructure and information and communication technology (ICT) and TFP in the Indian manufacturing sector for the period 1994-2008. The authors find that the impact of infrastructure and ICT is rather strong and more pronounced amongst sectors more exposed to foreign competition. Wan and Zhang (2017) used large-scale firm-level survey data of the period 2002-2007 from the People's Republic of China. They find that roads, telecommunication servers and cables were significant drivers of firm-level efficiency and also indirectly influenced firm-level efficiency via the agglomeration channel.

From the foregoing discussion, we note that there exists scanty empirical literature on the effect of infrastructure quality on productivity for the case of Africa despite the existence of World Bank Enterprise Surveys (WBES) for at least two waves for both developed and developing countries. We note that much of the empirical literature focusing on Africa was conducted before the new WBES that harmonized the survey questionnaire across the world (e.g Reinikka and Svensson, 2002; Escribano *et al.*, 2010). Yet, infrastructure inadequacies especially electricity has been ranked second topmost obstacle (after access to finance) affecting business operations in Sub-Saharan Africa (World Bank, 2017) calling for an urgent need for new evidence in this area. The absence of new empirical evidence regarding the effect infrastructure quality and firms productivity in African countries is the essence of this paper. The uniqueness of this paper in comparison all the rest of the literature is that we undertake both descriptive and empirical analysis according to some important firm categories: size, age, ownership and export status. Consequently, our findings are very enriching and recommendations are unique to particular firm groups. For example, a paper by Moyo (2013), apart from defining infrastructural quality narrowly, using only electricity outage as measure, does not undertake such in-depth disaggregated analysis like we do.

Additionally, this paper is different from previous papers (like Wan and Zhang, 2017) in the sense that we use the infrastructure quality to understand its effect on firm-level efficiency levels. Wan and Zhang (2017), just like studies that undertook a macro investigation, used the stock of infrastructural capital like the length of roads and the number of telecommunication servers to understand their efficiency effects at the firm level. The use of aggregate indicators of infrastructure introduces an endogeneity issue in the data set which many previous studies have been plagued with. The reverse causation is such that the growth in aggregate productivity may create the demand for infrastructure and vice versa (Reinikka and Svensson, 2002 and Escribano *et al.*, 2010). Consequently, following the works of Reinikka and Svensson (2002) and Escribano *et al.* (2010), this study employed firm-level disaggregated measures of infrastructure quality to circumvent the endogeneity problem during our estimations. Using a WBES data set for 26 African countries[1], this paper explores the effect of infrastructure quality on firm productivity. Our key research question is:

RQ1. Does the quality of infrastructure influence firm-level productivity?

The findings of this paper will advise African policy makers on how public infrastructure should be leveraged and targeted in order to ensure highest efficiency returns.

The reminder of the paper is as follows: the next section presents the methodology that includes the empirical strategy and data description. Section 3 presents the evidence of the impact of infrastructure quality on firm-level productivity gains. Section 4 concludes with implications for policy.

2. Methodology

2.1 Model

Following the works of Escribano *et al.* (2010), Bogetić and Olusi (2013), Wan and Zhang (2017) and Escribano and Guasch (2005), we estimated the effect of infrastructure quality on firm productivity using a Cobb-Douglas production function framework. The production function is written in an intensive form in order to allow output per worker to be our measure of firm-level efficiency/productivity:

$$y_{itjc} = \beta_o + \beta \inf_{tc} + \gamma' X_{itjc} + \lambda_t + \lambda_j + \lambda_c + \varepsilon_{itjc}, \quad (1)$$

where y_{itjc} is log output per worker of firm i in industry j at time t and country c which is a function of infrastructure quality measure ($\inf_{tc}$), and a vector of observable firm characteristics (X_{itjc}).

Infrastructure quality was our variable of interest. Following the work of Escribano *et al.* (2010), the infrastructure definition adopted in this paper includes the provision of customs clearance, energy, water, sanitation, transportation, telecommunications and information and communications technology. Consequently, we defined infrastructure quality as follows: Customs clearance: it was defined as the numbers of days it took exports or imports to clear customs. Firms also reported exports and imports longest days at customs. Firms were also asked to rank customs and trade regulation as an obstacle to enterprise operations. Electricity: we constructed a variable equal to 1 if a firm ever experienced electricity outage and 0 otherwise. We also used the number of power outages per month, length or duration of power outages, percentage of sales lost due to power outages, value of losses due to power outages, whether a firm owns a generator and percentage of electricity from a generator. Firms were also asked the extent of electricity as an obstacle to the enterprise operation.

Water: we constructed a variable equal to 1 if a firm ever experienced water shortages and 0 otherwise. We also used the frequency of water shortages, average length or duration of water shortages. Transportation: firms were asked to rank the extent of transport as an obstacle to the business operations. Firms were asked "How much of an obstacle is transportation?" We also constructed a variable equal to 1 if firms used their own transport and 0 otherwise. Additionally firms were asked the percentage of shipments using own transport.

Telecommunications: it was defined as the days it took to obtain a telephone connection after application, whether a firm used cellphones as a substitute to public phones for business operations. Firms were also asked to rank the extent of telecommunications as an obstacle to enterprise operations: "How much of an obstacle is telecommunication"? The internet: we constructed a variable equal to 1 if a firm used an e-mail, website, has a high-speed broadband internet and 0 otherwise. We also constructed another dummy variable equal to 1 if a firm ever experienced internet outage and 0 otherwise. We also used the frequency and length of internet outages.

X_{itjc} is a vector of firm-specific control variables which include firm size measured by employment, export status which is a dummy variable equal to 1 if firm i is an exporter (whether direct or indirect) and 0 if it sells to the domestic market only; ownership which is a

dummy variable equal to 1 if firm i is foreign owned and 0 if it is domestically owned; firm age measured the year of establishment minus the year in which the survey was done. Firm size is categorized into: small firms (employing less than 20 workers), medium firms (employing 20-99 workers) and large firms (employing 100 + workers). Firm age is also divided into classes: starters (one year of operation or less), young firms (more than one year but not exceeding five years) and old firms (over five years of operation). These firm categories: size, age, ownership and export status were the instruments while characterizing the nature of quality of infrastructure. We conjecture that infrastructure quality affects the productivity of firm groups differently and hence firm groups are instrumental in exposing the peculiar aspects of quality per group.

Finally, λ_t, λ_j and λ_c are time, industry and country fixed effects which are included in our model estimations. ε_{itjc} is the zero-mean error which is identically and independently distributed across firms/white noise.

2.2 Data

We used the WBES data set for 26 African countries to understand the effect of infrastructure quality on firm-level efficiency outcomes in the manufacturing sector. The WBES questionnaire was harmonized across the world since 2006 making it possible to undertake cross-country firm-level studies. There exists at least two waves of data for most countries in Africa which makes it rather easy to compute growth rates where necessary.

Infrastructure quality is a key variable of our study and is one of the variables comprehensively captured using various dimensions of quality by the WBES. The components of infrastructure considered in the WBES include: customs clearance, energy, water, sanitation, transportation, telecommunications and ICT. In terms of other firm characteristics, the data set is quite rich. It provides firms' current sales and sales three years ago, firms' current employment and employment three years ago, age of the firm, ownership, capital stock and investment, export and import orientation of firms, capacity utilization, measures of institutional quality and gender participation among others. Therefore, the WBES offers a good opportunity to study the productivity effects of infrastructure quality in Africa.

3. Findings

We present both descriptive and empirical evidence. Table I presents the summary statistics while Table II presents the correlation matrix of the variables included in the regression analysis. Tables III–V are cross-tabulations of the different measures of infrastructure quality by firm size, age, ownership and export status. Tables VI–IX show regression analysis of the association between infrastructure quality and firm productivity by firm size, ownership, export status and age classes, respectively.

3.1 Descriptive evidence

From the cross-tabulations, we note that large firms are more productive compared to small and medium firms (Table III). Similarly old firms are more productive compared to starters and young firms. Surprisingly, starters are more productive compared to young firms (Table IV). Likewise, foreign-owned firms are more productive compared to domestically owned firms and exporters are more productive compared to non-exporters (Table V).

In terms of power outages, on average, 80 percent of firms in our sample reported having experienced power outages in the financial year preceding the survey. However, there are differences across firm categories. A relatively smaller share of large firms

Variable	Obs	Mean	SD	Min.	Max.
Labor productivity	10,632	9.224488	1.747233	2.66503	15.4241
Power outage	13,477	0.801365	0.398987	0	1
No. of days of power outages	10,005	12.9963	17.81927	0	330
Use of generator	13,439	0.388943	0.487528	0	1
Electricity severe obstacle	13,500	0.54037	0.498386	0	1
Water outage	9,897	0.257048	0.437028	0	1
E-mail use	13,528	0.528755	0.499191	0	1
Website use	13,519	0.294918	0.456023	0	1
Telecommunication severe obstacle	12,302	0.125671	0.331491	0	1
Custom regulation severe obstacle	12,461	0.179279	0.383602	0	1
Transport severe obstacle	13,387	0.242922	0.428865	0	1
Foreign ownership	13,556	0.128356	0.334499	0	1
Age of the firm	13,362	18.11652	15.62445	0	133
Medium size	13,556	0.315801	0.464851	0	1
Large size	13,556	0.189141	0.391635	0	1
Export status	13,556	0.228902	0.420142	0	1

Source: Own computations from WBES

Table I.
Summary statistics of the variables used in the regression

(78 percent) reported power outages compared to 81 percent of medium firms and 80 percent of small firms (Table III). By firm age, a higher share of old firms (81 percent) reported power outages compared to 77 percent of young firms and 72 percent of starters (Table IV). A slightly higher share of foreign-owned firms (82 percent) reported power outages compared to 80 percent of domestically owned firms yet a higher share of non-exporters (80 percent) compared to 79 percent of exporters reported power outages (Table V). Overall, power outage is a serious problem in the African manufacturing sector. However, it is in line with the World Bank (2017) that ranked infrastructure (particularly electricity) as the second topmost obstacle affecting enterprises in the Sub-Saharan Africa.

Considering the number of times of power outages in a typical month during the financial year that preceded the survey, on average, African manufacturers experienced 13 times of power outages (Table I). Considering the differences across firm categories reveals that small firms reported on average 14 times while medium and large firms reported 13 and 11 times, respectively (Table III). Starters reported ten times of power outages while young and old firms reported 14 and 13 times, respectively (Table IV). There is no significant difference between foreign- and domestically owned firms in terms of the number of times of power outage. Exporters reported 10 times compared to 14 times of non-exporters (Table V). Overall small firms and non-exporters report more times of power outages compared to their counterparts and hence they are more likely to be affected by the unreliable supply of electricity from the public grid. However, the differences might be underpinned by differences in location of various firms; those located in a designated area of government (like industrial parks or export zones) are more likely to have reliable power or to experience fewer times of outages.

Looking at generator usage which is a substitute to power sourced from the public grid, on average, 40 percent of firms reported to having used a generator during enterprise operations (Table I). Considering firm groups reveals that a greater share of large firms (56 percent) used generators compared to 43 percent and 30 percent of medium and small firms, respectively (Table III). A higher share of old firms (40 percent) use generators compared to 34 percent of starters and young firms, respectively. A greater share of foreign-owned firms use generators (52 percent) compared to domestically owned firms (37 percent). Likewise a greater share of exporters (50 percent) use generators compared to

Table II. Correlation matrix

	Productivity	Power outage	No. of days of power outages	Use of generator	Electricity severe obstacle	Water outage	E-mail use	Website use	Telecommunication severe obstacle	Custom regulation severe obstacle	Transport severe obstacle	Foreign ownership	Age of the firm	Medium size	Large size	Export status
Productivity	1															
Power outage	−0.0515*	1														
No. of days of power outages	−0.1319*	–	1													
Use of generator	0.0888*	0.2165*	0.1306*	1												
Electricity severe obstacle	−0.1010*	0.2934*	0.2872*	0.1450*	1											
Water outage	−0.0034	0.1753*	0.0756*	0.1454*	0.1143*	1										
E-mail use	0.2968*	0.0093	−0.1666*	0.1878*	−0.0968*	−0.0071	1									
Website use	0.2356*	−0.0528*	−0.1070*	0.1213*	−0.1048*	−0.0178	0.5331*	1								
Telecommunication severe obstacle	0.0238*	0.0364*	−0.0028	0.0531*	0.1863*	0.0229*	0.0991*	0.0715*	1							
Custom regulation severe obstacle	0.0832*	0.0083	−0.0414*	0.0869*	0.0928*	0.0287*	0.1590*	0.1275*	0.2014*	1						
Transport severe obstacle	−0.0026	0.0326*	0.0503*	0.0794*	0.2114*	0.0659*	−0.002	−0.0009	0.2376*	0.2327*	1					
Foreign ownership	0.1327*	0.0185*	−0.0634*	0.1032*	−0.0417*	−0.0256*	0.1849*	0.1441*	0.053*	0.0870*	0.0114	1				
Age of the firm	0.1256*	−0.0009	−0.0651*	0.0579*	−0.0460*	−0.0497*	0.2071*	0.2394*	0.0419*	0.0550*	−0.0025	0.0235*	1			
Medium size	0.1101*	0.0220*	−0.0026	0.0616*	−0.014	0.0015	0.1926*	0.0871*	0.006	0.0366*	0.020*	0.0491*	0.0593*	1		
Large size	0.1799*	−0.0207*	−0.1033*	0.1664*	−0.0505*	0.0029	0.3482*	0.3856*	0.066*	0.1089*	0.0194*	0.0194*	0.2567*	−0.3281*	1	
Export status	0.1835*	0.0117	0.1172*	0.1282*	−0.0510*	−0.0024	0.3134*	0.3153*	0.0981*	0.1626*	0.0514*	0.2046*	0.1613*	0.0166	0.3699*	1

Note: $^{*}p < 0.05$

Source: Own computations from WBES

Variables	Small firms Obs	Small firms Mean	Medium firms Obs	Medium firms Mean	Large firms Obs	Large firms Mean
Labor productivity	5,382	8.80808	3,293	9.51178	1,957	9.8862
Power outage	6,654	0.79967	4,269	0.814242	2,554	0.7843
No. of power outages in a month	4,918	13.573	3,217	13.10382	1,870	11.295
Use of generator	6,640	0.29639	4,256	0.433036	2,543	0.5568
% of electricity from generator	1,835	36.7932	1,659	28.312	1,271	22.312
% of sales loss due to power outages	4,149	11.6815	2,769	11.02268	1,593	9.3803
Electricity severe obstacle	6,680	0.56692	4,262	0.530033	2,558	0.4883
Water outage	4,316	0.2551	3,353	0.257978	2,228	0.2594
Water outage frequency in a month	1,028	12.5924	796	9.398241	521	7.977
E-mail use	6,699	0.30109	4,273	0.670255	2,556	0.8889
Website use	6,695	0.1186	4,267	0.35341	2,557	0.659
Telecommunication severe obstacle	6,063	0.10622	3,904	0.128586	2,335	0.1713
High-speed broadband internet	518	0.22973	380	0.521053	255	0.6941
Custom days for exports to clear	222	7.19369	591	9.005076	1,082	8.573
Custom days for imports to clear	712	13.2135	1,365	13.85568	1,453	14.251
Custom regulation severe obstacle	6,028	0.13139	3,974	0.199799	2,459	0.2635
Transport severe obstacle	6,603	0.24443	4,239	0.230243	2,545	0.2601

Source: Own computation from WBES

Table III.
Infrastructure quality by firm size

Variables	Starters (≤1 year) Obs	Starters (≤1 year) Mean	Young firms (> 1 and ≤5 years) Obs	Young firms (> 1 and ≤5 years) Mean	Old firms (> 5 years) Obs	Old firms (> 5 years) Mean
Labor productivity	127	9.03685	1,836	8.945986	8,796	9.2826
Power outage	164	0.71951	2,179	0.76916	11,298	0.8076
No. of power outages	110	9.7	1,597	13.79649	8,408	12.844
Use of generator	158	0.33544	2,163	0.335183	11,276	0.3993
% of electricity from generator	51	33.6471	686	39.11953	4,079	28.44
% of sales loss due to power outages	83	8.60361	1,350	10.11496	7,161	11.21
Electricity severe obstacle	166	0.56024	2,187	0.534979	11,313	0.5414
Water outage	119	0.21849	1,500	0.288667	8,397	0.2514
Water outage frequency	24	9.29167	417	11.60432	1,928	10.24
E-mail use	167	0.31138	2,194	0.380128	11,334	0.5575
Website use	167	0.1497	2,192	0.171077	11,327	0.3189
Telecommunication severe obstacle	130	0.08462	1,976	0.097166	10,326	0.1311
High-speed broadband internet	13	0.23077	146	0.239726	1,007	0.4558
Custom days for exports	6	5.5	149	7.771812	1,746	8.6123
Custom days for imports	33	22.4849	388	13.47423	3,142	13.94
Custom regulation severe obstacle	149	0.16779	1,998	0.139139	10,463	0.1869
Transport severe obstacle	166	0.23494	2,170	0.230876	11,217	0.2453

Source: Own computation from WBES

Table IV.
Infrastructure quality by firm age

non-exporters (35 percent) (Table V). Overall, the ability to substitute generators for the poor quality public grid electricity seems to involve affordability aspects where small, young, non-exporters and domestically owned firms seem to be at an extreme disadvantage compared to counterparts.

In terms of the share of firms identifying electricity as a major or severe obstacle, on average, 54 percent of firms in our sample identified electricity as a major or severe obstacle (Table I). A higher share of small firms (57 percent) reported electricity as a major or severe obstacle compared to 53 percent of medium firms and 49 percent of large firms (Table III).

Variables	Foreign owned		Domestically owned		Exporters		Non-exporters	
	Obs	Mean	Obs	Mean	Obs	Mean	Obs	Mean
Labor productivity	1,276	9.852469	9,356	9.138842	2,398	9.81857	8,234	9.0515
Power outage	1,728	0.820602	11,749	0.798536	3,084	0.792802	10,393	0.8039
No. of power outages	1,287	12.59984	8,718	13.05483	2,227	10.63718	7,778	13.672
Use of generator	1,709	0.520772	11,730	0.3697357	3,073	0.503742	10,366	0.3549
% of electricity from generator	794	24.68023	3,971	31.03702	1,382	22.70781	3,383	32.948
% of sales loss due to power outages	1,062	10.0516	7,449	11.17687	1,860	9.74629	6,651	11.397
Electricity severe obstacle	1,732	0.486143	11,768	0.5483515	3,083	0.493675	10,417	0.5542
Water outage	1,456	0.230082	8,441	0.2616989	2,496	0.255208	7,401	0.2577
Water outage frequency	293	8.361775	2,052	10.78558	567	8.067019	1,778	11.253
E-mail use	1,732	0.769631	11,796	0.4933876	3,091	0.816241	10,437	0.4436
Website use	1,730	0.466474	11,789	0.269743	3,089	0.559081	10,430	0.2167
Telecommunication severe obstacle	1,471	0.173352	10,831	0.1191949	2,782	0.185838	9,520	0.1081
High-speed broadband internet	178	0.539326	975	0.4082051	170	0.658824	983	0.3886
Custom days for exports	512	8.568359	1,383	8.537961	1,895	8.546174	0	
Custom days for imports	867	14.28835	2,663	13.75854	1,616	13.15718	1,914	14.506
Custom regulation severe obstacle	1,665	0.264264	10,796	0.1661727	3,018	0.289596	9,443	0.144
Transport severe obstacle	1,713	0.255692	11,674	0.2410485	3,067	0.283339	10,320	0.2309

Source: Own computation from WBES

Table V. Infrastructure quality by firm ownership and export status

By age, 56 percent of starters reported electricity as a major or severe obstacle compared to 53 and 54 percent of young and old firms, respectively (Table IV). By ownership, 49 percent of foreign firms and exporters reported electricity as a major or severe obstacle compared to 55 percent of domestically owned firms and non-exporters, respectively (Table V). Overall, a higher share of small firms, starters, young, domestically owned and non-exporters report electricity as a major or severe obstacle. This might be partly attributed to their limited use of generators as a substitute to the public grid supply of electricity. Firms using generators find electricity as an obstacle but to a lower extent compared to counterparts.

Considering the percentage of electricity from generators, 37 percent of electricity for small firms comes from a generator compared to 28 percent for medium firms and 22 percent for large firms (Table III). This might be attributed to the scale effects with generators contributing a small share of power for large firms because they are big consumers but this is not to suggest that they consume less in absolute terms. Likewise, 34 percent of electricity for starters comes from generators compared to 39 percent for medium firms and 28 percent for old firms (Table IV). The same picture is visible while comparing exporters and non-exporters, foreign-owned and domestically owned firms in Table V. Again, scale effects might explain why a higher share of power comes from generators for non-exporters and domestically owned firms compared to counterparts.

In terms of the share of sales losses due to power outages, small firms report a higher share (12 percent) compared to medium firms (11 percent) and large firms (9 percent) (Table III). Starters report a lower share (9 percent) compared to 10 and 11 percent of young and old firms, respectively (Table IV). Exporters and foreign-owned firms report a lower share of 10 percent compared to 11 percent of non-exporters and domestically owned firms (Table V). Exporters, foreign-owned and old firms are more in position to use a substitute source of power (generator) compared to their counterparts. But also due to scale effects, the share of their losses might appear smaller.

Looking at water outage, on average, 26 percent of firms ever experienced water shortage in the financial year preceding the survey (Table I). By firm categories, there is no significant difference by firm size (Table III). By age, a higher share of young firms

Table VI.
Infrastructure quality and productivity by firm size

Variables	(1) Small firms	(2) Medium firms	(3) Large firms	(4) Small firms	(5) Medium firms	(6) Large firms
Power outages	−0.177** (0.0717)	−0.217*** (0.0818)	−0.00817 (0.0966)			
Generator	−0.0241 (0.0569)	0.0180 (0.0629)	0.301*** (0.0819)	0.0340 (0.0613)	0.0665 (0.0695)	0.330*** (0.0961)
Electricity severe	−0.329*** (0.0582)	−0.259*** (0.0657)	−0.0915 (0.0850)	−0.235*** (0.0648)	−0.190** (0.0756)	−0.0761 (0.0989)
E-mail use	0.652*** (0.0673)	0.674*** (0.0719)	0.459*** (0.133)	0.498*** (0.0734)	0.584*** (0.0819)	0.364** (0.155)
Website use	0.313*** (0.0964)	0.125* (0.0709)	0.236*** (0.0879)	0.346*** (0.107)	0.126 (0.0812)	0.291*** (0.0994)
Telecomm severe	−0.0631 (0.0895)	0.0119 (0.0919)	−0.0496 (0.108)	−0.0619 (0.0967)	0.0492 (0.104)	0.0303 (0.123)
Customs severe	0.0833 (0.0821)	0.149* (0.0787)	0.0489 (0.0926)	0.230** (0.0906)	0.225** (0.0881)	0.0124 (0.109)
Transport severe	0.0594 (0.0619)	−0.128* (0.0736)	−0.0611 (0.0953)	0.135** (0.0669)	−0.102 (0.0812)	−0.0929 (0.110)
Foreign owned	0.267** (0.114)	0.497*** (0.0865)	0.307*** (0.0933)	0.0903 (0.127)	0.576*** (0.0980)	0.428*** (0.108)
Age	0.000187 (0.00233)	0.00321 (0.00221)	0.00658*** (0.00218)	0.000985 (0.00268)	0.000334 (0.00252)	0.00945*** (0.00262)
Export status	0.0629 (0.0947)	0.286*** (0.0728)	0.389*** (0.0789)	0.0458 (0.107)	0.331*** (0.0838)	0.322*** (0.0933)
Number of outages				−0.188*** (0.0312)	−0.103*** (0.0354)	−0.0785* (0.0441)
Constant	8.968*** (0.0751)	9.173*** (0.0917)	8.819*** (0.147)	9.135*** (0.0884)	9.139*** (0.115)	8.886*** (0.185)
Observations	4,316	2,712	1,673	3,313	2,051	1,190
R^2	0.060	0.105	0.069	0.061	0.110	0.083
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Standard errors are shown in parentheses. *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$,

Variables	(1) Foreign firms	(2) Domestic firms	(3) Foreign firms	(4) Domestic firms
Power outages	−0.0185 (0.142)	−0.163*** (0.0502)		
Generator	0.346*** (0.115)	0.0224 (0.0397)	0.466*** (0.127)	0.0527 (0.0438)
Electricity severe	−0.274** (0.118)	−0.274*** (0.0411)	−0.102 (0.131)	−0.215*** (0.0467)
E-mail use	0.449*** (0.146)	0.671*** (0.0482)	0.432*** (0.164)	0.521*** (0.0537)
Website use	0.177 (0.120)	0.196*** (0.0535)	0.129 (0.133)	0.248*** (0.0602)
Telecomm severe	0.119 (0.146)	−0.0544 (0.0605)	0.162 (0.160)	−0.0364 (0.0668)
Customs severe	0.140 (0.129)	0.0823 (0.0531)	0.152 (0.142)	0.157*** (0.0595)
Transport severe	0.0382 (0.131)	−0.0224 (0.0449)	0.0260 (0.141)	0.0210 (0.0495)
Age	0.0155*** (0.00351)	0.00122 (0.00142)	0.0132*** (0.00408)	0.00184 (0.00163)
Export status	0.277** (0.120)	0.251*** (0.0521)	0.248* (0.133)	0.238*** (0.0599)
Medium firms	0.40117*** (0.1441)	0.2470*** (0.04619)	0.58275*** (0.1611)	0.2081*** (0.0516)
Large firms	0.20155 (0.1629)	0.2967*** (0.06498)	0.43775** (0.18239)	0.2919*** (0.07399)
Number of outages			−0.0488 (0.0591)	−0.150*** (0.0221)
Constant	8.810*** (0.168)	8.906*** (0.0534)	8.621*** (0.192)	9.041*** (0.0647)
Observations	988	7,713	742	5,812
R^2	0.114	0.114	0.139	0.112
Country FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes

Notes: Standard errors are shown in parentheses. *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$

Table VII. Infrastructure quality and productivity by firm ownership

Variables	(1) Exporters	(2) Non-exporters	(3) Exporters	(4) Non-exporters
Power outages	−0.111 (0.0896)	−0.177*** (0.0555)		
Generator	0.365*** (0.0759)	−0.0375 (0.0433)	0.371*** (0.0880)	0.0173 (0.0471)
Electricity severe	−0.180** (0.0781)	−0.294*** (0.0448)	−0.127 (0.0914)	−0.218*** (0.0503)
E-mail use	1.011*** (0.108)	0.579*** (0.0509)	0.827*** (0.125)	0.463*** (0.0564)
Website use	0.163** (0.0811)	0.214*** (0.0606)	0.220** (0.0923)	0.229*** (0.0679)
Telecommunication severe	0.0810 (0.0951)	−0.0909 (0.0684)	0.138 (0.108)	−0.0759 (0.0745)
Customs severe	−0.00207 (0.0821)	0.137** (0.0607)	−0.0214 (0.0954)	0.242*** (0.0670)
Transport severe	0.00261 (0.0840)	−0.0245 (0.0491)	−0.0288 (0.0948)	0.0393 (0.0536)
Foreign	0.364*** (0.0860)	0.383*** (0.0745)	0.431*** (0.1000)	0.390*** (0.0825)
Age	0.00683*** (0.00216)	0.000975 (0.00164)	0.00904*** (0.00256)	0.000256 (0.00188)
Medium firm	0.26477** (0.1073)	0.2779*** (0.0486)	0.28485** (0.12277)	0.2495*** (0.05402)
Large firms	0.2475** (0.1091)	0.2557*** (0.0767)	0.26135** (0.12522)	0.3261*** (0.08651)
Number of outages			−0.0893** (0.0428)	−0.146*** (0.0236)
Constant	8.527*** (0.122)	8.980*** (0.0585)	8.559*** (0.150)	9.072*** (0.0694)
Observations	2,025	6,676	1,427	5,127
R^2	0.135	0.087	0.139	0.088
Country FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes

Notes: Standard errors are shown in parentheses. **$p < 0.05$; ***$p < 0.01$

Table VIII. Infrastructure quality and productivity by export status

(29 percent) compared to old firms (25 percent) and starters (22 percent) experienced water outages (Table IV). There is no significant difference between exporters and non-exporters. However, a higher share of domestically owned firms (26 percent) compared to foreign owned (23 percent) experienced water shortages. In terms of the frequency of water

Table IX.
Infrastructure quality and productivity by firm age

Variables	(1) Starter	(2) Young	(3) Old	(4) Starter	(5) Young	(6) Old
Power outages	−0.764 (0.685)	−0.0185 (0.119)	−0.165*** (0.0515)			
Generator	−0.797 (0.483)	−0.0190 (0.0967)	0.0805** (0.0407)	−1.071* (0.588)	0.120 (0.106)	0.101** (0.0451)
Electricity severe	−1.039* (0.537)	−0.430*** (0.0991)	−0.240*** (0.0421)	−0.939 (0.589)	−0.257** (0.109)	−0.181*** (0.0481)
E-mail use	0.975* (0.575)	0.628*** (0.111)	0.647*** (0.0501)	0.983 (0.636)	0.589*** (0.123)	0.490*** (0.0561)
Website use	−0.0625 (0.689)	−0.0130 (0.140)	0.258*** (0.0519)	0.157 (0.750)	0.0343 (0.153)	0.293*** (0.0586)
Telecommunication severe	0.664 (0.851)	0.0378 (0.158)	−0.0482 (0.0592)	0.402 (1.056)	−0.0188 (0.170)	−0.00622 (0.0659)
Customs severe	0.409 (0.682)	0.257* (0.135)	0.0537 (0.0523)	0.656 (0.705)	0.294** (0.142)	0.129** (0.0595)
Transport severe	0.141 (0.552)	−0.0311 (0.109)	−0.00507 (0.0461)	−0.203 (0.629)	0.0281 (0.117)	0.0240 (0.0510)
Foreign	0.372 (0.780)	0.174 (0.154)	0.423*** (0.0609)	0.592 (0.793)	0.245 (0.176)	0.433*** (0.0685)
Export status	−1.054 (0.929)	0.414*** (0.153)	0.228*** (0.0498)	−1.563 (1.316)	0.430** (0.176)	0.216*** (0.0571)
Medium firms	−0.07325 (0.6565)	0.17457 (0.1103)	0.2902*** (0.0477)	−0.282 (0.7387)	0.1436 (0.1224)	0.2834*** (0.05352)
Large firms	−0.4275 (0.9556)	0.2152 (0.206)	0.2981*** (0.062)	−0.263 (1.09)	0.2096 (0.226)	0.3488*** (0.07064)
Number of outages				0.0835 (0.315)	−0.215*** (0.0535)	−0.127*** (0.0224)
Constant	10.69*** (0.550)	8.918*** (0.112)	8.868*** (0.0527)	9.883*** (0.722)	9.203*** (0.135)	8.950*** (0.0639)
Observations	88	1,490	7,282	68	1,146	5,453
R^2	0.203	0.082	0.134	0.177	0.100	0.134
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Standard errors are shown in parentheses. *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$

shortages, small firms experienced a higher frequency (13 times) compared to nine and eight times for medium and large firms, respectively (Table III). Considering age, starters experienced a lower frequency (nine times) compared to 12 and 10 times of young and old firms, respectively (Table IV). Foreign owned and exporters experienced a lower frequency (nine times) compared to 11 times of domestically owned and non-exporters, respectively (Table V). This might be attributed to the affordability to use substitute sources of water for exporters and foreign-owned firms compared to counterparts.

In terms of ICT usage, on average, 53 and 30 percent of firms in our sample used e-mail and website, respectively, to get into contact with their customers (Table I). However, there are remarkable differences by firm size. A lower share of small firms (30 and 12 percent) used e-mail and website, respectively, compared to medium firms (67 and 35 percent) and large firms (90 and 66 percent) used e-mails and website, respectively. The same applies to the high-speed broadband internet installed by only 23 percent of small firms compared to 52 percent of medium firms and 70 percent of large firms (Table III). By age, 31 and 15 percent of starters, respectively used e-mail and website compared to 38 and 17 percent of young firms and 56 and 32 percent of large firms that used e-mail and websites respectively. Additionally, 46 percent of old firm had a high-speed broadband internet compared to 23 percent of starters and young firms (Table IV).

By export status, a higher share of exporters (82 and 56 percent) compared to non-exporters (44 and 22 percent), respectively, used e-mails and websites. Likewise a higher share of foreign owned (77 and 47 percent) compared to domestically owned firms (49 and 27 percent), respectively, used e-mails and websites. In terms of a high-speed broadband internet, 66 and 54 percent of exporters and foreign-owned firms had a high-speed broadband internet compared to only 39 and 40 percent of non-exporters and domestically owned firms, respectively (Table V). Overall, ICT infrastructure is used more by large, old, exporters and foreign-owned firms compared to their counterparts.

Considering telecommunication, on average, 13 percent of firms in our sample reported telecommunication as a major or severe obstacle (Table I). By firm groups, only 10 percent of small firms reported telecommunication as a major or severe obstacle compared to 13 and 17 percent of medium and large firms, respectively (Table III). Similarly only 8 percent of starters reported telecommunication as a major or severe obstacle compared to 10 and 13 percent of young and old firms, respectively (Table IV). By ownership, 17 percent of foreign-owned firms reported telecommunication as a major or severe obstacle compared to 12 percent of domestically owned firms. Additionally, 19 percent of exporters compared to 11 percent of non-exporters reported it as a major or severe obstacle (Table V). Overall, telecommunication is reported a major or severe obstacle more by large, old, exporters and foreign-owned firms compared to counterparts.

In terms of customs, there are more import days than export days to clear customs in African countries. The African Government seems to have a longer red tape for imports than exports. Small firms reported 7 days for exports and 13 days for imports, medium firms reported 9 days for exports and 14 days for imports (Table III). Starters reported six days for exports and 23 days for imports, young firms reported 8 days for exports and 14 days for imports, old firms reported 9 days for exports and 14 days for imports (Table IV). Foreign-owned firms and exporters reported 9 days for exports and 14 and 13 days for imports respectively. Yet non-exporters reported 15 days for imports to clears customs (Table V). Overall, on average, firms reported 9 and 14 days for their exports and imports to clear customs, respectively. These are quite many days and African Governments should improve customs handling to reduce them considerably.

Considering customs and trade regulation, on average, 18 percent of firms in our sample reported customs and trade regulation as a major or severe obstacle (Table I).

Looking at firm groups, only 13 percent of small firms reported it as a major or severe obstacle compared to 20 and 26 percent of medium and large firms, respectively (Table III). By age, 17, 14 and 19 percent of starters, young and old firms reported it as a major or severe obstacle, respectively (Table IV). In total, 26 percent of foreign-owned firms compared to 17 percent of domestically owned firms reported it as a major or severe obstacle. In total, 29 percent of exporters compared to 14 percent of non-exporters reported it as a major or severe obstacle (Table V). Overall, customs and trade regulation affects more large, old, foreign-owned firms and exporters compared to counterparts.

Considering transport, on average, 24 percent of firms reported it as a major or severe obstacle (Table I). By firm categories, 24 percent of small firms report it as a major or severe obstacle compared to 23 and 26 percent for medium and large firms, respectively (Table III). By age, 24 percent of starters report it as a major or severe obstacle compared to 23 and 25 percent of young and old firms, respectively (Table IV). By ownership, 26 percent of foreign-owned firms report it as a major or severe obstacle compared to 24 percent of domestically owned firms. By export status, 28 percent of exporters consider it a major or severe obstacle compared to 23 percent of non-exporters (Table V). Overall, there is no major difference by size and age along transport as an obstacle but we realize significant differences by ownership and export status with foreign-owned firms and exporters experiencing a bigger effect.

3.2 Empirical evidence

From Table II, the correlation matrix shows that there is no worry about any multicollinearity between our explanatory variables. The only perfect match is between the number of power outages and the share of firms that reported power outages during the survey. Consequently, whereas we use both as explanatory variables, we do not include them in the same regression model.

In support of the descriptive evidence provided above, our empirical findings show that infrastructure quality is significantly associated with firm productivity. Power outages are negatively associated with the productivity of small, medium, domestically owned and non-exporters (Tables VI–IX). Power outage reduces the productivity of small firms, medium firms, domestically owned firms, non-exporters and old firms by approximately 0.2 percentage points. In a similar fashion, an increase in the number of power outages reduces the productivity of firms in our sample. An increase in the number of power outages by 1 reduces productivity by 0.1–0.2 percentage points for small, medium and large firms. However, we observe that the coefficient for small firms is twice bigger than that for medium and large firms suggesting that the productivity of small firms is more negatively affected by the frequency of power outages. Actually the relationship for large firms is statistically weakly significant at 10 percent level of significance (Table VI).

Additionally, an increase in the number of outages by 1 reduces the productivity of domestically owned firms, exporters and non-exporters by 0.1–0.15 percentage points once compared to their counterparts (Tables VII and VIII). However, the coefficient for non-exporters is almost twice that of exporters suggesting that non-exporters are more negatively affected by the increased frequency of power outages. Also the coefficient on young firms is twice that of old firms suggesting that young firms are affected more by the increased frequency of power outages than old firms (Table IX).

Our findings on the negative effect of the poor quality of infrastructure on firm productivity finds support in the previous literature (Reinikka and Svensson, 2002 for Uganda; Escribano *et al.*, 2010 for the African manufacturing sector; Bogetić and Olusi, 2013 for the Russian manufacturing sector and Velde, 2015 for the Sub-Saharan Africa).

On the contrary, using a generator is positively and significantly associated with the productivity of large firms, foreign-owned, exporters and old firms (Tables VI-IX). Using a generator increases the productivity of large firms by 0.3 percentage points compared to counterparts who do not use (Table VI). This relationship is not statistically different from 0 for small and medium firms. Similarly, using a generator increases the productivity of foreign-owned firms by 0.4–0.5 percentage points compared to counterparts who do not use a generator (Table VII). Additionally, it increases the productivity of exporters by 0.4 percentage points compared to those who do not use a generator (Table VIII). Likewise, using a generator increases the productivity of old firms by 0.1 percentage points compared to those who do not use (Table IX).

Overall, using a generator seems to improve the productivity of those firms that are more productive and who are in position to afford its cost and use it as a means of circumventing the adverse effects of publicly provided power outages. These findings on the generator use support the descriptive findings where we found the inability of small, young, non-exporters and domestically owned firms to substitute generators for power from the public grid. However, our findings on the generator use are in contrast with the findings by Reinikka and Svensson (2002) who found a negative and statistically significant effect on generator usage. The difference can, however, be attributed to the fact that Reinikka and Svensson (2002) did an analysis on all firms, yet in this paper we categorize firms and hence be in position to expose the peculiar aspects of firms according to their groups.

Firms that reported electricity as a major or severe obstacle are associated with lower productivity. Small and medium firms that reported electricity as a major or severe obstacle have a lower productivity of 0.2–0.3 percentage points compared to counterparts (Table VI). However, the effect is visibly stronger for small than for medium firms and completely absent for large firms. However, there is no difference between foreign and domestic firms that reported electricity as a major or obstacle. For both, productivity reduces by 0.3 percentage points compared to counterparts (Table VII). There is a big difference between exporters and non-exporters that mentioned electricity as a major or severe obstacle. The effect is bigger for non-exporters (0.3 percentage points) and is robust while it is smaller for exporters (0.2 percentage points) and is non-robust (Table VIII). Additionally, the effect is stronger for young firms (0.3–0.4 percentage points) compared to old firms (0.2 percentage points) (Table IX). These findings are reinforcing our descriptive evidence where we found a higher share of small firms, young firms, domestically owned and non-exporters reporting electricity as a major or severe obstacle.

In terms of ICT use, e-mail and website are positively associated with firm productivity and are robust across all models estimated (Tables VI–IX). Using an e-mail and a website increases firm productivity by 0.1 to 0.7 percentage points, irrespective of size, compared to counterparts who do not use (Table VI). However the coefficient on e-mail use is stronger than the coefficient website use both statistically and economically. Using an e-mail increases the productivity by 0.4–0.7 percentage points for foreign- and domestically owned firms. However the effect is stronger for domestic than for foreign-owned firms (Table VII). Additionally, using a website increases the productivity for domestically owned and not foreign firms. Specifically, using a website increases the productivity of domestically owned firm by 0.2 to 0.3 percentage points compared to counterparts who do not use (Table VII).

Using an e-mail and a website is uniquely very strong for exporters compared to non-exporters (Table VIII). Using an e-mail increase the productivity by 0.8 to 1 percentage points for exporters compared to non-users and by 0.5–0.6 percentage points for non-exporters compared to non-users. Using a website increases firm productivity for both exporters and non-exporters by 0.2 percentage points compared to non-users (Table VIII). Using an e-mail increases the productivity of firms across firm age classes by 0.5 to

0.9 percentage points. However, the effect is statistically stronger and robust for young and old firms compared to starters. Website use is important for only old firms and increases their productivity by 0.3 percentage points (Table IX).

Our findings of the impact of ICT infrastructure on firm productivity find support in the previous literature. For example, Commander *et al.* (2011) who found a strong positive association between ICT capital and productivity in both Brazil and India. Mitra *et al.* (2016) who found the impact of infrastructure and ICT strong and more pronounced amongst sectors more exposed to foreign competition in the Indian manufacturing sector. However, Bertschek *et al.* (2013) found no support for the broadband internet and firm productivity linkage but rather for innovation activity.

4. Conclusion

The paper set out to investigate the effect of infrastructure quality on firm productivity in Africa. We used the WBES for 26 African countries (Table X) and employed both descriptive and ordinary least squares techniques during the analysis. We circumvent the endogeneity of infrastructure in the productivity model by using firm-level measures of infrastructure quality rather than the stock of infrastructural capital. The infrastructure variables considered in this study included electricity, water, telecommunications, transport, customs and ICTs. We categorized firms according to size, age, ownership and export status and attempted to understand the effect of the infrastructure quality following this categorization. On an average, about 80 percent of manufacturing firms in Africa reported having experienced electricity outages representing a serious problem. However, this is in line with the World Bank (2017) that ranked electricity as the second topmost obstacle affecting enterprises in the Sub-Saharan Africa.

Small firms and non-exporters reported more times of power outages compared to their counterparts and hence they are more likely to be affected by the unreliable supply of

Table X.
List of countries in our sample

Country	Wave 1	Wave 2	Frequency
Angola	2006	2010	291
Benin	2009	2016	142
Botswana	2006	2010	199
Burundi	2006	2014	162
Cameroon	2009	2016	208
Cote d'Ivoire	2009	2016	310
DRC	2010	2013	365
Ethiopia	2011	2015	706
Egypt	2013	2016	3,188
Ghana	2007	2013	669
Guinea	2006	2016	162
Kenya	2007	2013	810
Madagascar	2009	2013	467
Malawi	2009	2014	268
Mali	2007	2010	461
Mauritania	2006	2014	132
Namibia	2006	2014	287
Niger	2009	2017	103
Rwanda	2006	2011	140
Senegal	2007	2014	508
Swaziland	2006	2016	145
Tanzania	2006	2013	713
Togo	2009	2016	80
Uganda	2006	2013	685
Zambia	2007	2013	668
Zimbabwe	2011	2016	665

electricity from the public grid. Empirically, power outages and the frequency thereof are negatively associated with the productivity of small, medium, young, domestically owned and non-exporters.

On the other hand, we observe a substitution effect of generators for the unreliable electricity from the public grid. This substitution effect positively influences the productivity of large, old, foreign-owned and exporting firms compared to their counterparts.

A higher share of small firms, starters, young, domestically owned and non-exporters reported electricity as a major or severe obstacle. Empirically, the negative effect on productivity is stronger small firms, starters, young, domestically owned firms and non-exporters compared to their counterparts. This might be partly attributed to their limited use of generators as a substitute to power from the public grid. Firms using generators finds electricity as an obstacle but to a lower extent compared to counterparts.

ICT infrastructure is used more by large, old, exporters and foreign-owned firms compared to their counterparts. Empirically, ICTs are important to firm productivity irrespective of firm size. However, we observe a stronger effect for domestically owned than foreign firms and exporters experience a stronger effect than non-exporters.

Overall, we argue that in addition to infrastructure capital at an aggregate level, dealing with quality issues at firm level is required to enhance productivity. More attention needs to be put to the elimination of power outages so as to improve the productivity of all firms particularly those that cannot afford to use generators in the place of electricity from the public grid.

Note

1. List of countries appears in Table X.

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