ELECTRICITY DISRUPTIONS AND THE EFFICIENCY OF MANUFACTURING FIRMS IN AFRICA: A STOCHASTIC FRONTIER ANALYSIS

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Abstract

Many African countries experience power shortages and regular interruptions in electricity supply. We use stochastic frontier models to study the impact of power disruptions on the efficiency of African manufacturing firms. Power disruptions appear to have negative effects on efficiency and the use of generators further exacerbates the impact. The interaction of power outages with generator ownership result in a negative effect on efficiency and this could probably be explained by the high cost of running these alternative power sources. Our results support a policy of investment in the electricity sector, to improve the maintenance and quality of infrastructure that is used to generate power in African countries.

1 Introduction

The industrialisation of the Africa continent is important to growth, innovation and employment creation. Manufacturing sector has a high multiplier effect, high productivity potential and spillover effects that can spur this industrialisation drive. The growth of the manufacturing sector was behind the unprecedented growth of Asian tigers and is still the engine that drives good economic performance in most developed countries. However, the growth of the African continent is still heavily driven by the primary sector with minerals and oil rents for the period 2012 to 2015 accounting for about 9% of GDP compared to 2% in East Asia and Pacific, 0,2% in the European Union (EU), 5% in Latin America and the Caribbean and 1.3% in South Asia (WDI, 2017). The pattern in the agriculture sector is similar. For the period 2007 to 2016, agriculture contributed about 19% to GDP in sub-Saharan Africa (SSA)

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compared to the world average of 3%, 5% in Latin America, 2% in the EU and 6% in East Asia and Pacific (WDI, 2017). This heavy dependency on commodities, and the associated price volatility, compromises the ability of the African continent to achieve high levels of economic growth.

The performance of the manufacturing sector in Africa has also been relatively poor in comparison with other developing regions. Between the years 2000 and 2016, manufacturing value added as a percentage of GDP was on average 10% in SSA compared to 15% in Latin America and the EU, 16% in South Asia and 23% in East Asia and Pacific (WDI, 2017). Although the World Economic Outlook (2017) reports that the African economy has been growing above the world average at 5% compared to the EU's 2%, the contribution of the continent's economy into the World economy is a meagre 2%. About 13% of the world population lives in Africa, suggesting that the continent is the third largest (population size) after East Asia and South Asia (World Economic Outlook, 2017). In general, a manufacturing sector that contributes only 10% to GDP is too small to stimulate the level of growth that will improve the standards of living of many people in the African continent[1].

The poor performance of the manufacturing sector and exports is of concern to the continent, since these are some of the conduits through which growth, employment creation, poverty reduction as well as globalization of the international economy can be encouraged (Dollar, Hallward-Driemeir & Mengistae, 2004). Development policy experts have for a long time debated on the factors that could explain the sluggish growth of the manufacturing sector. These factors include lack of appropriate technology, lack of skilled manpower, poor competitiveness, poor industrial policies, bureaucratic institutions, poor business climate[2] as well as poor infrastructure facilities particularly electricity and transport (Doing Business Report, 2017; Hummels, 2007).

Easy access to quality infrastructure is vital for the development and productivity of the manufacturing sector. Easy access to a reliable supply of water and electricity is key for efficient production to take place, but Africa lags the rest of the world in providing an uninterrupted supply of these infrastructure services. The 'Quality of Transport Infrastructure' index of the World Economic Forum show that only 10

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[1] Average GDP per capita for the period 2002 to 2016 is US$32016 for the EU, US$7363 for Latin America and the Caribbean, US$1070 for South Asia, US$1274 for SSA, US$7031 for East Asia and Pacific. This is far much less than the World average of US$8840 (WDI, 2017).

[2] According to the World Bank Doing Business report (2017), there are only eight SSA countries that are ranked below 100 out of 190 countries with Mauritius highly ranked below 50. In terms of getting electricity Tanzania and Cameroon are the only countries ranked below 100 whilst in terms of starting a business the best-ranked country is Rwanda at number 76.

African countries are ranked amongst the top half globally (i.e. they are in the top 74). Meanwhile, in the 'Quality of Electricity Supply' index, only five African countries are above the global median. Not surprisingly, these are the same countries with the highest levels of Manufacturing Value Added per capita on the continent. The World Bank (2009) report states that installed generation capacity of Africa's 48 Sub-Saharan countries is just 68 gigawatts, no more than Spain's. As much as one-quarter of this capacity is unavailable because of ageing plants and poor maintenance[3].

More than 30 African countries currently experience power shortages and regular interruptions in service, leading many to rely on very costly generators as emergency stopgaps (African Development Bank, 2015). The report further states that frequent power outages translate into big losses in forgone output and damaged equipment, with 6% of turnover on average being lost by formal enterprises whilst informal firms, which do not have backup generators, lose about 16%. The estimated economic costs of power shortages can exceed 2% of Gross Domestic Product and for some countries, these disruptions have shaved as much as one-quarter of a percentage point off annual per capita GDP growth rates.

Table 1: State of power problems in the world

Economy	Number of power outages in a typical month	Duration of a typical power outage a day (hours)	Losses due to electrical outages (% of annual sales)	Percent of firms owning or sharing a generator
All Countries	5,5	2,7	2,5	33,1
East Asia & Pacific	3,5	2,0	1,6	36,1
Eastern Europe & Central Asia	2,0	1,2	1,2	21,3
High income non-OECD	1,3	0,9	0,3	22,4
High income: OECD	0,4	0,4	0,1	13,1
Latin America & Caribbean	2,8	1,5	1,3	26,8
South Asia	17,2	1,3	4,0	43,4
Sub-Saharan Africa	7,8	5,0	4,9	45,8

Source: World Bank enterprise surveys (2016)

Table 1 above shows how acute the problem of power is in Africa. A number of firms in the continent have identified electricity problems as a constraint to doing business

[3] According to the World Bank (2017), electric power transmission and distribution losses as a percentage of GDP for the period 2007 to 2016 were on average 6% for East Asia and Pacific as well as EU, 15% for Latin America, South Asia (20%), SSA (11%) with World average being 8%.

compared to other regions. The losses as well as the length of power outages are also relatively higher in SSA. Although the SSA economy has been growing at an average rate of 5% per annum since 2000, and this growth is projected to accelerate to about 6% until 2018 (World Economic Outlook, 2018), achieving such growth rates might be a challenge given these continued power challenges.

The aim of this study is to analyse the extent to which power disruptions have affected the technical efficiency of firms in the manufacturing sector in selected African countries, using a parametric statistical approach. The study calculates efficiency scores, using a one-step stochastic frontier analysis (SFA) technique, popularized by Battese and Coelli (1993). There are also very few research papers for example by Cissokho and Seck (2013)[4] and Abotsi (2016) that have been done on the power sector in Africa specifically looking at how energy problems affect firm efficiency. Abotsi (2016) considered only ten African countries, compared to the 25 countries used in this study. Furthermore, Abotsi (2016) estimated the SFA efficiency model in two steps, in which the first step is the estimation of a standard model that ignores the effect of firm characteristics on inefficiency, and the second step is a regression of some measure of inefficiency on firm characteristics. This contrasts with one-stage SFA models in which the inefficiency effects are expressed as a function of a vector of observable explanatory variables and was proposed by Kumbhakar, Ghosh and McGuckin (1991), Reifschneider and Stevenson (1991), Huang and Liu (1994) and Battese and Coelli (1995). In this model, all parameters – frontier production and inefficiency effects – are estimated simultaneously. According to Wang and Schmidt (2002), the first step of the two-step procedure is biased for the regression parameters if firm characteristics and the inputs are correlated, as is well known. Even if these two are independent, the estimated inefficiencies are characterised with less variation when we ignore the effect of firm characteristics on inefficiency. This causes the second-step estimate of the effect of firm characteristics on inefficiency to be biased downwards (Wang & Schmidt, 2002).

Data Envelope Analysis (DEA) is a non-parametric approach which does not impose a priori functional form to the frontier and this reduces its vulnerability to the confounding effects arising from mis-specification of the functional form of the model. DEA is also a deterministic model, does not account for random variation in the data, and assumes all deviations from the frontier to be due to inefficiency (Ngui-Muchai & Muniu, 2012). Therefore, the computed efficiency scores are sensitive to extreme observations, number of observations, variable selection and measurement

[4] Cissokho and Seck (2013), used Data Envelope Analysis (DEA) to assess the impact of power outages on firms in Senegal alone.

errors in either output or the input variables (Chirwa, 2001). We therefore decided against using DEA in this study, since studies have shown that calculated efficiency scores are different from the ones using SFA[5] (Goudarzi, Pourreza, Shokoohi, Askari, Mahdavi & Moghri, 2014).

2 Literature review

The economic effects of power outages on firms' activities have been analysed in many studies (Beenstock, Goldin & Haitovsky, 1997; Caves, Herriges & Windle, 1992; Matsukawa & Fuji, 1994; Moyo, 2012). Most of these studies estimate the costs of power outages through either a subjective approach (self-assessment of lost production mostly done using surveys data), or an objective approach in which electricity intervenes directly as an argument in a production function as explained by Kessides (1993). These various approaches, coupled with the specificities of countries under study, have translated into a wide range of estimates, which make it difficult to generalize the findings. Furthermore, it seems that little attention has been devoted to the effect of power outages on efficiency especially in Africa. Studies by Soderbom and Teal (2003) of Ghanaian manufacturing firms investigated allocative and technical inefficiency. These authors found substantive allocative inefficiency and that technical inefficiency is higher in firms with foreign ownership or in older firms, and that its dispersion across firms was similar to that found in other economies. Mgui Muchai and Muniu (2012) investigated firm efficiency in Kenya. They studied efficiency differences and the distribution of efficiencies using SFA and found that efficiency estimates varied across the sample firms and period. They also found that exporting firms were less efficient in a period without export promotion incentives and that firm size was negatively related to efficiency especially in the metal and textile sectors. Krugell and Rankin (2012) looked at agglomeration and firm level efficiency in South Africa using World Bank enterprise survey data. Their objective was to examine whether location explains differences in efficiency and they found that the locations specific variables used support the notion that location does help in explaining differences in efficiency. They also found that production specialisation in a city was inversely related to efficiency suggesting that diversification is more beneficial to firms than specialization. Cissokho and Seck (2013), using Senegal data, and employing non-parametric (DEA) and parametric (SFA) approaches, found that power outages duration appeared to have a positive and significant effect on firms' productivity as measured by cost and technical efficiency scores, but have a negative effect on scale efficiency. This indicates that power outages, normally a hindrance to production, turned out to trigger best

[5] DEA efficiency scores have been found to be generally higher than SFA scores.

management practices from businesses, which mitigate the adverse effects of power outages. However, power outages did have a negative impact on scale efficiency, that is, in the context of disruptions, businesses were not motivated to grow towards their efficient scale. Niringiye, Luvanda and Shitundu (2010) investigated the relationship between firm size and efficiency in East African manufacturing firms. Contrary to their expectation, their results showed a negative association between firm size and efficiency in both Ugandan and Tanzanian manufacturing firms. The existence of a positive association between size squared and efficiency and a negative association between firm size and efficiency in Ugandan and Tanzanian manufacturing firms suggests an inverted U-relationship between these two variables.

Other studies that investigated the link between firm efficiency and various measures of firm value include Habib and Ljunqvist (2005) who implemented stochastic frontier analysis to determine firm efficiency in the US. They use firm inefficiency as a proxy for agency costs and find that about 16% of firm value is lost due to these inefficiencies. Bhandari and Maiti (2007) fit a translog stochastic frontier to the Indian firm level textile data and find that firm-level technical efficiency ranges between 68% and 84 % over the sample years, varies positively with firm size and negatively with firm age and that the public-sector firms are relatively less efficient than their private sector counterparts. Battese, Rao and Walujadi (2001) used stochastic frontier analysis to study firms in five different regions of Indonesia for the period 1990-1995 and found that there were substantial efficiency differences among the garment industry firms across the five regions.

3 Methodology

Stochastic frontiers models have been widely used to study technical efficiency since its introduction by Aigner, Lovell and Schmidt (1977), Meeusen and van den Broeck (1977). This technique has two components, a stochastic production frontier against which efficiency is measured and a one-sided random error term that is used to capture technical inefficiency across production units. The estimation of technical efficiency is only a first step in the efficiency analysis of power outages in this study. The next step is to measure to what extent electricity problems measured using the number of hours a day firms go without power, affect efficiency. Other firm-specific variables used include, *inter alia*, firm size, firm age, and foreign ownership. These steps as suggested by Battese and Coelli (1995) will be estimated simultaneously in one-step to reduce econometric bias of the two-step procedure[6].

[6] In a two-stage process, inefficiency scores are estimated from an SFA production function assuming that these scores are independently and identically distributed. In the second step, inefficiency scores are now assumed to

The Battese and Coelli (1995) model is expressed as follows:

$$Y_i = f(X_i;\beta)\exp(v_i - u_t) \tag{1}$$

where i indicates firms, X is a set of inputs; β is a set of parameters, v_i is a two sided random error term assumed to be iid N(0, σ_v^2) and u_i is a non-negative random variable representing inefficiency, independently distributed and truncated at zero $N(u_i;\sigma_u^2)$. The mean of this distribution is assumed to be a function of several explanatory variables and given as $u_i = \delta_i Z_i$. This gives the following inefficiency term:

$$u_i = \delta Z_i + W_i \tag{2}$$

where Z_i is a vector of variables that may affect firm efficiency, δ is also a vector of parameters to be estimated and W_i is a random variable defined by the truncation of the normal distribution with zero mean and constant variance (σ^2). In this case the point of truncation $-Z_i\delta$ is where $W_i > -Z_i\delta$. These assumptions are consistent with u_i being a non-negative truncation of the $N(Z_i\delta\sigma^2)$ distribution (Battese & Coelli, 1995).

The production function parameters β and the inefficiency coefficients δ_j are estimated using maximum likelihood techniques, together with the following variance parameters:

$$\sigma_s^2 = \sigma_u^2 + \sigma_v^2 \text{ and } \gamma = \sigma_u^2 / \sigma_s^2 \tag{3}$$

Since technical efficiency is the ratio of observed production over the maximum possible technical output (a case of zero inefficiency), the efficiency measure TE of firm i in any period could be expressed as follows:

be a function of some firm specific variables and this contradicts the assumption of identically distributed inefficiency effects (Diaz & Sanchez, 2008).

$$TE = \frac{f(X_i;\beta)\ \exp(v_i - u_i)}{f(X_i;\beta)\exp(v_i)} \ = \ \exp(-u_i) \tag{4}$$

The above efficiency scores will assume the value of one when the firm is fully efficient and less than one otherwise. Since this model will be estimated using cross sectional data, we will assume that technical inefficiency term is independent of the variables.

To estimate technical inefficiency scores we will use both a trans-log production function because of its flexible nature and a log-linear Cobb-Douglas function assuming constant returns to scale. The stochastic frontier, trans-log production function, to be estimated is specified as follows:

$$\begin{aligned}\ln Y_i = \beta_0 + \beta_1 \ln L_i + \beta_2 \ln M_i + \beta_3 \ln K_i + \beta_{11}(\ln L_i)^2 + \beta_{22}(\ln M_i)^2 + \beta_{33}(\ln K_i)^2 \\ + \beta_{12}(\ln L_i)(\ln M_i) + \beta_{13}(\ln L_i)(\ln K_i) + \beta_{23}(\ln M_i)(\ln K_i) + v_i - u_i\end{aligned} \tag{5}$$

where K represents capital, L is labour and M equals material inputs used in production. The resulting technical inefficiency effects are defined as follows

$$u_i = \delta_0 + \delta_1(Age) + \delta_2(Size) + \delta_3(Poutages) + \delta_4(Fowned) + \delta_5(\exp dummy) + W_i \tag{6}$$

Equation (5) and (6) will be estimated simultaneously using Frontier 4.1 software for stochastic frontier analysis.

3.1 Data and variables measurement

The data used in this study was sourced from the World Bank through their enterprise surveys portal. We use the latest cross-sectional data for each country and the selection of study countries was based solely on availability of data on variables of interest and surveys done on or after 2009. The values of variables like output, materials, capital measured in local currency units were converted into the common currency, US dollars using the real effective exchange rate for each country and respective year. Data on the real effective exchange rate was obtained from the IMF World Economic Outlook. We measured size using the number of permanent full-time employees and this differentiate it from the labour input variable measured using total temporary and permanent employees, age as the difference between the year the survey was done and the year firm started operations. The net realisable value of machinery, vehicles, equipment, land and buildings is used to measure capital; experience of top manager is measured in years, whilst foreign ownership is expressed as a percentage of firm equity. The main variable of interest, power outages, is measured in days per month, hours per day and percentage of output lost per year.

4 Stylised facts on the study countries

We use a dataset of 25 Sub Saharan African countries and 13600 manufacturing firms in this study. These firms are grouped into seven manufacturing sectors namely food and tobacco; textile, leather and garment; chemical and petrol; metal and mineral; electronic and instruments; machinery and transport; paper and printing as well as plastic rubber and recycling. According to Table 2 below, Burkina Faso and Zimbabwe are two of the four countries that have an average firm size greater than 100 employees with Mali being the country with the smallest average firm size (see Table 2 for more). The oldest firms are in Zimbabwe and the youngest in South Sudan. These statistics also show that a large proportion of firms with foreign ownership component are in Botswana (49%) and Gabon (62%) whilst Kenya and Madagascar have a large percentage of firms that export, 36% and 47% respectively. Firms that complain about power as a major problem to doing business are in Ghana (63%), Liberia (64%) and Sierra Leone (60%). In 14 out of these 25 countries, it takes at least 30 days to get an electricity connection and this is acute in Tanzania where firms can wait as much as 64 days on average. Countries with acute power problems measured in terms of percentage of output lost due to power, number of hours a day firms go without power and number of firms using generators include Angola, Nigeria and Sierra Leone. At sectoral level, a large percentage of firms in the wood and furniture, metal and minerals go for about six hours a day without power but the percentage of output lost due to power problems is high in the paper and printing sector as well as wood and furniture. Many firms in the food and tobacco sector, chemical and petroleum as well as paper and printing have backup generators (see Table 8 appendix). Firm size is relatively higher in food and tobacco as well as chemical and petroleum sectors and this could explain why they could afford generators and hence mitigate the effects of power outages on output lost. The other interesting thing is that these two sectors have a relatively large component of foreign ownership and percentage of firms that export. This probably imply that being foreign owned and export-oriented result in a firm being less tolerant of power outages.

Efficiency scores presented on Table 4, 5 and 6 in the appendix also show some interesting facts. Generally, most of the firms in the sample are not very efficient with an average efficient score being 0,58 suggesting that they are roughly 60% efficient. The countries with the least efficient firms are South Sudan (48%), Ghana

(51%) and Zimbabwe (52%) [See Table 4]. In most of these countries, being large, foreign owned and owning a generator improves efficiency slightly but in Ghana and South Sudan, the change in efficiency (for large and foreign owned firms) is relatively larger. This pattern of efficiency is replicated at sector level, with average efficiency scores in each sector averaging 57% and 58% (see Table 6). This partly suggest that efficiency has very little to do with the sector that a firm operates in.

The pattern is however very different when looking at the efficiency scores of export-oriented firms only (see Table 5). The average efficiency score in the sample jumps from 58% to 90%. This partly confirms the old argument that exporting improves efficiency through learning by doing and that efficient firms probably self-select themselves into exporting. The unavailability of panel data makes it difficult for us to confirm or reject any of these arguments in this study. Most exporting firms that have experienced power outages, own a generator, are large and foreign owned, show reduced levels of efficiency. This could be explained by the fact that large firms have large fixed costs, owning a generator increases operational costs, and this may affect efficiency.

Table 2: Stylized facts about African firms

Country	Firm size	Firm age	Capacity utilization	Foreign ownership (%)	Exporting firms (%)	Power as a major problem (% firms)	Electricity wait delays	Outages output lost (%)	Outages days	Outages hours	Own generator (%)
Angola (2010)	41	16	66	29	6	40	8	14	5	8	80
Botswana (2010)	83	21	76	49	12	36	46	5	5	3	36
Burkina Faso (2009)	127	20	72	14	12	59	22	5	9	3	42
Burundi (2014)	64	16	70	20	17	50	40	7	13	5	62
Cameroon (2009)	108	25	72	18	15	54	21	5	10	2	44
Djibouti (2013)	43	18	54	12	23	46	36	6	2	2	71
DRC (2010)	44	16	74	17	16	54	30	11	12	5	58
Gabon (2009)	62	20	77	62	12	57	36	4	7	4	25
Ghana (2013)	40	17	66	16	20	63	39	17	9	8	54
Ivory Coast (2009)	52	16	72	18	8	49	20	8	4	3	14
Kenya (2013)	111	24	73	11	36	28	36	9	7	5	61
Liberia (2009)	32	17	73	13	1	64	30	8	5	4	69
Madagascar (2013)	106	18	69	29	47	36	30	15	8	2	27
Mali (2010)	14	21	76	6	14	22	6	4	8	6	18

Country	Firm size	Firm age	Capacity utilization	Foreign ownership (%)	Exporting firms (%)	Power as a major problem (% firms)	Electricity wait delays	Outages output lost (%)	Outages days	Outages hours	Own generator (%)
Mauritius (2009)	82	27	69	11	26	44	30	4	3	3	35
Namibia (2014)	41	13	80	6	19	17	15	5	3	3	32
Nigeria (2014)	60	19	79	11	23	56	15	19	18	7	81
Senegal (2014)	55	18	80	12	13	49	37	5	6	2	63
Sierra Leone (2009)	37	22	76	15	4	60	18	12	15	10	77
South Sudan (2014)	17	6	67	40	4	54	12	12	8	4	66
Sudan (2014)	28	15	76	1	9	8	7	2	4	2	55
Tanzania (2013)	72	17	82	5	20	54	64	13	10	6	39
Uganda (2013)	63	17	73	14	22	32	41	17	9	6	47
Zambia (2013)	39	17	68	28	17	36	28	11	6	3	27
Zimbabwe (2011)	129	39	46	17	12	50	32	10	8	6	55
All countries	**65**	**19**	**71**	**17**	**19**	**42**	**23**	**10**	**8**	**5**	**51**

Source: Own calculation based on World Bank survey data

5 Results presentation and analysis

Table 3: Results

	TRANSLOG FUNCTION			**COBB-DOUGLAS FUNCTION**		
Sector dummies	NO	YES	YES	NO	YES	YES
LnK	0,2664*** (,0543)	0,2314*** (0,0874)	0,1987* (0,0986)	0,3642*** (0,0532)	0,2644*** (0,0435)	0,3573* (0,1654)
LnM	0,0664 (0,0652)	0,1563 (0,0892)	0,2146* (0,0959)	0,2561 (0,1590)	0,5631** (0,2342)	0,4563 (0,2342)
LnL	1,7260*** (0,1382)	1,8846* (0,9282)	1,9765*** (0,5382)	0,4560 (0,2382)	0,4030*** (0,1371)	0,4860*** (0,1475)
$(LnK)^2$	0,0345*** (0,0021)	0,0211*** (0,0036)	0,0432*** (0,0087)			
$(LnL)^2$	0,0086 (0,0089)	0,0187 (0,0176)	0,0156 (0,0143)			
$(LnM)^2$	0,0272*** (0,0036)	0,0285 (0,0183)	0,0295** (0,0089)			
LnK *LnL	-0,0345*** (0,0103)	-0,0398** (0,0156)	0,0270* (0,0132)			
LnK * Ln M	-0,0347 (0,0189)	0,0657 (0,0398)	-0,0436* (0,0201)			
LnL * LnM	-0,0594*** (0,0120)	-0,0762*** (0,0245)	-0,0894* (0,0430)			

	TRANSLOG FUNCTION			COBB-DOUGLAS FUNCTION		
Sector dummies	NO	YES	YES	NO	YES	YES
Size	-0,0047*** (0,0008)	-0,0082*** (0,0005)	-0,0165** (0,0078)	-0,0048*** (0,0010)	-0,0068*** (0,0018)	-0,0057*** (0,0014)
Size squared		0,0185** (0,0089)				
Age	0,0185*** (0,0021)	0,0149* (0,0067)	0,0376*** (0,0087)	0,0327*** (0,0015)	0,0298* (0,0102)	0,0317*** (0,0016)
Experience top-manager	-0,0012 (0,0011)	0,0032 (0,0021)	-0,0024 (0,0019)	-0,0048* (0,0020)	-0,0063 (0,0034)	-0,0075 (0,0060)
Foreign ownership	0,0121*** (0,0019)	0,0111*** (0,0020)	0,0162*** (0,0024)	0,0189*** (0,0026)	0,0163*** (0,0025)	0,0167*** (0,0024)
Experience power outages	-0,0059*** (0,0008)			-0,0067*** (0,0009)		
Export dummy	0,0023 (0,0019)	0,0064*** (0,0018)	0,0076*** (0,0032	0,0081* (0,0036)	0,0097*** (0,0034)	0,0073*** (0,0022)
Power generator x power outages hrs		0,0019 (0,0010)	0,0031* (0,0016		0,0049** (0,0019)	0,0035* (0,0018)
Outages output lost			-0,0063*** (0,0009)			0,0003 (0,0001)
Power outages hours			-0,0004 (0,0003)			-0,0024* (0,0013)
σ^2 (=$\sigma_u^2+\sigma_v^2$)	4,3231 (0,0325)	3,8654 (0,0043)	3,7986 (0,5421)	2,9546 (0,0098)	3,1897 (0,0076)	3,7643 (0,0342)
γ(=σ_u^2 / σ^2)	0,6532 (0,0034)	0,6554 (0,0061)	0,7001 (0,0021)	0,5576 (0,0008)	0,6698 (0,0083)	0,7765 (0,0032)
Log likelihood value	-3,142	-2,783	-3,267	-3,579	-2,087	-2,976
Mean TE	0,58	0,59	0,58	0,61	0,61	0,61
No of firms	**13602**	**11926**	**10791**	**13600**	**13346**	**13480**

N.B: We estimated Models 4-6 using a Log linear Cobb Douglas function. ***1% LOS; ** 5% LOS; *10% LOS; Standard errors are in parenthesis

We use a translog production function and assumed an exponential function for the truncated error term for our main model. As stated by Kneller and Stevens (2003) and Kumbhakar and Wang (2005), the translog form does not impose constant elasticity of substitution, as is the case with the Cobb Douglas model. Results on Table 3 above show that capital and labour are inputs that are important for production but the impact of labour appears to be relatively larger than that of capital. This pattern is also replicated even when using the Cobb Douglas function[7]. The raw materials variable though positive is insignificant and this could suggest that the way capital combines with labour is very important in enhancing efficiency. The next step

[7] We also carried out a generalised likelihood ratio test (LR) with the test statistic $\lambda = -2\{\log[Likelihood(H_0) - \log[Likelihood(H_1)]\}$ and we failed to reject the null hypothesis that input coefficients are equal to zero. We also conducted another separate hypothesis test on material inputs (LnM) and its products, since results consistently show that it is not significant. We still rejected the null hypothesis in favour of the alternative that the parameters of any variable included in the production function containing this input is not equal to zero.

that we carried out is testing for inefficiency effects (δ) defined in equation 6 above. As in the case of Battese and Coelli (1995) we carried out the likelihood ratio test, to check for inefficiency effects as well as check whether they are stochastic or not (these results are not presented but available on request). We rejected the null hypothesis that state that inefficiency effects are absent and that they are not stochastic. This means that these effects are related to the controlled variables included in equation 6. The average level of efficiency for all the firms in the study ranges between 58% and 61% depending on the production frontier model used. This shows that the level of efficiency is not very high in Africa.

There is also little variation at country level. We therefore do not use country dummies in the model to capture country heterogeneity in the efficiency model. However, efficiency statistics on Table 4 below show that on average foreign owned firms are slightly more efficient that other groups of firms. Technological transfers that are characteristic of foreign owned firms could probably explain this difference.

The efficiency model show that firm size has a consistently negative but significant relationship with efficiency. The positive sign carried by the square of the size variable shows that the relationship between efficiency and size is U shaped. Increasing the size of the firm has positive efficiency benefits after a certain size threshold has been reached. The descriptive statistics on Table 5 appendix partly support these results. The average efficiency scores of large firms are relatively smaller than those of medium and small firms in the case of export-oriented firms. This shows that probably the size threshold level has not been reached yet. The age variable is however also consistently positive suggesting that old age is good for efficiency probably through learning by doing and experience.

Other variables like foreign ownership and exporting carry expected signs and are generally significant. Thus, being involved in exporting and having some foreign ownership in the firm boost the level of efficiency. Thus, the competitiveness faced by exporters in the export market and the technical expertise that normally comes with some foreign investors helps in improving efficiency.

The variables of interest in this paper are those related to power disruptions. We want to see how electricity disruption that is common in many African countries affects efficiency of manufacturing firms. We first use a binary dummy called experience power outages and results show that the variable is negative and significant as expected. Firms that have suffered power disruptions have lower level of efficiency compared to those who did not. We then decided to measure electricity interruptions using percentage of output lost due to outages. The result is also as expected, negative and significant. The same result is also found using number of hours firms go without power per day. We finally decided to take account of the fact that many of these firms in the countries use generators as alternative sources of power. We interacted hours without power with generator ownership dummy. This is meant to ascertain the impact of owning a generator when there are power outages. Results show that the effect is generally negative and significant. Having a generator does not necessarily ameliorate the negative effects of power outages on efficiency. The increased operational costs associated with using these alternative power sources could explain this result. We also estimated an export model and found that all power related variables carry the expected sign and are significant (see Table 7 appendix). Sector level regressions however show mixed results. These results however should be taken with caution because there is a possibility that these self-reported power outage indicators are endogenous. It is possible for some firm managers to under report the frequency of outages because they have back up power sources and this could create measurement error problems. However, correcting for endogeneity problems in cross sectional models is very difficult.

6 Conclusion

The manufacturing sector in Africa contributes comparatively less to the continent's GDP, even though this is the sector with the highest potential in terms of reducing employment and promoting long-term sustainable growth and industrialisation. Understanding the problems afflicting the sector is important when designing policies to promote its growth. The efficiency of the manufacturing sector in Africa is one issue that is central in realising the industrialisation goals that the African Union is promoting as part of Agenda 2063.

The results show that inefficiency effects can be explained by the control variables used in the model and power is very important in enhancing the performance of the manufacturing sector. These results confirm several findings on electricity done in and outside Africa (Alam, 2013; Eberhard, 2011; Abotsi, 2016; Cissoko & Seck, 2013). There is need for government to invest funds into the electricity sector to improve the maintenance and the quality of infrastructure that is used to generate power. This will boost electricity production, reduce transmission losses and minimize power outages. Harnessing other energy sources, like solar or wind, could also help in improving the supply of electricity.

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Appendix

Table 4: Efficiency scores

Country	Country Average	Large firms	Foreign owned	Firms with severe power problems	Firms owning a generator	Old firms Age> 19
Angola (2010)	0,62	0,60	0,60	0,64	0,62	0,62
Botswana (2010)	0,56	0,57	0,56	0,56	0,57	0,57
Burkina Faso (2009)	0,63	0,64	0,64	0,63	0,63	0,63
Burundi (2014)	0,63	0,65	0,63	0,62	0,62	0,62
Cameroon (2009)	0,62	0,64	0,64	0,62	0,60	0,63
Djibouti (2013)	0,63	0,62	0,63	0,63	0,63	0,64
DRC (2010)	0,60	0,61	0,63	0,60	0,61	0,61
Gabon (2009)	0,63	0,63	0,63	0,62	0,63	0,64
Ghana (2013)	0,51	0,54	0,55	0,52	0,52	0,51
Ivory Coast (2009)	0,60	0,65	0,63	0,60	0,62	0,62
Kenya (2013)	0,59	0,59	0,59	0,59	0,59	0,59
Liberia (2009)	0,58	0,57	0,61	0,58	0,61	0,59
Madagascar (2013)	0,60	-	0,59	0,60	0,59	0,59
Mali (2010)	0,59	0,60	0,58	0,58	0,60	0,58
Mauritius (2009)	0,58	0,60	0,60	0,58	0,58	0,58
Namibia (2014)	0,54	0,55	0,56	0,57	0,53	0,57
Nigeria (2014)	0,57	0,59	0,57	0,56	0,57	0,58
Senegal (2014)	0,61	0,63	0,64	0,61	0,61	0,62
Sierra Leone (2009)	0,64	0,60	0,65	0,64	0,65	0,64
South Sudan (2014)	0,48	0,53	0,50	0,50	0,49	0,51
Sudan (2014)	0,54	0,50	0,55	0,54	0,53	0,53
Tanzania (2013)	0,60	0,59	0,60	0,60	0,60	0,60
Uganda (2013)	0,61	0,61	0,61	0,58	0,60	0,59
Zambia (2013)	0,64	0,63	0,65	0,63	0,64	0,63
Zimbabwe (2011)	0,52	0,51	0,53	0,52	0,52	0,52
All countries	**0,58**	**0,58**	**0,59**	**0,58**	**0,58**	**0,58**

Source: Own calculation based on World Bank survey data

Table 5: Export oriented firms only

Country	Country Average	Experience power outages	No outages experienced	Small firms	Medium Firms	Large Firms	Foreign owned	Own a generator	Do not own a generator
Angola (2010)	0,85	0,82	0,93	0,82	0,78	0,93	0,85	0,83	0,93
Botswana (2010)	0,93	0,93	0,93	0,93	0,93	0,93	0,93	0,93	0,93
Burkina Faso (2009)	0,91	0,91	0,94	0,93	0,88	0,93	0,93	0,88	0,93
Burundi (2014)	0,93	0,93	0,94	0,93	0,93	0,93	0,93	0,93	0,93
Cameroon (2009)	0,78	0,78	0,75	0,84	0,81	0,74	0,71	0,85	0,93
Djibouti (2013)	0,93	0,93	0,93	0,93	0,93	0,93	0,93	0,93	0,93
DRC (2010)	0,87	0,85	0,93	0,89	0,84	0,85	0,76	0,82	0,93
Gabon (2009)	0,76	0,77	0,62	0,70	0,83	0,70	0,82	0,84	0,65
Ghana (2013)	0,93	0,93	0,93	0,93	0,93	0,93	0,93	0,93	0,93
Ivory Coast (2009)	0,84	0,81	0,93	0,84	0,86	0,82	0,85	0,86	0,93
Kenya (2013)	0,92	0,92	0,93	0,93	0,92	0,90	0,90	0,91	0,93
Liberia (2009)	0,94	-	0,94	0,94	-	-	-	0,94	-
Madagascar (2013)	0,92	0,92	0,93	-	-	-	0,92	0,92	0,91
Mali (2010)	0,93	0,93	0,93	0,93	0,93	0,93	0,93	0,93	0,93
Mauritius (2009)	0,92	0,91	0,93	0,93	0,93	0,90	0,90	0,93	0,93
Namibia (2014)	0,93	0,93	0,93	0,93	0,93	0,93	0,93	0,93	0,93
Nigeria (2014)	0,91	0,91	0,89	0,93	0,89	0,89	0,89	0,91	0,92
Senegal (2014)	0,76	0,79	0,65	0,84	0,87	0,61	0,70	0,76	0,79
Sierra Leone (2009)	0,93	0,93	0,93	0,94	0,93	0,93	0,93	0,93	-
South Sudan (2014)	0,93	0,93	0,93	0,93	0,93	-	0,93	0,93	0,93
Sudan (2014)	0,92	0,91	0,93	0,90	0,93	0,93	0,93	0,91	0,93
Tanzania (2013)	0,89	0,88	0,93	0,93	0,93	0,81	0,86	0,87	0,92
Uganda (2013)	0,89	0,87	0,93	0,86	0,90	0,86	0,83	0,85	0,93
Zambia (2013)	0,80	0,79	0,85	0,79	0,85	0,71	0,79	0,81	0,80
Zimbabwe (2011)	0,93	0,93	0,93	0,93	0,93	0,93	0,93	0,93	0,93
All countries	**0,90**	**0,89**	**0,91**	**0,91**	**0,91**	**0,87**	**0,88**	**0,89**	**0,91**

Source: Own calculation based on World Bank survey data

Table 6: Sector level efficiency scores

Country	Food and Tobacco	Textile Leather and Garments	Wood and furniture	Chemical and petrol	Metal and minerals	Electronic and instruments	Machinery and Transport	Paper and printing	Plastic, rubber and recycling
Angola (2010)	0,64	0,62	-	0,57	0,62	-	0,57	-	0,65
Botswana (2010)	0,56	0,55	-	0,56	0,57	0,54	0,54	-	0,54
Burkina Faso (2009)	0,61	0,59	-	0,63	0,61	-	0,60	-	0,63
Burundi (2014)	0,59	0,58	0,57	0,60	0,58	-	-	0,59	0,58
Cameroon (2009)	0,60	0,60	-	0,60	0,59	0,60	0,58	-	0,61
Djibouti (2013)	0,62	-	0,61	0,62	0,60	0,63	0,66	0,60	-
DRC (2010)	0,60	0,60	0,60	0,62	0,60	0,61	0,61	0,61	0,61
Gabon (2009)	0,64	0,62	-	0,61	0,61	-	-	-	-
Ghana (2013)	0,54	0,53	0,51	0,54	0,54	0,55	0,40	0,54	0,53
Ivory Coast (2009)	0,61	0,60	-	0,61	0,60	0,51	0,58	-	0,61
Kenya (2013)	0,59	0,58	0,58	0,58	0,59	0,62	0,58	0,59	0,58
Liberia (2009)	0,53	0,57	-	0,66	0,57	0,62	-	-	0,63
Mali (2010)	0,60	0,56	-	-	0,58	-	0,67	-	-
Mauritius (2009)	0,58	0,56	-	0,58	0,58	-	-	-	0,57
Namibia (2014)	0,56	0,58	0,57	0,55	0,56	0,49	0,58	0,55	0,57
Nigeria (2014)	0,57	0,56	0,57	0,59	0,57	0,57	0,57	0,56	0,58
Senegal (2014)	0,60	0,60	0,58	0,62	0,60	0,67	0,61	0,61	0,59
Sierra Leone (2009)	0,64	0,65	-	0,65	0,65	-	-	-	0,65
South Sudan (2014)	0,53	0,41	0,54	0,55	0,54	-	0,56	0,48	-
Sudan (2014)	0,55	0,49	0,55	0,56	0,49	0,54	0,55	0,56	0,39
Tanzania (2013)	0,59	0,59	0,59	0,57	0,61	0,58	0,59	0,59	0,58
Uganda (2013)	0,58	0,59	0,59	0,62	0,59	0,61	0,57	0,61	0,57
Zambia (2013)	0,61	0,61	0,61	0,61	0,61	0,58	0,62	0,62	0,60
Zimbabwe (2011)	0,54	0,53	0,54	0,53	0,53	0,56	0,54	0,54	0,52
All countries	**0,58**	**0,57**	**0,58**	**0,58**	**0,58**	**0,57**	**0,58**	**0,57**	**0,57**

Source: Own calculation based on World Bank survey data

Table 7: Export and sector level results

	Export Model	**Food and Tobacco**	**Textile, leather and garments**	**Wood and Furniture**	**Metal and mineral**	**Paper and printing**	**Chemical and petrol**
Sector dummies	YES	NO	NO	NO	NO	NO	NO
Size	-0,0058*** (0,0011)	-0,0080*** (0,0014)	-0,0110*** (0,0017)	-0,0074** (0,0030)	-0,0030 (0,0026)	-0,0057* (0,0029)	-0,0003 (0,0032)
Age	0,0096*** (0,0023)	0,0027 (0,0024)	-0,0008 (0,0038)	-0,0017 (0,0049)	-0,0091 (0,0048)	0,0073 (0,0056)	-0,0002 (0,0054)
Experience top-manager	-0,0044** (0,0021)	0,0003 (0,0022)	-0,0092*** (0,0034)	0,0041 (0,0043)	-0,0009 (0,0042)	-0,0051 (0,0051)	0,0020 (0,0048)
Foreign ownership	0,0065** (0,0032)	0,0072 (0,0043)	0,0061 (0,0064)	-0,0108 (0,0109)	0,0114 (0,0070)	0,0216** (0,0102)	0,0245*** (0,0079)
Experience power outages	-0,0147*** (0,0021)	-0,0034 (0,0022)	-0,0057* (0,0034)			-0,0112 (0,0089)	-0,0102 (0,0101)
Export dummy		0,0059 (0,0040)	-0,0008 (0,0053)	-0,0106 (0,0074)	0,0122 (0,0080)	-0,0018 (0,0092)	0,0104 (0,0076)
Power generator interaction	0,0112*** (0,0021)	0,0048** (0,0023)	0,0030 (0,0031)	-0,0104* (0,0057)	-0,0108 (0,0056)	-0,0057 (0,0060)	0,0021 (0,0061)
Outages output lost	-0,0002* (0,0001)						
Power outages hours				0,0009* (0,0005)	0,0002 (0,0005)		
Mean TE	0,90	0,58	0,57	0,58	0,58	0,57	0,58
No of firms	**1164**	**1306**	**839**	**307**	**438**	**335**	**324**

***1% LOS; ** 5% LOS; *10% LOS; Standard errors are in parenthesis

Table 8: More stylized facts on African firms

	Exporting firms	**Food and Tobacco**	**Textile, Leather and garments**	**Wood and Furniture**	**Metal and mineral**	**Chemical and petrol**	**Paper and printing**
Size of firm	160	127	98	31	62	99	52
Age of firm	23	22	18	18	20	22	22
Experience top-manager	17	16	17	15	16	16	15
Foreign ownership (%)	31	19	12	08	18	25	13
Experience power outages (%)	27	22	29	32	22	14	18
Power outages hours	4,5	4.9	5.5	5.6	5.9	4.2	5.3
Outages output lost (%)	12	13	14	17	13	09	18
Exporting firms (%)		26	30	15	17	34	19
Own generators (% of firms)	55	62	34	34	52	64	59

Source: Own calculation based on World Bank survey data