Costly outages: The Economic Cost of Unreliable Electricity Infrastructure in Africa

An empirical study on electricity outages and firm productivity in Africa

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Abstract

Countries with better quality infrastructure tend to grow faster. This stylised fact is investigated by examining the effect of poor electricity infrastructure, measured as the average number of power outages experienced by firms per month within a certain region, on labour productivity. By estimating an enterprise level random effects model on an unbalanced panel of over 1,000 manufacturing firms in 16 African countries between 2006 and 2015, the findings suggest that a one unit increase in the number of electricity outages at a regional level, corresponding to around a 10 percent increase, is associated with a reduction in labour productivity of around 2 percent. Furthermore, the findings indicate that owning a generator does not appear to significantly reduce the impact of poor electricity reliability and that the impact may be non-linear and increasing in the number of outages.

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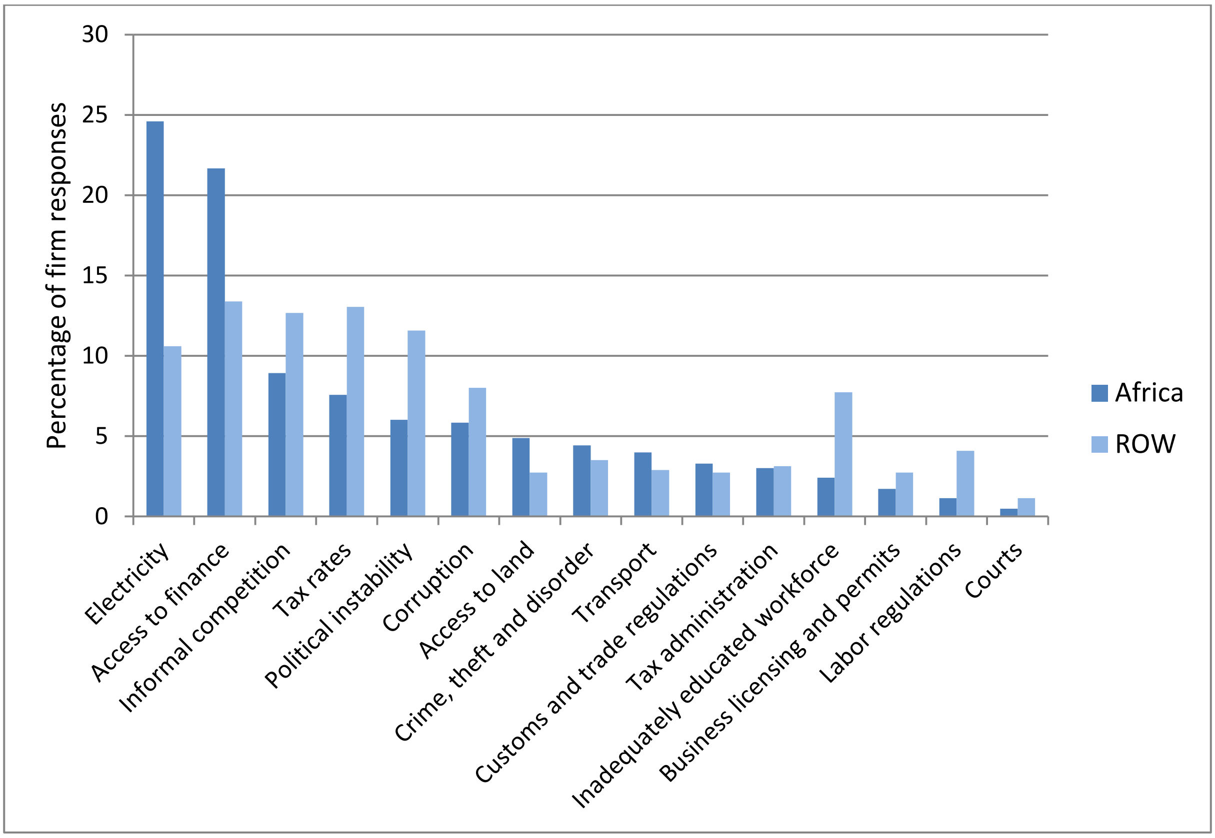
1. Introduction

Infrastructure (transport networks, utilities and amenities) is often hailed as an engine for growth. This view is supported by evidence that countries with better infrastructure tend to grow faster. The notion is that good quality infrastructure reduces frictions for the private sector and thereby fosters a positive business environment and improves standards of living. However, the reverse may significantly limit a countries growth potential. Target 9.1 and 9.2 of the 2030 United Nations Sustainable Development Goals state that "develop[ing] quality, reliable, sustainable and resilient infrastructure" is important to support "economic development, human well-being" and "raise industry's share of employment and gross domestic product", with an emphasis in "least developed countries" (United Nations, 2015, pg.20). In Africa, electricity, water, roads and telecommunications infrastructure are crucial factors in promoting growth (Estache, 2005). In particular, poor electricity infrastructure plays a key role in constraining potential growth in the region. Poor electricity infrastructure, rising demand and low investment has led to frequent power outages which means "big losses in forgone sales and damaged equipment" (African Development Bank, 2011, pg. 1) and is a "major cause of the high cost of manufacturing in developing countries" (Jyoti, Ozbafli & Jenkins, 2006, pg. 0).

Figure 1.1: Main obstacle to business operations in Africa compared to the rest of the world



Note: Rest of world (ROW) does not include Africa. Based on Authors calculations from the entire Enterprise Survey (2006 – 2016) composed of 27,753 firms in Africa and 90,191 firms in the ROW.

Around 25 percent of firms in Africa complain that electricity poses the largest obstacle to their business operations (see Figure 1.1). While poor electricity reliability is not a unique African problem, the figure shows that enterprise in the rest of the (developing) world generally views electricity problems with relatively lower concern. The World Bank (2013) highlights four key issues with Africa's energy sector: low access, insufficient capacity, poor reliability and high costs. For example, only around 24 percent of the population in Sub-Saharan Africa has access to electricity. Furthermore, manufacturing firms have to deal with electricity outages on a weekly basis[1] and face high costs of around US$0.13 per kilowatt-hour on average, approximately double what most other developing nations pay[2]. Arnold, Matoo & Narciso (2008) note that these "inadequacies in power provision may disrupt the production process, cause productive assets to lie idle and thus decrease productivity".

The literature studying the relationship between infrastructure and economic growth can be divided into two research approaches: at an aggregate level and at the firm level. This thesis focuses on the latter as recent literature, based on improved availability and quality of firm level data, has concentrated on identifying the effects of infrastructure at a micro level. Firm level analysis represents a methodological improvement because it is more likely that firms take the infrastructural setting as given (exogenous) while, on aggregate, more productive areas may demand better quality infrastructure creating a simultaneity bias (Dollar & Kraay, 2003). While the empirical methods of analysis tend to differ, most researchers postulate that the channel through which infrastructure affects growth is via improved allocative and productive efficiency within the economic area (Schiffbauer, 2007).

This study pays particular attention to the large volume of empirical literature that has focused on developing countries. Firstly, the study by Sharma & Mishra (2009) examines the effect of infrastructural improvement on labour productivity (taking into consideration its elasticity) in the manufacturing sector in India for the post-reforms era. The authors use data on eight manufacturing industries from the Centre for Monitoring Indian Economy for the period 1994 – 2006. By regressing labour productivity on a composite index which includes energy, ICT and transportation infrastructure, they find a slight but positive correlation suggesting that better infrastructure is associated with higher labour productivity. Furthermore, Arnold, Mattoo & Narciso (2008) investigate the relationship between productivity and access to services inputs for around 1,000 manufacturing firms in Sub-Saharan Africa using the World Bank Enterprise Survey. They adopted the regional aggregated variation instead of the single firm level to isolate possible endogeneity issues obtaining significant results for each of the three service sectors (electricity, telecommunications and banking) analysed. The authors also find a significant and positive effect going from service performance towards firm productivity, concluding that there is evidence that infrastructure enhances the performance of downstream economic activities and as such promotes growth. Finally, Moyo (2013) finds that power infrastructure is an important determinant of manufacturing productivity. Based on a firm level analysis on five countries[3] in Sub Saharan Africa the author finds a significant

[1] On average 56 days a year.
[2] An equivalent unit of power costs around US$0.04 to US$0.08 in most other developing countries. Note: this ignores the additional costs associated with self-generation of electricity by means of a generator.
[3] South Africa, Tanzania, Uganda, Zambia and Mauritius.

and negative relationship between sales and two measures for electricity reliability: the number of hours per day without electricity and the percentage of output lost due to outages.

There are however several limitations of the aforementioned literature. Firstly, the literature has typically only gone so far as to try to identify the direction of causality (which is quite obvious) and has not put much attention towards estimating the actual economic costs. Therefore, it becomes difficult for policymakers to apply the research in the real world. Secondly, the studies are generally undertaken on a small sample of firms, based on a few countries and only cover a short period of time. This means it is difficult to implement more precise estimation techniques such as random or fixed effects on a panel of firms. Finally, insufficient attention is paid to identification issues. There is little discussion about how the variable capturing electricity infrastructure may also be correlated to the provision of other infrastructure variables (such as water and roads) and whether firm level (survey) responses about service allocation are reliable.

This paper contributes to the literature on electricity infrastructure and firm productivity in three ways; firstly this is the first paper (to the Authors knowledge) that looks specifically at the variability of electricity outages using panel data at the firm level on 16 countries, this signifies a significantly larger sample of observations compared to previous studies. Past research on the effects of electricity infrastructure on firms has either been performed on a panel of firms from a single country (see Sharma & Mishra, 2009; Fisher-Vanden, Mansur & Wang, 2012) or on a cross section of firms for a variety of countries (see Alby, Dethier & Straub, 2012). This is predominantly due to data limitations at the firm level as surveys are often incomparable over countries and time. Therefore this thesis presents a methodological improvement over prior research as it exploits an enterprise random effects model to capture both time and regional variation by using panel techniques. Secondly, I demonstrate the importance of including a dummy variable for generator ownership as the exclusion may lead to endogeneity issues. I show evidence that Moyo’s (2013) finding that a generator significantly reduces the negative impact of poor electricity infrastructure is questionable. Finally, I present various models to test the robustness of the findings and illustrate that the impact of electricity infrastructure may be non-linear and negative in the number of regional outages.

This paper is separated into 6 sections. Section two develops a model of firm productivity under unreliable electricity infrastructure and outlines the hypotheses. Section three constructs an empirical model to test the hypotheses and section four describes the data used. Finally, section five presents the results and section 6 concludes.

2. Theoretical framework

2.1. The Model

The following section develops a model to understand the mechanisms through which an unreliable electricity supply may affect firms' choices and therefore productivity. The firm's problem is defined as one of constrained optimisation such that (1) the firm cannot produce above its technological capabilities[4] and therefore must produce on or below its production function and (2) the firm faces an unreliable electricity supply. Given a similar set-up, Fisher-Vanden et al. (2012) show that electricity blackouts affect firm productivity negatively as it constrains a firms input choices, therefore increasing costs. This is channelled through three main choices for firms: investing in a generator, outsourcing electricity production or investing in more efficient technologies. All of these would imply increasing costs[5] as it limits the firm's possible production choices, and force firms to apply second-best solutions in the form of factor reallocation and alternative, less efficient, energy sources (Alby, Dethier & Straub, 2012). In the following section I explain how electricity outages may constrain the production function following the model in Fisher-Vanden et al. (2012).

In order to construct a model of firm productivity, several assumptions must first be acknowledged. Firstly, as noted above, it is assumed that a firm faces a constrained optimisation problem where profits are maximised subject to a production function which takes prices and infrastructure as given. Therefore firms operate in a competitive market and cannot influence these factors. Following the model by Fisher-Vanden et al. (2012) I assume a firms output is generated by the following general production function:

$$y = f(k, l, m, e, n; \theta), \tag{1}$$

where y is the firm output (or sales), k, l, m, e and n are capital, labour, material, electricity and other inputs and θ represents the probability of an electricity outage in the region (therefore proxying for the unreliability of electricity infrastructure). If there are no outages, then $\theta = 0$ and the unconstrained profit function can be expressed as a function of exogenously determined input prices[6] and output prices:

$$\Pi_u = \Pi_u\left(p_y, p_k, p_l, p_m, p_n, p_e\right) = p_y y^* - (p_k k^* + \ ... + p_e e^*), \tag{2}$$

where p_i refers to the corresponding prices for the output and inputs in (1), therefore on the left side $p_y y^*$ represents the revenues and $p_k k^* + \ ... + p_e e^*$ represents the costs (the asterisk * denotes the optimal level). From this, one can derive the input demands using Hotelling's lemma:

$$-x^* = \frac{\partial \Pi}{\partial p_x}, \qquad x = k, l, m, e, n \tag{3}$$

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[4] The technology determines and therefore constrains how a firm can transform inputs into outputs.
[5] Although switching technologies can be expensive and in the long run it may be beneficial, Alam (2013) shows that while it may lead to a relatively lower impact of power outages, firms still face a drop in productivity.
[6] Input prices are determined in a competitive market and therefore firms cannot directly influence prices as they are assumed to have no market power.

However, if electricity is unreliable, i.e. $\theta > 0$, then the constrained level of electricity, $\hat{e}$, will be less than the optimal usage e^* such that: $0 \leq \hat{e} < e^*$. This follows from the logic that when a firm faces an additional constraint, assuming that the input is not perfectly substitutable[7], it will substitute the unreliable input for other inputs such as capital (i.e. by purchasing a generator). Therefore the electricity constraint enters the profit function as:

$$\Pi_c = \Pi_c(p_y, p_k, p_l, p_m, p_n, p_e, \hat{e}) = p_y y^* - (p_k k^* + \ ... + p_e \hat{e}) \tag{4}$$

As such, for a risk neutral firm, the expected profit function for producing a given amount of output $\bar{y}$ is:

$$E[\Pi(\bar{y})] = (1-\theta)\Pi_{\mathrm{u}}(\bar{y}) + \theta\Pi_{\mathrm{c}}(\bar{y}) \tag{5}$$

and therefore because of the additional electricity constraint the effect on productivity is likely to be negative:

$$\frac{\partial E[\Pi(\bar{y})]}{\partial\theta} = \Pi_{\mathrm{c}}(\bar{y}) - \Pi_{\mathrm{u}}(\bar{y}) \leq 0 \tag{6}$$

as the constraint on electricity limits a firms production possibilities which can at best[8] reach the unconstrained level of profits.

2.2. Derivation of hypotheses

It is now possible to analyse the effects of the previously cited three options a firm may use to deal with poor electricity infrastructure. In case of switching to self-generated electricity, the firm would switch to other energy sources which are an imperfect substitute for public electricity provision and the marginal cost function shifts up. If the firm decides to outsource a portion of energy production, materials purchased are substitutes for electricity, and this decision may sub-optimally reallocate the use of labour, capital and other inputs. In the latter case, a firm may decide to invest in improving its efficiency, and this is particularly observed in case of favouring policies implemented in the region where the firm is established. Overall, these second best solutions imply a lower share of electricity inputs and a loss in productivity due to poor substitutability. Following this I decide to test the main hypothesis that:

H_1: *The unreliability of electricity infrastructure negatively affects firm productivity.* (a)

where the null hypothesis is that the unreliability of electricity infrastructure does not affect firm productivity.

As proposed by Fisher-Vanden et al. (2012) one of the channels through which electricity constraints effect productivity is via a second best investment into an alternative, more

[7] This is a realistic assumption as, unlike water which can be easily stored, electricity is prohibitively expensive to store (Fisher-Vanden et al., 2012). According to Alby et al. (2012), self generated electricity is 313% more expensive in Africa and therefore firms have to respond to shortages in other ways.

[8] If the input is perfectly substitutable, which I argue is not the case.

reliable energy source such as a generator. Considering that almost half of the firms in the dataset own or have access to a generator (see Table 4.1 in the Data section), this suggests that one response to power outages in Africa is to invest in self-generation. By including an interaction term between the quality of power infrastructure and a dummy for whether a firm owns or shares a generator, Moyo (2013) finds that generators partially reduce the negative impact of poor power infrastructure on firms in the sample. Furthermore, in an analysis of Ugandan firms, Reinikka & Svensson (2002) observed that many of them indeed reacted to poor electricity supply by investing in generators, which led to reduced overall investment and less productive capital. The costs and scope for self-generation are large; Alby et al. (2012) observe that in Nigeria, 40% of electricity consumed comes from a generator while self-generated electricity is 313% more costly[9] in Africa. Following this argumentation, I decide to test whether access to alternative energy in the form of a generator reduces the impact of electricity instability, leading to the second hypothesis that:

H_1: *Access to a power generator ameliorates the effect of poor electricity infrastructure* (b)

where the null hypothesis is that access to a power generator does not ameliorate the effect of poor electricity infrastructure.

A rational extension to hypothesis (a) and (b) is that the magnitude of productivity losses increases for industries that are more electricity intensive. Indeed, both Alby et al. (2012) and Alam (2013) find that electricity related constraints have non-linear effects and vary by the sectors reliance on electricity. Alby et al. (2012) find that the largest distortions are encountered in sectors heavily relying on electricity, such as textile and chemical sectors, causing a bigger efficiency gap. Furthermore, Dollar, Hallward-Driemeier & Mengistae (2005) find that more reliable power supply is correlated with increased productivity in garment manufacturing. As such I will investigate the hypothesis that:

H_1: *The impact of electricity reliability on firm productivity is heterogeneous between industries* (c)

where the null hypothesis is that the impact of electricity reliability on firm productivity is not heterogeneous.

[9] Reinikka & Svensson (2002) also observe that self-generated electricity is around 3 times as costly.

3. Empirical strategy

3.1 Empirical model

The empirical strategy is to exploit regional level variation in the provision of electricity infrastructure to estimate the impact of electricity reliability on firm productivity. Following the approach by Arnold et al. (2008) and Alby et al. (2012) I construct measures of electricity reliability by aggregating firm responses[10] per region. I argue that aggregating firm responses is better than using direct survey responses because it minimises endogeneity issues. Omitted variable bias may arise as electricity outages could be influenced by unobserved factors such as building quality and whether a bribe has been paid to ensure a steady flow of electricity which may also impact firm productivity. Furthermore, there may be reverse causality as individual firms that are more productive may be able to afford a better electricity connection and therefore sort into these areas. Finally, as firm level information is generally based on survey questions, firms that perceive electricity as a larger (smaller) issue may overestimate (underestimate) the number of outages causing systematic measurement error. In all circumstances, this may lead to an overestimate of the effect of electricity reliability on productivity.

To identify the impact of electricity infrastructure on firm productivity the following enterprise level random effects model is estimated:

$$ln(Prod_{i,j,k,p,t}) = \beta Infra_{k,p,t} + \gamma \Omega_{i,j,k,p,t} + \sum_{m=1}^{m} \delta_m + \eta_i + \varepsilon_{i,j,k,p,t} \quad (1)$$

where $ln(Prod_{i,j,k,p,t})$ corresponds to the natural logarithm of productivity for firm *i* operating in sector *j* within region *k* and country *p* in time period *t*. The main explanatory variable of interest $Infra_{k,p,t}$ represents the infrastructure variables and are aggregated at the regional level *k*. Furthermore $\Omega_{i,j,k,p,t}$ represents a vector of control variables at the firm level. These controls include: capital stock, age, size and dummies for whether the firm trains their employees, is an exporter, is foreign owned, is state owned and is located in the capital[11]. Finally, we include an expansive set of fixed effects, represented by the vector $\sum_{m=1}^{m} \delta_m$, for industry type δ_j, country δ_p, and time δ_t. Furthermore, to control for potential variation in macroeconomic conditions over time and market power, I include country-year δ_{pt} and country-industry δ_{pj} fixed effects. The rationale behind these controls is twofold; (1) to prevent endogeneity arising from omitted variable bias and (2) to improve the efficiency of the estimators. Finally, η_i represents an enterprise specific random effect and $\varepsilon_{i,j,k,p,t}$ represents a robust clustered standard error[12].

[10] As the methodology is based on survey data, firms are asked how many outages they experience in an average month. These survey responses are aggregated to create the measure of electricity reliability at the regional level.
[11] Note: Exporters and foreign owned firms may be endogenously determined and therefore the final regression equations are also tested for their robustness when these variables are not included (Melitz, 2003; Arnold et al., 2008). The argument for including them is that the estimates may be more precise (efficiency purposes).
[12] As explained in Arnold et al. (2008) it is important to cluster the standard errors around the unit of aggregation (regional level) in order to ensure standard errors are not underestimated.

The specific control variables are based on economic theory and literature. A firm's capital stock is likely to be correlated to their productivity as it is an input in production. The natural logarithm of capital is included in the regression as the production function may respond to relative changes in capital and the input of capital in production may change given infrastructure conditions (Arnold et al., 2008; Moyo, 2013). The rationale for including age is that firms experience learning by doing effects and therefore to survive and not exit the market new firms would have to improve their productivity over time (Benfratello & Sembenelli, 2006). Age may have a non-linear functional form so I use a log functional form as in Haltiwanger et al. (1999) and Emami Namini, Facchini & López (2013). The abovementioned authors also include the log of the number of employees to proxy for the size of the firm and therefore potential efficiencies from economies of scale. Furthermore, larger firms may also be more endowed with skilled labour (Söderbom & Teal, 2001). The functional form assumption corresponds to the general notion that learning-by-doing and economies of scale efficiencies are diminishing and therefore concave. Knowledge spillovers may arise from foreign ownership and exporting, therefore I include dummy variables if the firm has any foreign ownership and if it exports (Arnold et al, 2012; Moyo, 2013). Furthermore employee training programmes may improve the human capital and skills in the labour force and therefore productivity, hence I also include a dummy variable for whether there was a training programme at the firm. As noted in Arnold et al (2008), the capital city may receive more policy importance relative to other regions and therefore infrastructure quality may be higher. This variable also captures differences in agglomeration economies which may lead to higher productivity between regions (Ciccone & Hall, 1996; Koster, van Ommeren & Rietveld, 2014). Therefore, I include a dummy variable for whether a firm is located in the capital city.

I include a variety of fixed effects to control for geographical, institutional and temporal, market and industry heterogeneities. Firstly, firms operating in the same location may be influenced by common variables, such as macroeconomic conditions, public capacities and locational advantages, which may influence both the productivity of firms and also the provision of infrastructure. Therefore I include country fixed effects which absorbs any time invariant locational advantages. These conditions however may change over time, for example due to exchange rate fluctuations and political instability that are country specific which is especially present in the African region (Collier, 2008, pg.17). For this reason I also include country-year fixed effects. Certain macroeconomic conditions may also influence firms in all locations, such as the global financial crisis which caused an overall depression in demand; hence I also include time fixed effects. Furthermore, some sectors may receive favourable policies such as preferential access to electricity for energy-intensive industries and productivity may vary over industries. Therefore I include industry fixed effects. Lastly, preferential policies and market failures are also likely to result in heterogeneities in industrial competitiveness between countries. Therefore I include country-industry fixed effects to control for heterogeneities in market power and industrial concentration which may influence both firm productivity and infrastructure provision.

The analysis proceeds by estimating a panel analysis with enterprise level random effects and comparing the results to an enterprise level fixed effects model and a pooled OLS model[13]. In order to determine which empirical model is more appropriate, several aspects need to be considered, specifically; whether there is sufficient variation over time and whether the individual specific effects are correlated. These aspects are dependent on the data available and are discussed in the results section. A Hausman test is performed to determine which empirical model is statistically more appropriate. The null hypothesis states that:

$$H_0: E[\eta_i | \Omega_{i,j,k,p,t}, \dots, Infra_{k,p,t}] = 0$$

where both random and fixed effects are consistent, but the random effects estimator is more efficient because it captures both the variation within individuals over time and between individuals on average[14]. The alternative hypothesis is that:

$$H_1: E[\eta_i | \Omega_{i,j,k,p,t}, \dots, Infra_{k,p,t}] \neq 0$$

which states that only fixed effects is consistent[15]. One disadvantage of the fixed effects model in this analysis is that it is not possible to perform out of sample predictions as η_i is by definition unknown for firms not included in the sample.

3.2 Identification issues

Endogeneity may arise from three sources, measurement error, omitted variable bias and reverse causality. The first two issues are partially controlled for by aggregating the infrastructure indicator as explained above. However, there may still be unobserved characteristics at the regional level that are correlated to both labour productivity and electricity infrastructure. For example, in regions that have poorer electricity infrastructure, this may signal a failure of local government in providing public services. Therefore the infrastructure indicator may also capture other infrastructural deficiencies. To investigate whether the regional electricity infrastructure variable *only* captures the deficiencies in electricity infrastructure a measure for the electricity intensity is created. One would expect that if the variable correctly captures only electricity infrastructure, firms that use electricity relatively more intensively will be effected more than firms that use less electricity. Therefore, a median split is performed and a dummy for firms that use electricity more intensively and less intensively is interacted with the infrastructure variable of interest such that:

$$ln(Prod_{i,j,k,p,t}) = \beta_1 Infra_{k,p,t} * \delta_{int} + \beta_2 Infra_{k,p,t} * \delta_{nint} + \delta_{int} + \cdots + \varepsilon_{i,j,k,p,t} \quad (2)$$

where β_1 represents the estimator for the impact of poor electricity infrastructure on firms that use electricity relatively intensively (δ_{int}) while β_2 represents the same impact on firms that

[13] Therefore assuming no panel component so η_i drops out of specification (1).
[14] While fixed effects only captures the variation within individuals over time.
[15] As it suggests that the firm specific effect η_i is systematically correlated causing the RE model to be inconsistent. Note: the RE model assumes that η_i is uncorrelated between firms, therefore: cov(η_i, η_j) = 0, where *j* stands for all other firms.

use electricity relatively less intensively (δ_{nint}). The dummy variable δ_{int} is also included in the regression because there may be a difference in firm characteristics and productivity between electricity intensive and non-intensive firms which is captured by the main effect. Having estimated (2) an F-test is performed such that:

$$H_0: \beta_1 = \beta_2$$
$$H_1: \beta_1 \neq \beta_2$$

If the null hypothesis is rejected, this suggests that the measure for electricity infrastructure is more likely to be a suitable measure.

An alternative way to circumvent this issue would be to apply an instrumental variable approach. If a variable capturing the exogenous variation in electricity infrastructure can be found, such as natural disasters which influence the average number of electricity outages but does not directly influence firm productivity (other than via outages), this could be used to instrument the potentially endogenous variable and also control for potential sorting effects which may be present. While this is a promising approach to determine whether a causal relationship exists, it is beyond the scope of this thesis and I encourage further research to propose and implement other potential instruments.

3.3 Marginal effects

A log-linear functional form is estimated in order to identify the impact of a change in electricity infrastructure on the percentage change in firm productivity. In this respect, the coefficient of interest β can be interpreted as:

$$\beta = \frac{\partial \ln(Prod)}{\partial Infra} = \frac{\partial Prod}{\partial Infra} * \frac{1}{Prod}$$

This functional form is convenient for interpretation because the marginal effect β represents the growth rate or the percentage change in productivity associated with a marginal change in infrastructure. By rearranging terms, the marginal effect of a change in infrastructure on firm productivity can be derived as:

$$\ln(Prod) = \beta Infra + \cdots + \varepsilon$$

$$Prod = exp(\beta Infra + \cdots + \varepsilon) = exp\ (Prod)$$

$$\frac{\partial Prod}{\partial Infra} = \beta exp\ (Prod)$$

which can be used to calculate a monetary estimation of the economic cost of an improvement (or degradation) in infrastructure for each country.

4. Data

4.1 Data collection

The data used in this analysis comes from the World Bank's Enterprise Survey where firms are classified using the ISIC Rev 3.1[16]. The survey provides a representative sample of the private sector of an economy using a stratified random sampling approach by grouping enterprises into homogenous clusters following three main criteria: firm size, sector of activity and geographical location (Enterprise Surveys, 2016). The survey is performed via face-to-face interviews with owners and top managers. Furthermore, the majority of the surveys were undertaken in and around large urban cities, where most firms concentrate.

Two types of datasets are available; (1) a cross-sectional dataset compiling (periodic) annual surveys on developing countries and also (2) more detailed country specific datasets which contain panel information[17]. I chose to collect firm level information at the country level as the panel data allow me to observe firms over multiple periods and therefore represent higher quality information[18], but this comes at the trade-off of having a smaller sample size. I append the datasets at the country level, paying close attention to maintain consistency in variable names. The complete dataset contains information on around 28,000 firms in 16 Africa countries[19] between 2006 and 2015 that adhere to the Enterprise Surveys Global Methodology[20].

Of this sample, over 6,000 firms have panel information, however due to missing data; the final sample contains an unbalanced panel of 2,241 observations which are used in the proceeding analysis and also to draw the descriptive statistics below. Due to limitations in the availability of data on capital stock, the sample is restricted to manufacturing firms. While this is not fully representative of the population of firms, it allows for comparison with previous papers which focus exclusively on manufacturing firms. Figures A.1 & A.2 in the appendix show the distribution of firms over countries and industries. Firms are relatively evenly spread over countries; however Egypt has a large number of firms, while Ghana only has a few. Furthermore, the majority of firms in the sample manufacture food and beverages. The following section describes the construction of variables in the dataset and the final compilation.

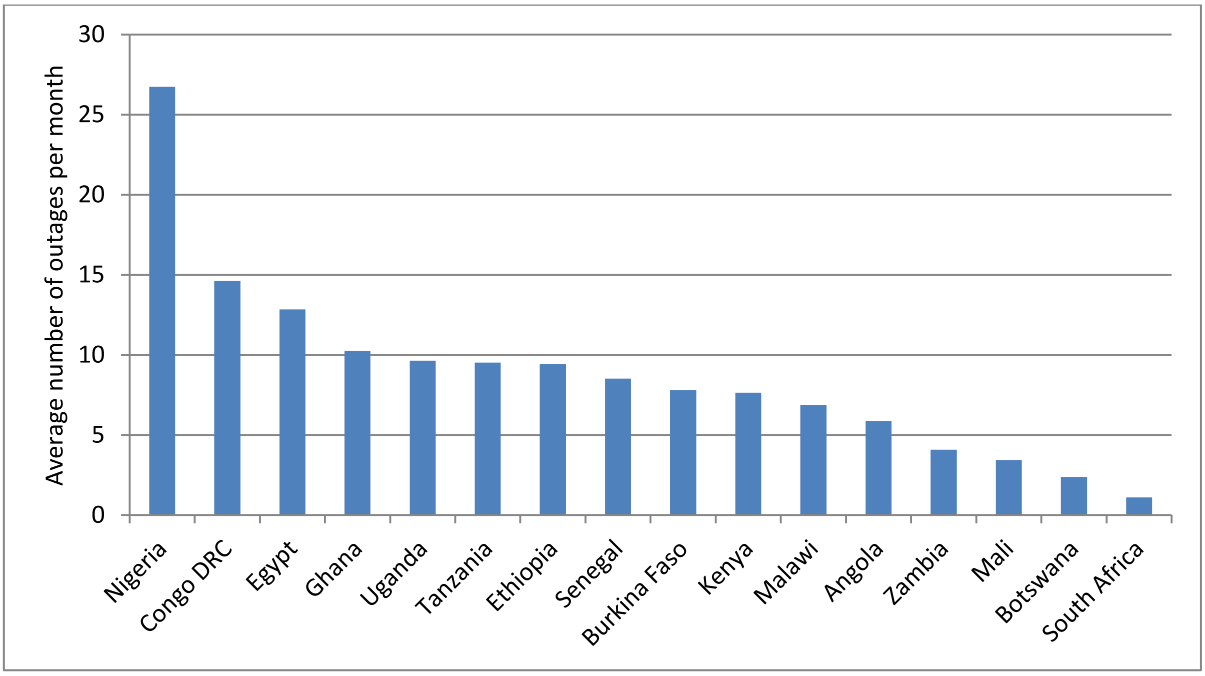
4.2 Construction of the dataset and descriptive statistics

Elaborating on the variables in the estimation equation, the dependent variable, firm productivity, is proxied by labour productivity which is measured as the natural logarithm of total firm sales[21] over the number of full time employees, as in Sharma & Mishra (2009). The logarithmic functional form is chosen because it normalises the data and improves interpretation of the estimates. Alternatively, it may be more appropriate to measure labour

[16] International Standard Industrial Classification of All Economic Activities, Rev.3.1.
[17] Thereby following firms in the same country over time.
[18] More advanced and precise statistical analysis can be carried out to investigate causality more deeply.
[19] This sample represents around 30 percent of countries in Africa (total 54), see Figure 4.2 for map.
[20] This is important for consistency and comparability.
[21] Measured in local currency units (LCUs).

productivity as the value added, or profit[22], per employee. This however reduces the size of the dataset considerably and the correlation between the two measures is very high (correlation coefficient equals 0.98) which suggests that variation in labour productivity is almost entirely captured by the first measure. Labour productivity is preferred over other measures of productivity because the main interest of this paper is to estimate the costs of electricity outages. By examining the percentage change in labour productivity with respect to electricity outages the costs can be directly computed via the dependent variable using the procedure explained in section 5.3. On the other hand, if the dependent variable is TFP, as in Arnold et al. (2008) which can be estimated as the residual of the production function[23], one may expect that electricity reliability is encapsulated in the estimate as production is likely to be a function of electricity costs (among other factors). As such a correlation between the independent variable of interest and the dependent variable may exist by default. One limitation is that the dependent variable cannot be directly compared between countries because the exchange value of currency differs over space and time[24]. While this does not pose an issue with the econometric specification due to country, time and country-time fixed effects which capture the variation in macroeconomic conditions between countries over time it is not possible to directly compare firm productivities. Nevertheless, I provide some anecdotal evidence that firm productivity is negatively related to outages in Figure A.3 in the appendix.

Figure 4.1: Average number of outages in a typical month aggregated by country



Note: Sorted from highest to lowest. Based on Authors calculations of 2,241 obs. between 2006 and 2015 in the African region.

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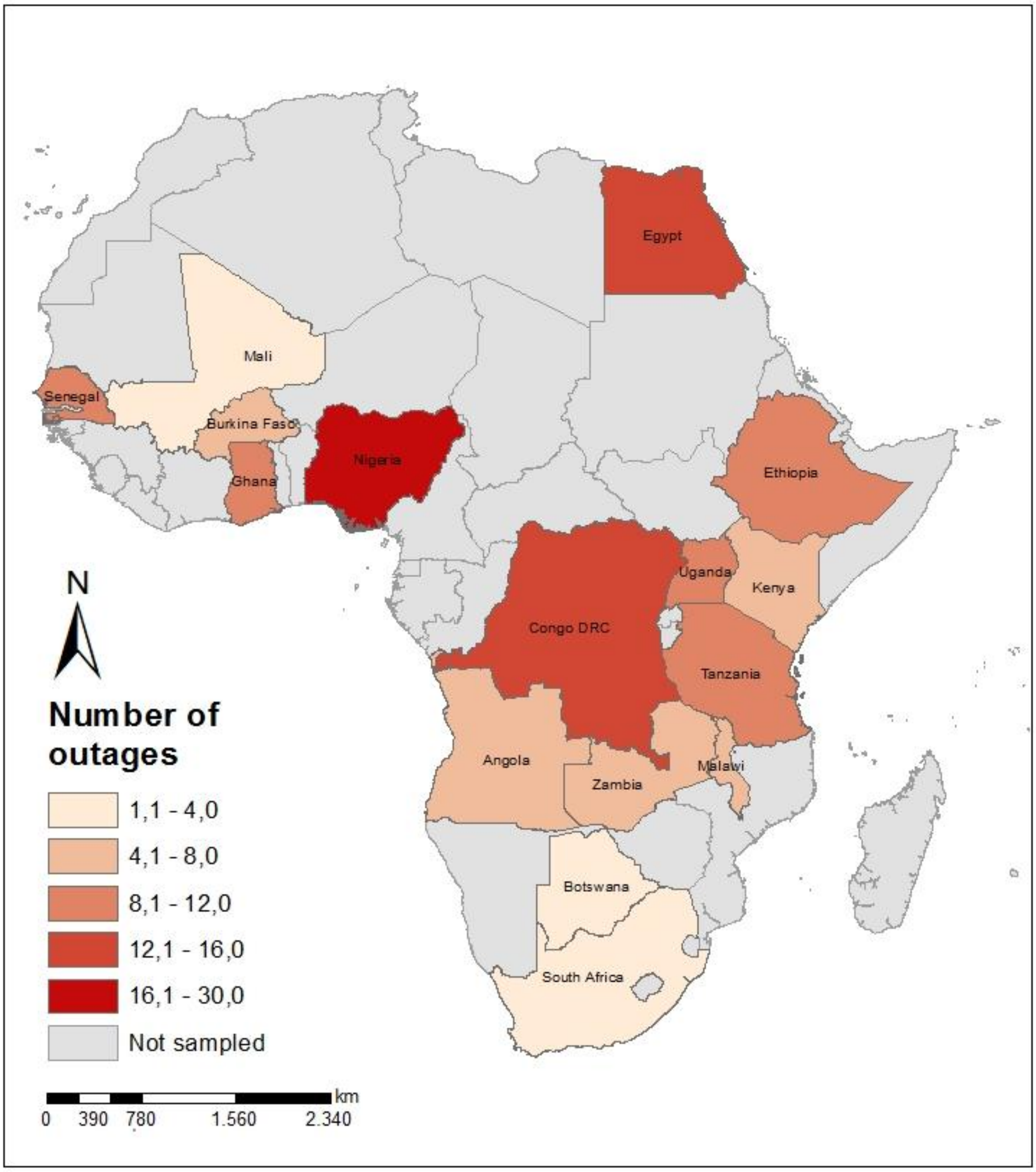
[22] Calculated as the total sales (revenues) minus total costs.

[23] Production = f(l, k, etc) + e where TFP = ê.

[24] Exchange rate information is available from Penn World Tables; however I chose not to convert the currencies due to the large number of countries and the potentially additional measurement error due to for example official rates diverging from market rates because of black markets.

The main explanatory variable of interest is the reliability of electricity infrastructure. This is measured as the average number of electricity outages firms experienced in a typical month aggregated at the regional level and therefore represents how poor the electricity infrastructure is in a region. In order to construct this variable, I draw upon a question in the survey which asks “In a typical month, over the fiscal year [X], how many power outages did this establishment experience?” (World Bank, 2008). On average there are 6 regions per country (94 total) and each region is observed over two or three years which introduces a significant degree of variation in the quality of electricity infrastructure. Figure 4.1 shows the variation in the average number of outages by country and Figure 4.2 presents a map of the sample area and the spatial variation in the main variable of interest.

Figure 4.2: Map of the sample area and average number of outages per month by country



Note: Number of outages per month based on Authors calculations. See Figure 4.1 for data.

Table 4.1 below shows the main descriptive statistics. As can be seen, the average number of regional outages in a month is 9.52 and there is a large variation in outages in the sample. Furthermore, a large proportion of the sample has access to a generator, around 39 percent. This suggests that firms may have responded to unreliable electricity by purchasing a generator. Furthermore, the average firm in the sample has 127 employees[25] and has been operating for almost 20 years, indicating that firms are generally quite large and experienced. This raises some concern as it may suggest that the sample is not entirely representative of the underlying population of firms. Bigger firms may be more likely to be surveyed more than once because they move location less or are easier to find (and therefore are included in the panel) and therefore it is important to acknowledge this aspect when interpreting the findings.

Table 4.1: Descriptive statistics

Variable (unit)	Mean	Std. Dev.	Min	Max
Number of outages (per month)	9.52	7.00	0.24	39.30
Own generator (dummy)	0.39	0.49	0	1
Size (number of employees)	127.11	351.02	2	5000
Age (in years)	19.46	15.71	1	166
Trained (dummy)	0.31	0.46	0	1
Exporter (dummy)	0.18	0.38	0	1
Foreign owned (dummy)	0.14	0.35	0	1
State owned (dummy)	0.03	0.16	0	1
Capital location (dummy)	0.24	0.43	0	1

Note: 2,241 observations. Productivity, sales, costs and capital stock data not included due to incomparability over LCU units.

As for the dummy variables included, on average 31 percent of firms in the sample had formal training programmes for their full time employees in the last year, 18 percent export more than 10% of their total sales, 14 percent have more than 10% foreign ownership, 3 percent have more than 10% state ownership and 24 percent of firms are located in their countries respective capital city.

[25] Note: I exclude firms with size larger than 5,000 (8 obs. dropped) due to potential measurement error and because they represent large outliers compared to the sample.

5. Results

5.1 Main results

In this section I go over the statistic and economic interpretation of the main results testing the hypotheses outlined in Section 2. Firstly, Table 5.1 presents the main findings of the panel analysis. In specification (1) I estimate a random effects model by regressing the variable of interest and fixed effects for year, country, industry, country-year and country-industry on the natural logarithm of labour productivity. The number of outages is negative and significantly associated with labour productivity (at the 1% level). The coefficient indicates that, on average, an additional outage per month is associated with 2.2% lower productivity. Comparing this to the average number of outages in the sample, this is equivalent to a 10% increase in outages[26]. The overall R-Squared is equal to 0.75 suggesting that around 75% of the variation in labour productivity is explained by the explanatory variables[27].

Table 5.1: Main findings

Main Variables	(1) RE	(2) RE	(3) RE	(4) RE	(5) FE	(6) POLS
Number outages	-0.0220***	-0.0230***	-0.0274***	-0.0194**	-0.0126	-0.0201***
	(0.00779)	(0.00768)	(0.00778)	(0.00801)	(0.0131)	(0.00765)
x Own generator			0.0144*	-0.00833	0.0333	-0.00842
			(0.00765)	(0.0119)	(0.0244)	(0.0180)
Own generator				0.343***	0.0672	0.341**
				(0.111)	(0.284)	(0.170)
Controls	No	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,241	2,242	2,241	2,241	2,241	2,241
Overall R-squared	0.754	0.792	0.793	0.794	0.0451	0.794

Note: The dependent variable is the natural logarithm of labour productivity. All specifications include year, country, industry, country-industry and country-year fixed effects. Control variables include: ln(Capital), ln(Size), ln(Age) and dummies for Trained, Exporter, Foreign owned, State owned and Capital location. See appendix for full list of controls included and their estimates. Clustered, robust standard errors in parenthesis with ***, ** and * denoting significance at 1% (p<0.01), 5% (p<0.05) and 10% (p<0.1) level, respectively.

In specification (2) I include the control variables described in the empirical model[28]. The majority of control variables have the expected signs. Capital stock, training, exporting status, foreign ownership and capital location are positively and significantly associated to labour productivity while state ownership and surprisingly age and size are negatively associated with labour productivity (however state ownership and age are not significant).The coefficient of interest does not change significantly suggesting that the fixed effects sufficiently control for most external, potentially omitted, factors. Furthermore, the overall R-squared does not change much (increases to 0.79) which suggests that the fixed effects already capture most of

[26] Calculated as the change in outages divided by the mean outages: 1 / 9.52 = 10.5%

[27] I perform join F-tests to check whether the fixed effects are improve the model estimation. All of the F-tests are significant at the 1% level indicating that the fixed effects are important.

[28] Correlation matrix (available upon request) shows no reason to suspect the presence of multicollinearity between the control variables.

the variation in labour productivity. This suggests there is a methodological trade-off between precision and consistency. On the one hand, many observations (around 3,000) are missing some of the firm characteristics and therefore the sample size declines (precision), while on the other hand, these controls may be important in further analysis when testing whether a generator[29] impacts the effect of outages (consistency). Nevertheless, I include the control variables as I am interested in estimating the causal effect.

In specification (3) I examine whether owning a power generator reduces the negative effect of electricity outages using an interaction term, without the main variable, as proposed by Moyo (2013). The coefficient for the interaction term is positive and significant (at the 10% level) suggesting that as Moyo (2013) finds, owning a generator reduces the negative impact of electricity outages. The generator appears to reduce the effect by over half[30], representing a significant improvement. However, more productive firms may be more likely to own a generator. By excluding the main effect of the generator in his equation, Moyo (2013) ignores the sorting effect that may be present and therefore his estimate may be biased. In specification (4) I include the main effect of the generator and show that indeed, firms that own a generator do appear to be more productive (the coefficient of the dummy for generator ownership is positive and significant at the 1% level). Furthermore, the interaction term between the number of outages and generator ownership becomes negative and insignificant. This may indicate that self-generation of electricity is highly expensive and the costs of owning a generator do not necessarily outweigh the benefits. Alby et al. (2012) observe that self-generated electricity is 313% more costly[31] in Africa and Reinikka and Svensson (2002) observed that investing in generators led to reduced overall investment and less productive capital.

Finally, in specification (5) and (6) I re-estimate the final model (4) with enterprise level fixed effects (FE) and also as a pooled OLS model (POLS). The fixed effects model has in general, similar effects as the random effects model, however the coefficient for the number of outages is insignificant. This insignificant result may be indicative of low (time) variation within the panel. Taking a closer look, the within R-squared is equal to 0.39, much less than the between R-squared and overall R-squared from the random effects model (0.81 and 0.79, respectively). This suggests that the random effects model is more efficient as the fixed effects model ignores the large degree of variation between firms. A Hausman test fails to reject the null hypothesis (p-value = 0.53) suggesting that random effects are consistent and more efficient than fixed effects. I also check whether random effects are more efficient than a pooled OLS model where I leave out the enterprise level effect using a Breusch-Pagan Lagrangian multiplier test. The chi-squared test statistic is equal to 18.09 suggesting that random effects is indeed a better model (p-value = 0.00). Therefore I decide to do all further analysis using enterprise level random effects.

[29] Larger firms with more capital are more likely to own a generator (due to high fixed costs) and therefore there may be omitted variable bias if these variables are not included.

[30] Owning a generator reduces the impact of electricity outages from - 2.7% to – 1.3%.

[31] Reinikka & Svensson (2002) also observe that self-generated electricity is around 3 times as costly

5.2 Identification revisited

As noted in the methodology, the average number of electricity outages in a region may be endogenous because other factors which also determine labour productivity, such as corruption, civil-war or water infrastructure, may also be correlated to the measurement of electricity infrastructure which could lead to an overestimate of the effect. As such, I create a variable which captures the intensity of electricity use by a firm, which is measured as the proportion of electricity costs over total sales, and perform a median-split by creating two dummy variables and interacting these with the variable of interest as in specification (2) of section 3.

Table 5.2: Testing regression results for robustness

	(7)	(8)	(9)	(10)	(11)	(12)
Main Variables	Median-split	Ind int	Intervals	Exp&Fown	Duration int	Std
Number outages		-0.0169*		-0.0213***	-0.0204**	-0.136**
		(0.00873)		(0.00773)	(0.00906)	(0.0561)
x Elec intensive	-0.0365***					
	(0.0121)					
x Elec non-intensive	0.00488					
	(0.0115)					
x Dummy elec. int.	-0.425***					
	(0.0992)					
x Textiles		-0.0181				
		(0.0187)				
x Rubber & Plastic		-0.0162				
		(0.0226)				
x Basic metals		-0.0614				
		(0.0569)				
x $0 < Nout < 10$			-0.00934			
			(0.0212)			
x $10 \leq Nout < 20$			-0.0181*			
			(0.00993)			
x $20 \leq Nout < 30$			-0.0146			
			(0.00932)			
x $Nout \geq 30$			-0.0313**			
			(0.0137)			
x Duration					0.000692	
					(0.00170)	
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,819	2,241	2,241	2,241	2,240	2,241
Overall R-squared	0.809	0.794	0.794	0.789	0.798	0.794

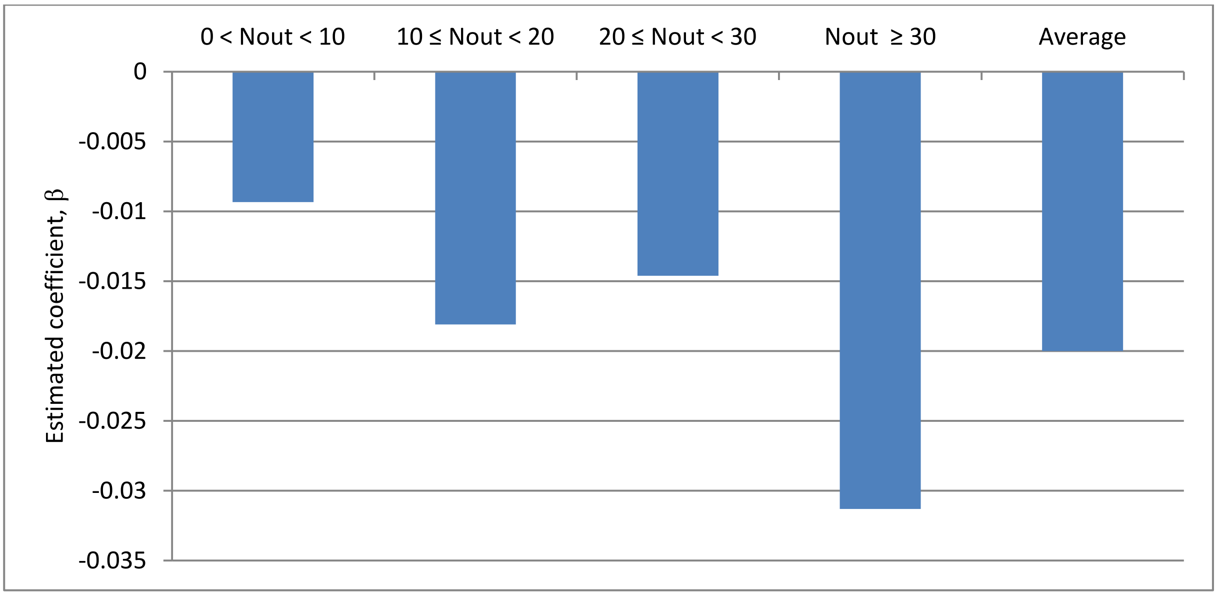
Note: The dependent variable is the natural logarithm of labour productivity. All specifications include year, country, industry, country-industry and country-year fixed effects. Control variables include: ln(Capital), ln(Size), ln(Age) and dummies for Generator ownership, Trained, Exporter, Foreign owned, State owned and Capital location. See appendix for full list of controls included and their estimates. Clustered, robust standard errors in parenthesis with ***, ** and * denoting significance at 1% ($p<0.01$), 5% ($p<0.05$) and 10% ($p<0.1$) level, respectively.

Specification (7) in Table 5.2 shows that the electricity outages are particularly damaging for electricity intensive firms, while less electricity intensive firms are not significantly affected by poor electricity infrastructure[32]. Furthermore, an F-test shows that the coefficients are significantly different (p-value = 0.00). This suggests that the measure for electricity is good at capturing variation in electricity infrastructure and is unlikely to be highly correlated, and therefore capturing the effects, of other public goods. Additionally, the dummy variable for electricity intensive industries is negative and significant indicating that it is indeed important to control for the main effect as it appears that firms that use electricity more intensively are not identical[33] and tend to be systematically less productive.

In specification (8) I investigate whether there are industry heterogeneities. Firstly, I identify the top three electricity intensive industries on average (see Figure A.4 in appendix) which are Basic metals, rubber & plastic and textiles (industry codes are 27, 23 and 17 respectively). The interactions show the expected negative sign however are insignificant. This may be because of the small number of observations.

In specification (9) I test the assumption that electricity outages has a linear effect on labour productivity by creating dummies for intervals; between 0 – 9, 10 – 19, 20 – 29 and finally 30+ outages. I interact these dummies with the number of outages to determine whether the negative impact of electricity infrastructure is increasing in outages. Figure 5.1 illustrates the impact of outages over the intervals compared to the average estimate of around -0.02. It appears that indeed there is an increasing impact of outages as they become more severe and the average linear affect may not appropriately model the functional form correctly.

Figure 5.1: Testing the functional form of outages on the estimated marginal effect



Note: Significance levels shown in Table 5.2 based on specification (9). Nout represents the average number of outages per region.

[32] Note: the number of observations declines slightly, as the cost of electricity is not observed for all firms.
[33] A further breakdown of the descriptive statistics for both groups shows that the two samples are not entirely identical, providing further justification to include the main effect (see Table A.1 in appendix)

In specification (10) I check whether including dummies for exporting status and foreign ownership biases the results due to potential reverse causality discussed in the methodology. The findings show that the impact is not significant. Furthermore, specification (11) examines whether the duration of outages also impacts the effect of electricity infrastructure as it might be expected that areas that have more outages also have longer durations of outages. Interestingly, the coefficient for the interaction between the number and duration of outages is positive but not significantly different than zero. This may suggest that the variability of outages is important, but not necessarily the duration. Finally, in specification (12) the number of outages is standardised to make the interpretation more straightforward. It indicates that a one standard deviation increase in electricity outages is associated with a reduction of labour productivity of around 14 percent[34].

5.3 Measuring the economic cost of poor electricity infrastructure

This study aims to contribute to the policy debate on infrastructure provision. Along these lines, I present a methodology to estimate the economic cost imposed by an additional outage and therefore approximate how much money could be saved, and therefore should be allocated, if public finances were geared towards improving electricity infrastructure. In order to estimate this, I use the marginal effects calculated in section 3.3 to estimate the additional value added per employee[35] in the manufacturing sector from a one unit reduction in outages. These estimates are country specific to aid interpretation.

First, I calculate the marginal effect of an increase in the number of outages using the formula derived in section 3.3:

$$\frac{\partial Prod}{\partial Infra} = \hat{\beta} exp\,(Prod)$$

Then I aggregate these effects by country to determine the marginal effect in local currency units (LCUs). Finally, I convert these LCUs to 2010[36] USD using the Penn World Tables exchange rates in order to compare the estimates.

Figure 5.2 (see next page) illustrates the economic benefit from a marginal reduction in electricity outages based on the linear and non-linear functional form models. The calculations suggest that Ghana, Kenya and Congo DRC would stand to gain the most from a marginal reduction in electricity outages. Furthermore, the estimates from the non-linear model are consistently smaller than the average linear model. This suggests that the average effect may not be as accurate as it does not account for the non-linear effect of outages. While this is an interesting practical extension to this work, it is important to question and interpret

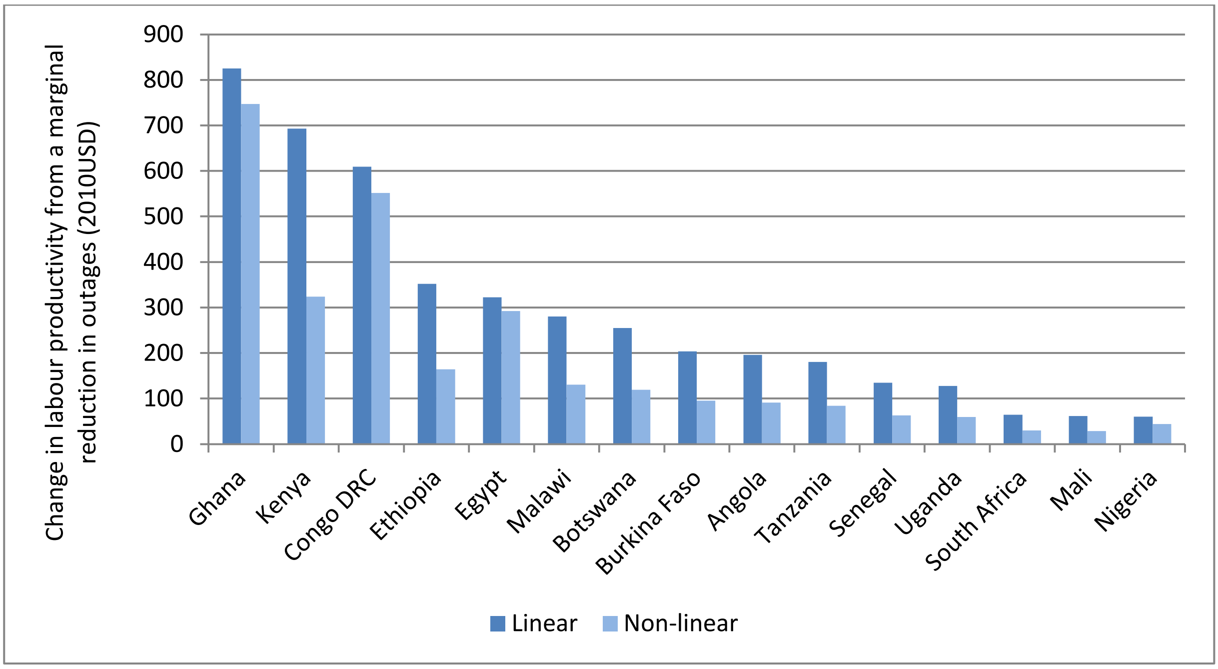
[34] This is intuitive as Table 4.1 shows that the std. dev of outages is 7 (multiplied by -0.0.2 = -0.14) but provides an intuitive comparison for future studies.

[35] For this estimation, productivity is measured as: (Sales – All costs (labour +machines + material inputs + fuel + electricity)) divided by total number of employees to get a better understanding of the loss in value added. Note: there is a high correlation (0.98) between this measure and the measure used in the estimations.

[36] 2010 is chosen for simplicity because it is in the middle of the sample.

the economic relevance of these findings. Firstly, I am somewhat critical of some of the estimates. Ghana's GDP per capita in 2010 was USD2,126[37] which implies that a marginal change in the number of outages would significantly contribute to GDP. This may be due to measurement error in the dependent variable as one might expect that GDP per capital is approximately equal to the sum of the marginal productivity of labour, capital and other activities such as resource extraction. Therefore labour productivity should be less than the GDP per capita. Alternatively this may also be capturing the return to capital or show that manufacturing workers are significantly more productive in African countries. Nevertheless, the lower bound suggests a more conservative estimate as Nigeria and Mali are expected to gain around 60USD (or 44USD and 29USD, respectively, in the non-linear model) per manufacturing employee per year for a marginal reduction in outages. This represents a significant economic gain and may encourage policy makers to make the right investment in electricity infrastructure. Furthermore, it is important to recognise however that this only considers the effect on manufacturing firms and therefore the impact is likely to be larger as households and other firms are also likely to benefit from better quality electricity infrastructure.

Figure: 5.2: Economic benefit of a reduction of one outage in 2010 USDs per employee



Notes: Zambia excluded as an outlier. Benefit is measured as the average value added by labour (revenues – costs) / number employees converted into 2010USD. For the linear model, I use the rounded estimate for $\hat{\beta}$ = -0.02 from specification (4) and for the non-linear model I use the estimates from specification (9).

[37] In 2011 constant USD (see Penn World Tables 8.0)

6. Conclusions & discussion

This paper examines the economic impact of poor electricity infrastructure on manufacturing firms in Africa. Electricity poses an important obstacle to African enterprise. Power outages are likely to cause disruptions to production and may force firms to switch to alternative, less efficient fuel sources. The findings suggest that blackouts have a statistically significant and economically meaningful impact on labour productivity. A one unit increase in outages at a regional level, corresponding to around a 10 percent increase, is associated with a reduction in labour productivity of around 2 percent. This seems to be a reasonable estimate for the impact of unreliable infrastructure on manufacturing firms which often plays a key role in the production process. I test whether the measure for electricity outages is endogenous by comparing the impact on electricity intensive and non-intensive firms as it might capture the effect of poor public good provision. The results corroborate the abovementioned finding as it suggests that firms that use electricity relatively more intensively are affected more by poor infrastructure. I provide counter-evidence to the findings of Moyo (2013) that generators lessen the negative effects of electricity outages. This may suggest that the increased costs of self generation do not necessarily outweigh the benefits of a more stable supply. Furthermore, I show that in the sample, the impact of electricity outages may be heterogeneous as some industries are impacted relatively more by outages, however the affects are not statistically significant. Finally, I also show that the functional form of the effect may be non-linear, specifically negative in the number of outages, as demonstrated by Figure 5.1 and 5.2 in the results section.

The policy implications are relatively straightforward. The economic rationale is to increase expenditure on the provision of electricity infrastructure until the benefits of a marginal increase in spending to reduce electricity outages equals the costs of the additional unit of spending. By estimating the costs in 2010 USD I provide some interpretation of how much these benefits may be for the countries in the sample. However, caution is urged when interpreting the findings as (1) the measure for labour productivity appears to be quite high compared to the country's GDP per capita and (2) this only captures the impact on manufacturing firms and therefore does not relate to the total social benefits.

Further research should be geared towards refining these estimates of the economic costs in order to provide accurate informed policy advice. Moreover, additional attention can be taken to estimate firm productivity. Lastly, more comprehensive and detailed data collection could improve the estimates and expand the sample to include more countries.

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8. Appendix

Figure A.1: Distribution of firms in the sample

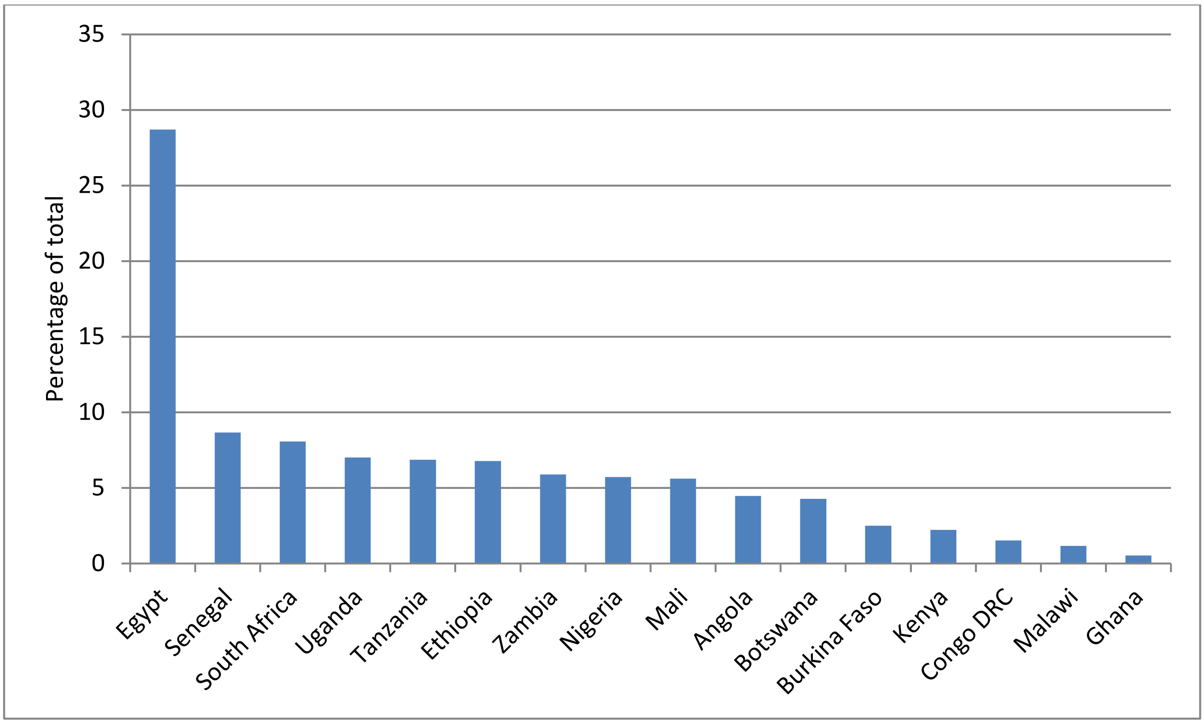
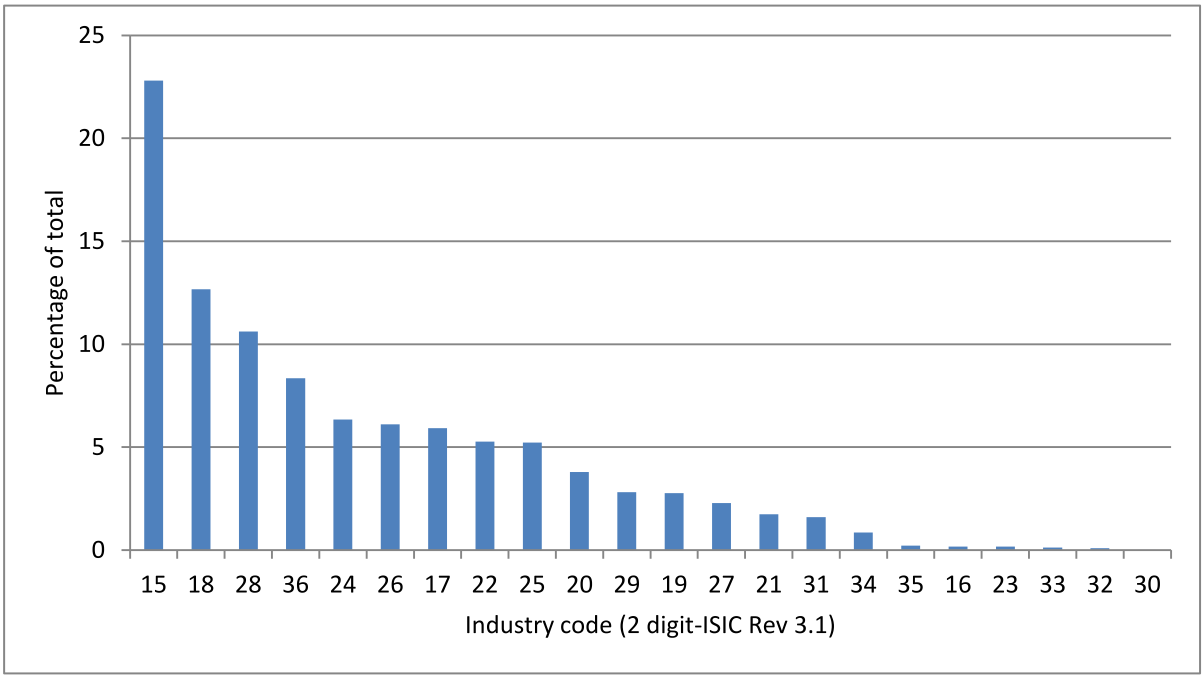
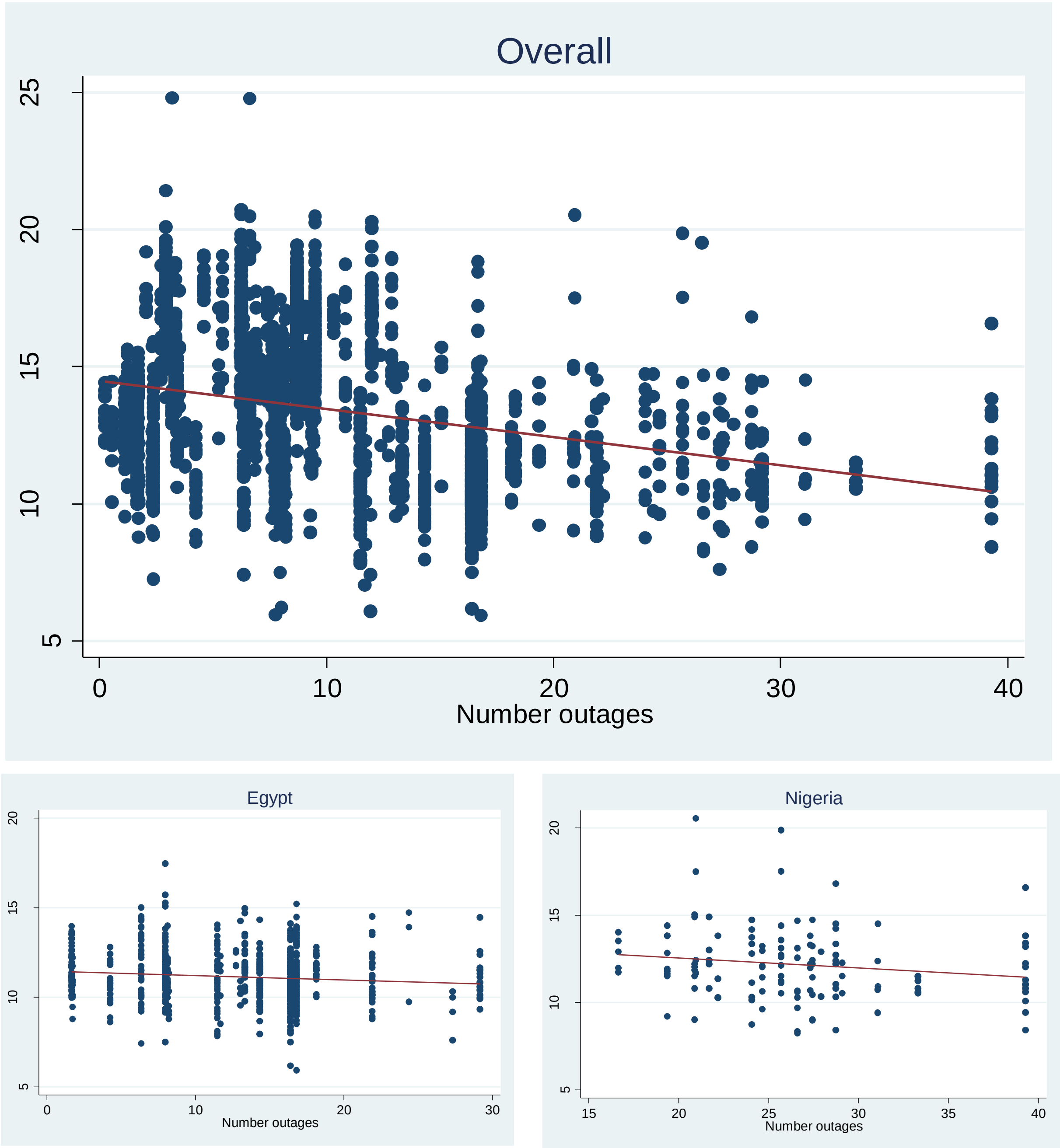


Figure A.2: Distribution of firms by 2-digit industry code in the sample



Note: See ISIC Rev3.1 for details on industry classification

Figure A.3: Some anecdotal evidence of the negative relationship between labour productivity (y-axis) and the average number of electricity outages per region (x-axis).



Notes: As explained in the text, the overall effect cannot be directly compared over countries due to differences in currency units. Egypt and Nigeria are chosen for illustrative purposes only. On the y-axis is ln(Prod) while on the x-axis is the average number of electricity outages per region.

Table 5.1: Main results (cont.)

VARIABLES	(1) RE	(2) RE	(3) RE	(4) RE	(5) FE	(6) POLS
Number outages	-0.0220***	-0.0230***	-0.0274***	-0.0194**	-0.0126	-0.0201***
	(0.00779)	(0.00768)	(0.00778)	(0.00801)	(0.0131)	(0.00765)
x Own generator			0.0144*	-0.00833	0.0333	-0.00842
			(0.00765)	(0.0119)	(0.0244)	(0.0180)
Own generator				0.343***	0.0672	0.341**
				(0.111)	(0.284)	(0.170)
Ln(Capital)		0.216***	0.216***	0.213***	0.182***	0.215***
		(0.0219)	(0.0222)	(0.0220)	(0.0327)	(0.0227)
Ln(Size)		-0.164***	-0.179***	-0.185***	-0.166**	-0.185***
		(0.0371)	(0.0369)	(0.0366)	(0.0710)	(0.0386)
Ln(Age)		-0.0554	-0.0543	-0.0607	-0.0903	-0.0610
		(0.0388)	(0.0385)	(0.0387)	(0.0963)	(0.0450)
Trained		0.179**	0.180**	0.174**	-0.0569	0.178**
		(0.0768)	(0.0767)	(0.0766)	(0.150)	(0.0724)
Exporter		0.430***	0.413***	0.403***	0.471**	0.408***
		(0.0879)	(0.0876)	(0.0875)	(0.185)	(0.0990)
Foreign owned		0.447***	0.448***	0.428***	0.428*	0.425***
		(0.0923)	(0.0922)	(0.0926)	(0.255)	(0.107)
State owned		-0.0679	-0.0437	-0.0358	-0.227	-0.0375
		(0.229)	(0.229)	(0.229)	(0.439)	(0.216)
Capital location		0.188**	0.192**	0.182**	0.575**	0.175
		(0.0917)	(0.0910)	(0.0911)	(0.270)	(0.147)
Constant	13.43***	10.51***	10.50***	10.34***	8.143***	11.94***
	(0.187)	(0.380)	(0.380)	(0.374)	(1.610)	(0.532)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Country *Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Country*Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,241	2,242	2,241	2,241	2,241	2,241
Overall R-squared	0.754	0.792	0.793	0.794	0.0451	0.794

Note: The dependent variable is the natural logarithm of labour productivity. Clustered, robust standard errors in parenthesis with ***, ** and * denoting significance at 1% (p<0.01), 5% (p<0.05) and 10% (p<0.1) level, respectively.

Table 5.2: Testing regression results for robustness (cont.)

VARIABLES	(7) Median-split	(8) Ind int	(9) Intervals	(10) Exp&Fown	(11) Duration int	(12) Std
Number outages		-0.0169*		-0.0213***	-0.0204**	-0.136**
		(0.00873)		(0.00773)	(0.00906)	(0.0561)
x Elec intensive	-0.0365***					
	(0.0121)					
x Elec non-intensive	0.00488					
	(0.0115)					
x Dummy elec. int.	-0.425***					
	(0.0992)					
x Textiles		-0.0181				
		(0.0187)				
x Rubber & Plastic		-0.0162				
		(0.0226)				
x Basic metals		-0.0614				
		(0.0569)				
x $0 < Nout < 10$			-0.00934			
			(0.0212)			
x $10 \leq Nout < 20$			-0.0181*			
			(0.00993)			
x $20 \leq Nout < 30$			-0.0146			
			(0.00932)			
x $Nout \geq 30$			-0.0313**			
			(0.0137)			
x Duration					0.000692	
					(0.00170)	
x Own generator					-0.00987	-0.00833
					(0.0117)	(0.0119)
Own generator	0.218***	0.265***	0.266***	0.320***	0.342***	0.343***
	(0.0751)	(0.0700)	(0.0700)	(0.0705)	(0.111)	(0.111)
Ln(Capital)	0.217***	0.215***	0.214***	0.218***	0.213***	0.213***
	(0.0234)	(0.0221)	(0.0220)	(0.0222)	(0.0218)	(0.0220)
Ln(Size)	-0.174***	-0.187***	-0.188***	-0.136***	-0.185***	-0.185***
	(0.0395)	(0.0366)	(0.0366)	(0.0361)	(0.0365)	(0.0366)
Ln(Age)	-0.0956**	-0.0590	-0.0584	-0.0652*	-0.0617	-0.0607
	(0.0406)	(0.0386)	(0.0385)	(0.0389)	(0.0383)	(0.0387)
Trained	0.190**	0.175**	0.174**	0.227***	0.173**	0.174**
	(0.0769)	(0.0766)	(0.0764)	(0.0767)	(0.0767)	(0.0766)
Exporter	0.367***	0.397***	0.407***		0.402***	0.403***
	(0.0934)	(0.0873)	(0.0872)		(0.0874)	(0.0875)
Foreign owned	0.379***	0.430***	0.435***		0.427***	0.428***
	(0.0887)	(0.0923)	(0.0917)		(0.0921)	(0.0926)
State owned	-0.118	-0.0498	-0.0609	0.0819	-0.0311	-0.0358
	(0.268)	(0.228)	(0.228)	(0.230)	(0.230)	(0.229)
Capital location	0.198**	0.181**	0.173*	0.191**	0.186**	0.182**
	(0.0981)	(0.0907)	(0.0953)	(0.0907)	(0.0914)	(0.0911)

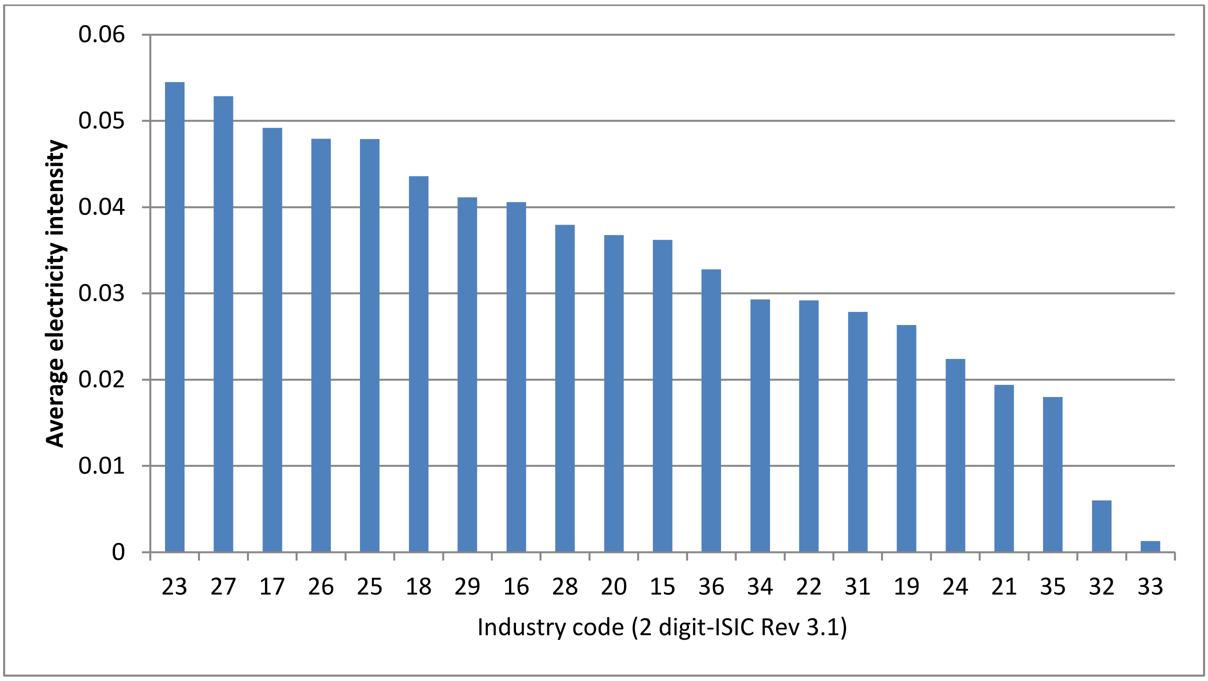
(cont.)	(7)	(8)	(9)	(10)	(11)	(12)
Constant	10.38***	10.33***	10.30***	10.16***	10.09***	10.15***
	(0.387)	(0.375)	(0.384)	(0.373)	(0.400)	(0.367)
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Country *Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Country*Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1,819	2,241	2,241	2,241	2,240	2,241
Overall R-squared	0.809	0.794	0.794	0.789	0.798	0.794

Note: The dependent variable is the natural logarithm of labour productivity. Clustered, robust standard errors in parenthesis with ***, ** and * denoting significance at 1% ($p<0.01$), 5% ($p<0.05$) and 10% ($p<0.1$) level, respectively.

Table A.1: Descriptive statistics between the median-split for electricity intensive firms

	Mean	
Variable (unit)	Intensive	Non-intensive
Number of outages (per month)	9.76	8.44
Own generator (dummy)	0.39	0.43
Size (number of employees)	96.73	111.00
Age (in years)	18.64	18.93
Trained (dummy)	0.30	0.37
Exporter (dummy)	0.16	0.17
Foreign owned (dummy)	0.12	0.20
State owned (dummy)	0.02	0.02
Capital location (dummy)	0.22	0.26
Observations (number)	905	915

Figure A.4: Electricity intensity by industry code



Note: Top three electricity intensive industries are basic metals, rubber & plastic and textiles (industry codes are 23, 27 and 17 respectively). Intensity is measures as sales over electricity costs.