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ABSTRACT
Universal electrification may be a necessary but not sufficient condition for reliable electricity supply. Yet countries that have achieved universal electrification have made significant investments in building reliable electricity infrastructure relative to countries with low electrification rates. We examine the relationship between power outages and firm performance in four middle-income countries with universal electrification. Using data from the World Bank Enterprise Survey on over 8,000 firms from 39 regions across Egypt, Morocco, Tunisia, and Indonesia, we find no discernable negative association between outages and firm performance in two of three different specifications we employ. There is also some cross-country heterogeneity; we find that outages are associated with lower sales for firms in Tunisia in our main specification. However, these results for firms in Tunisia are not robust to other specifications with value added and total factor productivity as explained variable. Overall, our results are mixed, showing either a nonexistent or weak negative relationship between power outages and firm performance. These findings suggest that universal electrification is an important development goal, and while universally electrified countries may suffer some outages — which are fewer relative to those in low-electrification countries, firms in universally electrified countries are able to adapt to the remaining problems of reliability without incurring significant productivity losses.

JEL **classifications: D24, H54, O13, O14**
Keywords: universal electrification, power outages, reliability, middle-income countries

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1 Introduction

There is a well-established body of literature documenting positive impacts of electrification rollout on rural employment, firm productivity and other development outcomes. In these studies, electrification is used to imply an investment in electrical and grid infrastructure that increases the pool of people, households, and firms that are connected to the grid. However, the literature on the impact of electrification is now mixed. Findings from more recent studies using experimental designs have called into question long-standing, positive impact found in earlier studies (Bayer et al., 2020; Lee et al., 2020). In these earlier studies, electrification has been shown to improve female employment in rural South Africa (Dinkelman, 2011), and the Human Development Index and living standards in Brazil (Lipscomb et al., 2013), to name just a few examples. Yet, a replication of Lipscomb et al. (2013), a work which relies heavily on geography for identification, asserts that there are inconsistencies in the definition of geographical areas used throughout the study (Bensch et al., 2020). Similarly, Bensch et al. (2021) argue in a another replication of Dinkelman (2011) that the exclusion restriction — a central requirement which drives the validity of the instrumental variable — is not satisfied.

In this study, we focus on the relationship between power outages on firm performance in countries with universal electrification. Universal electrification refers to a 100 percent rate of electrification in any country of interest, where access to electricity has reached both urban and even sparsely populated rural areas, and all households and firms are connected to the grid. Power outages are a common feature of life in many developing countries and often result from poorly managed and insolvent utilities, low generation capacity, rising electricity demand, and even lower distributed power due to aging transmission and grid infrastructure. Evidence from extant literature on the effects of power outages suggests that firms suffer a reduction in productivity and revenue, even if modest. Allcott et al. (2016), for example, estimate that outages in India reduce average plant revenue and producer's surplus by 5 to 10 percent; average productivity losses are estimated to be significantly smaller. Extant literature has focused mostly on the impact of power outages within the context of persistent outages — where universal electrification is yet to be achieved.

The African Development Bank and United Nations have set ambitious targets for attaining universal electrification by 2025 and 2030, respectively. Other development-oriented institutions have articulated similar targets.[1] This emphasis on universal electrifica-

[1] The DFID Energy Africa campaign launched a campaign to achieve universal access to electricity by

tion largely ignores concerns about reliability. Nevertheless, universal electrification does not necessarily imply a reliable or readily high quality of electricity supply to industry. Therefore, firms in countries with universal electrification may well find the quality of electricity supply to be an obstacle affecting productivity. While persistent outages are a common feature in sub-Saharan Africa, with nearly all firms experiencing outages in some countries of the sub region,[2] by contrast, in all four countries in this study, the number of firms experiencing outages in a given year is below 30 percent (see Figure 1). But even so, many of these firms have reported power outages as a part of the obstacles they face, as shown in Figure 2. Yet, outages, otherwise referred to as electricity, in firms' ranking of obstacles do not rank in the top five of the biggest obstacles to business operations in these countries according to survey responses provided by firms. Figure 5 shows a ranking of the biggest obstacles to business operations in the full sample of all firms. Ayaburi et al. (2020) define a metric to measure "reasonable reliability" as fewer than 12 outages in a year. While all four countries in this study have reached a 100 percent rate of electrification, average power outages monthly are between 2 and 3 for affected firms.[3] This amounts to over twenty outages per year, and raises a concern about reliability. However, only a relatively small subset of firms experience outages, and it is possible that affected firms may be able to adapt to outages such that their productivity is not impacted.

The status of universal electrification does not induce any special mechanism other than reduction in outages. Achieving universal electrification involves expanding access to remote areas — an undertaking involving a huge outlay of investments and a financially viable utility, which is able to manage both existing and new grid infrastructure without running at a loss. For countries which have yet to attain universal electrification, available financial resources are likely to be expended on new power generation projects, whereas universally electrified countries spend more on upgrading existing infrastructure, which bolsters reliability. New power projects which also serve to expand access to unreached populations are capital intensive. Several estimates suggest that a total of US $17 billion dollars yearly is needed to attain universal access in sub-Saharan Africa by 2030 (Trimble et al., 2016). One major difference, therefore, between countries with low electrification rate and those with universal electrification is that while the former are likely to experience more frequent outages resulting from poorly maintained grid infrastructure, the latter, with relatively better

2030 including through the deployment of off-grid solutions.

[2] In certain sub-Saharan African countries, over 50 percent of firms experience outages, and the worst-hit firms experience up to 100 hours of power outage per month. This figure is computed from WBES data on a select sub-Saharan African countries.

[3] Average monthly outages for affected firms in each of the four countries are calculated from the WBES dataset.

infrastructure, have fewer outages.

We use a repeated cross-sectional dataset containing $8,348$ firms from the World Bank Enterprise Survey to estimate the relationship between outages and firm performance. Our dataset which is collected using a stratified random sampling approach covers three different sizes of firms — small, medium and large. Sectors are broadly classified into manufacturing and retail, but we use the two-digit standard industrial classification (SIC) dummies in our regressions. Surveys are generally prone to errors of recall which can result in attenuation bias in our estimates. We discuss our approach to alleviating this problem in Section 4. Firm performance is measured using the logarithm of value-added and total annual sales — the two outcome variables of interest. Following Hjort and Poulsen (2019), value-added is computed as total sales revenue less the cost of raw materials and intermediate input. We also compute total factor productivity (TFP) as a residual from industry-specific ordinary least squares (OLS) regression of the logarithm of sales on the logarithm of labor and material inputs.[4] We use both a dummy variable — whether a firm experiences outage or not (Outages Dummy) — and the total number of outage hours (Outage Hours) as a measure of reliability. Assessing the impact of infrastructure on growth and development outcomes is fraught with endogeneity. Outages are usually not exogenous to firm productivity. Weak institutions at the national or regional level could impact both outages and firm performance, and investments in critical infrastructure such as roads and transportation systems may be concentrated in certain localities. Such investments are likely to boost productivity in localities where they are made while also affecting reliability of power supply. Instrumental variables have been employed to address these concerns in many electrification studies. Yet, satisfying the exclusion restriction is often an uphill task when studying the placement of infrastructure, even with the most carefully constructed instruments. Further, instrumental variables are unable to address the problem of self-selection in which firms locate in regions or cities with favorable economic or power supply arrangements. Consequently, studying the impact of outages in countries where outages are a function of economic or political conditions presents several challenges. Put differently, absent random assignment of outages as in Abeberese et al. (2021), in which an electricity rationing program was exploited to generate exogenous variation in exposure to outages, estimating the causal impact of outages remains intricate. While we can not claim that outages are completely random in the countries we study, we estimate the relationship between outages and productivity in these

[4]While TFP measures from Olley-Pakes (Olley and Pakes, 1992), Levinson-Petrin (Petrin et al., 2004) and Wooldridge (Wooldridge, 2009) are commonly used in the literature, the lack of panel data prevent the use of these methods. More so, our data set does not include information on the capital stock of firms, so we include material input as a proxy for capital stock; hence, our measure of TFP is arguably not the most reliable. As a result, we use sales in the main specification, and TFP for robustness checks

countries using OLS with fixed effects while controlling for firm and city level effects as our main specification. For comparison with our OLS estimates only, we construct an instrumental variable,[5] which although satisfies the relevance requirement fails to met the exclusion requirement. Consequently, our estimates likely feature some biases due to the endogeneity concerns mentioned earlier.

The results of the relationship that we estimate are nuanced and mixed. We find no significant relationship between outages and firm performance in the total sample of 8,348 firms across all four countries from our main specification. Similarly, the results across generator ownership category mirror that of the full sample of all firms, i.e., in the full sample, outages have no negative association with firm performance regardless of whether firms own a generator or not. When we disaggregate across countries and generator ownership in each of the countries, results from our main OLS specification show that firms experiencing outages in Tunisia may be more susceptible to loss in sales. While the outages dummy measure suggests that experiencing outages is associated with an 11 percent reduction in total sales, we do not find statistically significant association using the outage hours measure. However, when we use TFP as measure of firm performance we fail to find a significant relationship between outages and firm performance using both outages measures for firms in Tunisia. Similarly, we find no statistically significant evidence of the outage measures when we use valueadded as the explained variable. For firms in the other three countries, we equally find no evidence of a significant negative association between outages and firm performance, although the coefficient on both measures of reliability are mostly negative for all the countries. Contrastingly, in the same specification with TFP as explained variable, we find a minuscule yet statistically significant relationship between the outage hours variable and firm performance. However, this relationship is not repeated in the other specifications.

The main contributions of this paper are, therefore: First, to establish that firms, even in settings with universal electrification, self-report that power outages are an obstacle to performance, even if reliability is relatively higher for these firms than for those in sub-Saharan Africa. Second and most importantly, investigating the impact of outages on performance of these firms provides useful knowledge about the extent to which reliability is a problem even for firms where universal electrification prevails. We find the results across

[5]We employ as an instrument for the discrete measure of outage — outages dummy — for firm i, a measure of average outages for firms other than firm i in the same region. In a similar fashion, yearly outages of firm i is instrumented by a measure of average yearly outages for firms other than firm i in the same region. Our instruments, while correlated with the endogenous variables, may not directly affect firm performance once we condition on firm-level and city-level controls. Unobserved time-invariant regional and industry-level effects are accounted for by region and industry fixed effects. However, confounders affecting the endogenous variable are likely baked into the instrument as well since it is computed as an average.

the countries ranging from null to mixed. But an important question arises here: why should the potential impacts of power outages be any different for firms operating under conditions of universal electrification, for a given outage frequency? One reason is that in countries with universal electrification, only a small percentage of firms invest in generators. The total percentage of firms in Morocco that own a generator for example is about 10; it is about the same for the other countries except for Indonesia with over 20 percent of firms owning a generator as shown in Figure 3. This could mean, on one hand, that for most firms, the disruption caused by outages is not severe enough to justify owning a generator.[6] Therefore , firm performance may not be significantly impacted by occasional outages. On the other hand, the low percentage of generator ownership could mean that most firms cannot afford to own a generator even though their productivity[7] is impacted by outages. Our results suggest that these countervailing explanations of generator ownership differ across countries. Finally, estimating the relationship between outages and firm productivity also helps us understand if productivity across firms operating under conditions of universal electrification differs significantly in the wake of outages affecting only a subset of these firms.

The rest of this paper is organized as follows: Section 2 examines more extensively the literature on electrification and its impact on firm productivity and other development outcomes. Section 3 provides a succinct background on the state of the electrification in each of the 4 countries. Section 4 details source of data and empirical approach. Results are discussed in Section 5. Section 6 concludes.

[6]According to data from the World Bank Enterprise Survey, the percentage of firms that own or share a generator in the sub-Saharan Africa region is significantly higher than that of firms in the countries profiled in this study.

[7]We use firm productivity interchangeably with firm performance.

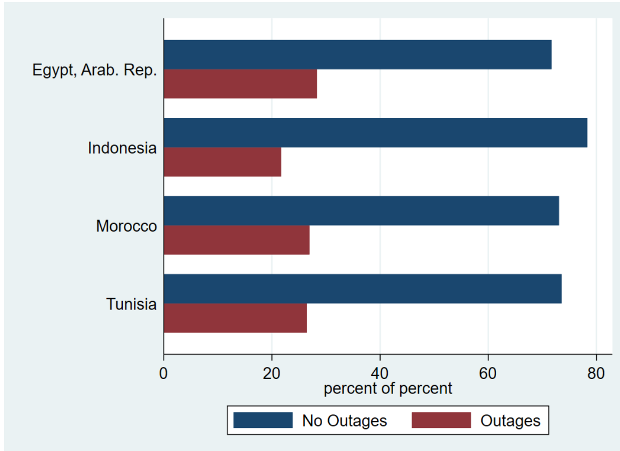

Figure 1: This figure shows the percentage of firms in each country that reported experiencing outages in the year preceding the survey. The percentage of firms that experienced outages is shown in red, while the percentage of firms that did not experience an outage is shown in blue.

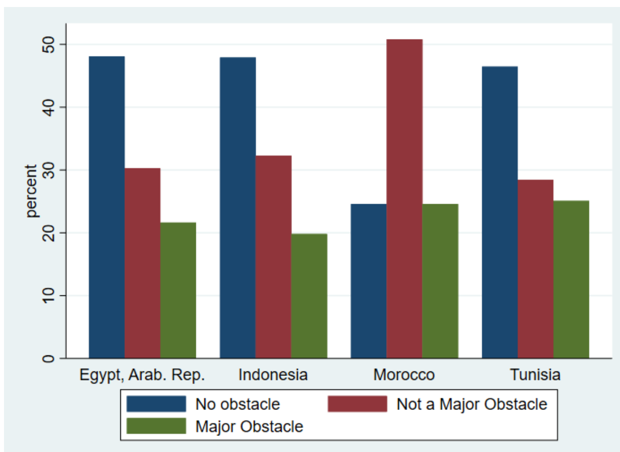

Figure 2: This figure shows the level of obstacle that electricity represents for all firms in each of country. This is a self-reported measure of how firms perceive power outages to be a hindrance to their operations. Originally, there are five categories of obstacle levels: no obstacle, minor obstacle, moderate obstacle, major obstacle and very severe obstacle. We collapse minor and moderate obstacle to Not a Major Obstacle (red), major and very severe obstacle to Major Obstacle (green). No Obstacle (blue) remains unchanged.

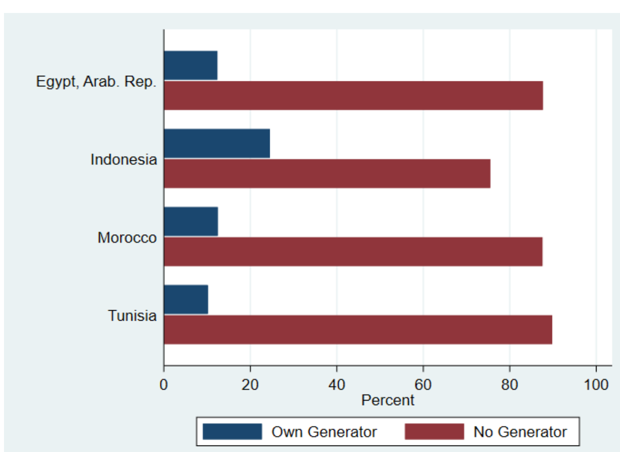

Figure 3: This figure shows the percentage of firms that own or share a generator in comparison with those that do not in all four countries. The percentage of firms that own a generator is shown in blue, while the percentage of firms that do not own or share a generator is shown in red.

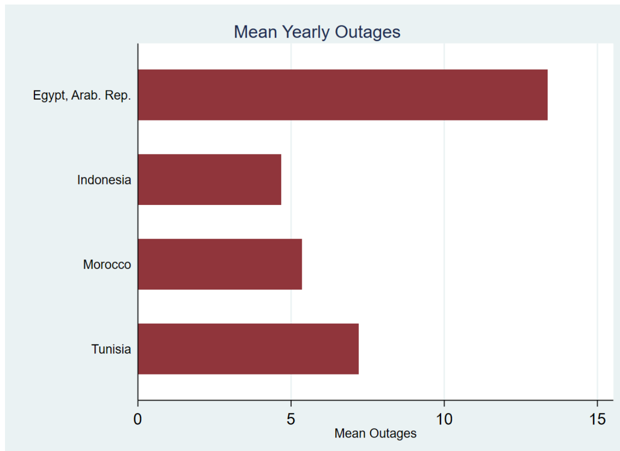

Figure 4: This figure shows the average number yearly outages experienced by the firms in each of the four countries. This number is calculated as the mean of total number of yearly outages among all the firms in each of the four countries. Egypt has the highest number, followed by Tunisia, while Indonesia has the lowest number of average yearly outages.

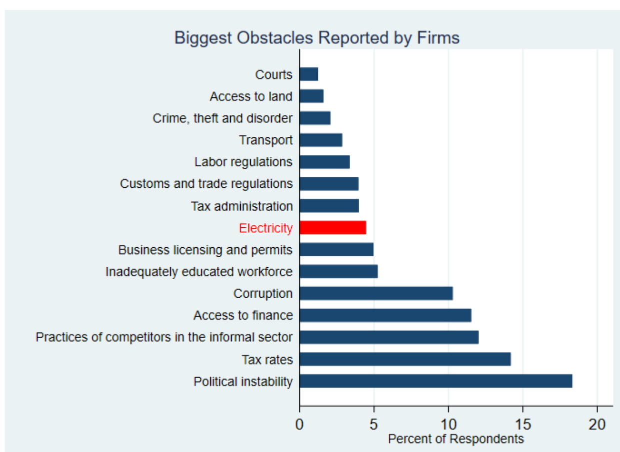

Figure 5: This figure shows the self-ranking of the biggest obstacles faced by firms across all four countries. Political instability is ranked as the biggest obstacle while electricity, marked in red, is ranked 8^{th} amid the 15 obstacles identified from firms responses. The ranking of the these obstacles differ slightly across the countries.

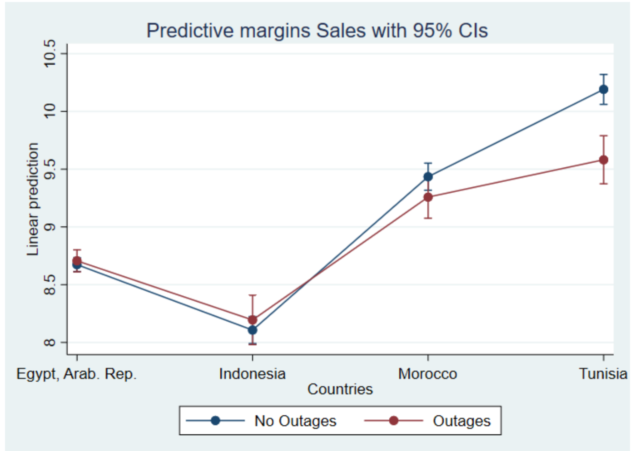

Figure 6: This figure shows the predicted average sales with 95% confidence intervals for both firms that experienced outages (red line) and those that do not (blue line) across the four different countries we study. Noticeably, the difference in average revenue is more pronounced for firms in Tunisia. The figure comes from linear regressions of sales on outages and a set of control variables.

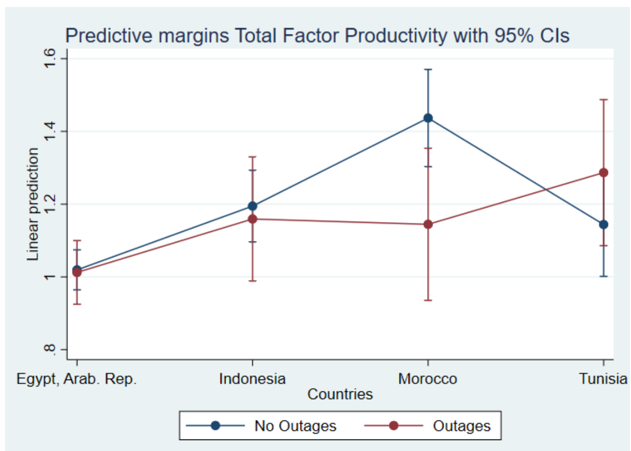

Figure 7: This figure shows the predicted average total factor productivity with 95% confidence intervals for both firms that experienced outages (red line) and those that do not (blue line) across the four different countries we study. Noticeably, the difference in average revenue is more pronounced for firms in Tunisia. The figure comes from linear regressions of total factor productivity on outages and a set of control variables.

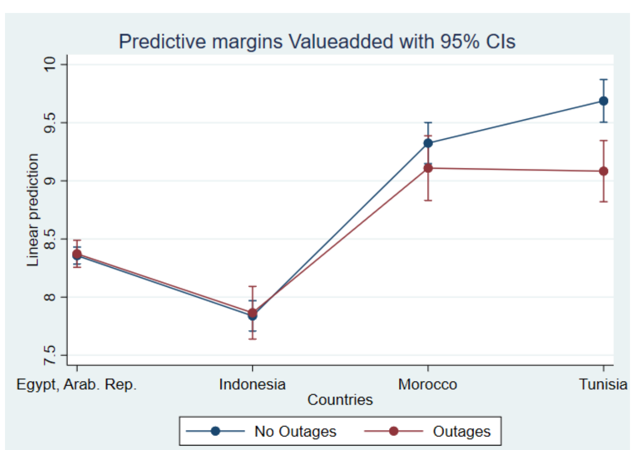

Figure 8: This figure shows the predicted average total factor productivity with 95% confidence intervals for both firms that experienced outages (red line) and those that do not (blue line) across the four different countries we study. Again, the difference in average valueadded is more pronounced for firms in Tunisia. The figure comes from linear regressions of valueadded on outages and a set of control variables.

2 Literature Review

There is scant literature to date on the impact of power outages on firm performance under conditions of universal electrification. Alby et al. (2013) study reliability of electricity supply in 87 developing countries, including countries in North Africa and Southeast Asia. However, they focus on the link between electricity reliability and firms' decisions to invest in self-generation. Countries with high rates of electrification, approximately 100 percent, have reached a milestone that developing countries aim for; hence, the vast majority of research on the subject focuses on countries where power outage is endemic. This overwhelming focus on countries suffering more frequent outages seems to presuppose that outages in high-electrification countries are not of significant interest. The studies reviewed here are among the body of work examining the effect of power outage on various measures of firm performance in developing countries with varying rates of electrification.

An appreciable number of studies have examined the impact of electricity supply reliability on households' decisions to connect — Bajo-Buenestado (2021) and Millien (2017) — and on firms' performance and revenues Allcott et al. (2016), Cole et al. (2018), Fisher-Vanden et al. (2015) and Alam (2013); job creation potential Mensah (2018); economic growth and industrial development Andersen and Dalgaard (2013), Kassem (2021). Identifying the effect of infrastructure on growth and development outcomes is often empirically challenging since both development and the placement of infrastructure tend to occur simultaneously in developing countries. However, a range of studies in the development literature have made progress in this area through the application of instrumental variables (IV) strategy. Duflo and Pande (2007) and Banerjee et al. (2020). But even so, finding or devising a completely exogenous instrument is often an exacting task. As Briggs (2021) argues, other than economic and technical factors, politics is also critical in project placements or resource allocation. Therefore, IV strategies that rely on infrastructure as an instrument may still have to contend with potential correlation between the instrument and other confounders.

Fisher-Vanden et al. (2015) find that in response to electricity outages, per unit cost of production increased by 8% across all industries in China, consisting of 23,000 Chinese firms within the study period. The ability of the firms to re-optimize by buying intermediate goods rather than producing them in-house in the wake of outages averts substantial productivity losses. Allcott et al. (2016) estimate that due to power outages, Indian manufacturers suffer a mere 1.5% loss in productivity, although revenues reduce by a greater percentage. Fried and Lagakos (2020), in a departure from empirical modelling, build a dynamic macroeconomic model to analytically show how power outages affect firm productivity in sub-Saharan Africa. They argue that empirical models describe only short-run partial equilibrium effects, which may be modest. However, longrun general-equilibrium effects from their analytical model include an increase in productivity per worker from eradicating power outages. They conclude, therefore, that engineering policies to tackle outages is a worthwhile goal. While most of these studies examine the causal effect of power outage in countries where outages are widespread, this paper attempts to identify the effect of outages on firm performance within the context of universal electrification. The findings from the cited studies vary in magnitude of effect, and relate to different outcome variables, but there is a common theme: unreliable power supply reduces firm productivity, even if modestly in some countries.

This paper resembles Allcott et al. (2016) and Cole et al. (2018) in spirit, in that it studies how firms' performance is impacted by outages, even if under different operating conditions. Allcott et al. (2016) adopt change in the supply of electricity from hydropower production as an instrument. They submit that the effect of power outage depends on firm characteristics, where firms with back-up generators suffer increased production costs while firms without generators may need to temporarily delay production, in turn, incurring more productivity losses. Another study on Indian firms finds that the effect of power shortage varies across industries. While some firms possess the capacity to re-optimize in the wake of power outage, others — mostly electricity-intensive industries — are inevitably hard hit, and suffer productivity losses (Alam, 2013). In a similar study of Ghanaian firms, Abeberese et al. (2021) argues that due to rationing of power supply in Ghana, outages can be viewed as arguably random; thus, they estimate the effect of outages on firm productivity using a fixed effects model. Their findings show that among small Ghanaian firms, outages result in a 10% loss in productivity. Adenikinju (2005) similarly finds that in Nigeria, small-sized firms are most impacted by power outages.

Work in the electrification literature has focused on the problem of power outage where a sizable number of firms list power outage as a major problem. However, there is a considerable gap in knowledge regarding the effects of power outage where only a relatively smaller percentage of firms list electricity as an obstacle, and outage frequencies are lower. This paper fills that gap in knowledge. In order to understand some of the mechanisms through which productivity losses occur, this paper also disaggregates firms into two categories: generator ownership — firms that own a generator, and no generator — firms that do not own a generator. The main objective is to assess the extent to which firms suffer losses in productivity when they experience power outages. Understanding the relationship between outages and firm performance in these countries can provide a basis for comparison with firms for which electrification rates are lower, and outages are more frequent.

3 Background

Electrification rates have since reached a 100% in the countries we study with the exception of Indonesia, where it reached 99% in 2019. Among these four countries, Egypt and Tunisia attained universal electrification in 2016. However, in Egypt, outages became more prevalent in 2014 as a result of unmet rising demand and low investments in infrastructure and power stations. The outages were particularly severe between 2011 in 2014 following political uprising, averaging six power cuts a day for up to two hours at a time at its peak.[8] The key challenges of the power sector in Egypt include very high subsidies and poor maintenance of power infrastructure (Rana and Khanna, 2020)

According to responses by firms in Tunisia, electricity is considered less of an obstacle, ranking at 12^{th} place among the 15 biggest obstacles identified by firms. Unlike Egypt, news of power outages in Tunisia are not as common in the media. Other than the infamous major outage that hit most parts the country in August 2014, outages have been infrequent and restricted to certain localities at different times (Kilani et al., 2019).

Morocco implemented a sweeping power reform in the 90s which introduced private sector participation for generation capacity expansion and electricity distribution. Following this reform, the country experienced a massive growth in electrification from less than 60% in the 90s to over 90% by mid 2000s. Rural electrification also soared from a paltry 15% in 1995 to nearly a 100% in 2017. Yet, challenges stemming from reliance on electricity exports and unsustainable tariff from the country's utility persists (Usman and Amegroud, 2019).

Finally, in Indonesia, the state electric utility, Perusahaan Listrik Negara (PLN), went through a transition period that rendered it bankrupt and bereft of competent personnel leading to mismanagement of the utility. This situation resulted in rationing of electricity supply to households and business. However in the 90s, following a rapid expansion of transmission grid in parts of the country, supported by massive national investments, the country experienced a surge in electrification rate, which lead to a significant decrease in reliance on back-up generators particularly for manufacturing firms (?).

[8] https://www.theguardian.com/world/2014/aug/20/egypt-blackouts-energy-crisis-power-cuts

4 Empirical Approach

This paper estimates the relationship between outages and firm performance across four middle-income countries. The ideal dataset for investigating this relationship is a large dataset that comprises different categories of firms in these countries, and is nationally representative. Such a dataset will also cover information on a wide range of firm attitudes, challenges and performance indicators. Additionally, details such as the community-level location of firms is important for grouping firms at a more granular level because certain firm and community characteristics may differ at the community rather than regional level. We use cross-sectional data from the World Bank Enterprise Survey (WBES). The survey originally covers $8,348$ firms in 39 different regions across four countries. Survey years span 2013 to 2020. However, the WBES dataset does not provide the community-level locations of firms, so we group firms at the regional level. Table 1 provides the summary statistics of the key variables used in this paper.

The WBES is a nationally representative survey, which provides information on firms' attitudes, attributes, access to infrastructure, and obstacles that firms face in the day-today running of business. The survey adopts a two-stage stratified random sampling strategy. Top managers and business owners in 139 countries are interviewed face-to-face to gather this information. The countries in this study were selected because they are middle-income countries that have achieved universal electrification, and have a sufficiently large sample of firms that both responded to the WBES survey and answered questions related to the reliability of electricity supply. The measures of firm performance that we use in this study are the logarithm of total annual sales and the logarithm of value added and total factor productivity. All monetary variables are deflated to 2010 levels using a GDP deflator from the World Bank development indicators database and then transformed into US dollar values using the Purchasing Power Parity (PPP) Index from the International Monetary Fund. The explanatory variable of interest is outages, which is measured as both a dummy variable — whether a firm experienced an outage or not — and the total hours of outages in a month. Other control variables include the total number of workers employed, managers' years of experience, age of firm and access to finance. These control variables are important covariates. For instance, the strength of the workforce and level of experience of a manager often have an impact on overall firm performance. Other dummy variables include generator ownership, government ownership, foreign ownership, size of firms, and city size. While generator ownership affects how a firm responds to outages, the level of government and foreign stake in a firm may indirectly affect productivity. We also control for access to finance which plays an important role in the ability of firms to expand production activities.

The variables in this study are constructed mostly from self-reported figures, and are thus prone to the usual errors associated with self-reporting. Such self-reported figures also result in the creation of outliers. To reduce the impact of outliers, we log-transform values of all variables, and return as missing those values that are three standard deviations away from the mean.[9] Firms in this study are of three sizes: small, medium and large. Large firms, which constitute 22 percent of all firms in our sample, have over 100 employees, while medium (between 20 and 100 employees) and small firms (less than 20 employees) constitute 29 and 49 percent of all firms, respectively. Out of the total 8,348 firms in the sample, 4,592 are in Egypt, 1,452 in Morocco, 1,203 in Indonesia, and 1,101 in Tunisia. On the broad categorization by industries, 63 percent of all firms in the sample are manufacturers, while all others are service firms. Egypt has the highest average number of yearly outages, and the highest percentage of firms experiencing outages, followed by Tunisia and Morocco. Indonesia has both the lowest number of yearly outages and the percentage of firms experiencing outages. Unlike firms in sub-Saharan Africa, firms in this study do not suffer as acute power outages. Calculated average number of power outage for affected firms in our study is about 117[10] hours per year, whereas in some countries in sub-Saharan Africa, firms face more than 500 hours of outage per year.[11] Over 4,000 firms claimed that electricity represents some level of obstacle to their productivity in these countries. However, it is curious that many of the firms that cite electricity as an obstacle reported not to have experienced outages in the past financial year.[12] Moreover, as shown in Figures 13 through 16 in the Appendix, electricity does not rank in the top five obstacles enumerated by firms in any of these countries. Indonesian and Tunisian firms in particular rank electricity very low in the list of obstacles they face. Also, the percentage of firms that own or share a generator is low compared to the sub-Saharan average.[13] The average number of firms that own or share a generator is only 14 percent in our sample.

[9]The log-transformation is performed only to remove outliers, but control variables are not logged in the regressions. This follows the recommendations of the Enterprise Analysis Unit of the World Bank. See https://www.enterprisesurveys.org/en/methodology

[10]This figure is calculated from the WBES dataset as average number of monthly outages multiplied by average total duration of outage.

[11]In a study of the impact of power outages on firm performance in sub-Saharan Africa, Cole et al. (2018) estimate that 8 countries out of the 14 they examine face on average more than 500 hours of outages each year.

[12]The total number of firms that claimed to have experienced outages in the year preceding the survey is 2243.

[13]Cole et al. (2018) estimate that the continental average of generator ownership, using 14 countries in sub-Saharan Africa is 52%.

4.1 Empirical Approach — OLS

If the incidence of power outages experienced by firms were randomly assigned, the effect on performance outcomes can be estimated using a simple ordinary least squares (OLS) method. However, the occurrence of outages as experienced by some firms is likely to be influenced by a range of factors. For example, the location of firms may determine whether they experience an outage or not. Moreover, high productivity, high revenue-generating firms may self-select into regions where power outages are typically non-existent, while firms that are not as productive may be clustered in regions where outages are pervasive. This selection effect is likely to bias any OLS estimate comparing firms on the basis of outages experienced.

Another source of endogeneity that can result in biased estimates is the influence of unobserved factors that are correlated with outages and firm performance. Political institutions and socioeconomic factors can influence both the occurrence of outages and the outcome variable of interest. If this were the case, it can be argued that results generated from an OLS regression may be partly driven by these unobservable factors, rather than by outages only. Specifically, other firm-level unobserved characteristics such as access to other infrastructure like proximity to road transport can result in a positive bias as firms with access to this infrastructure are likely to experience fewer outages, thereby creating a positive correlation between access to other infrastructure and the explanatory variable of interest. The bias could also be negative for firms with lower access to referenced infrastructure.

Finally, self-reported measure of outages is likely to contain some margins of error, which can result in attenuation bias in an OLS estimate. Our main specification is an OLS regression which examines the relationship between power outages on an outcome variable of interest — sales, controlling for both firm-and city-level characteristics. Industry, regional and country fixed effects are also applied where applicable. It is specified as follows:

$$\mathrm{Y}_i = \beta_0 + \beta_1 Outage + \mathbf{X}_i'\beta_2 + \delta_j + \lambda_r + \phi_t + \varepsilon_i \tag{1}$$

where Y_i is the outcome variable of interest at firm i. Outage represents both a dummy variable, indicating whether a firm experiences outage or not, and the total outage hours measure. The observable firm-level characteristics, $\mathbf{X}_i'$, include top manger's years of experience, total number of workers, age of firm, generator-ownership, government ownership, foreign ownership, access to finance, size of firm and city size. Industry fixed effects which capture time-invariant factors that are common across firms within an industry are represented by δ_j, while λ_r represents district/region fixed effects and ϕ_t is year fixed effects. The error term is represented by ε_i. This simple specification provides a straightforward way to estimate β_1. The estimated coefficient of β_1 represents the extent of association between outages and firm performance. While this specification can provide an estimate of the relationship between outages and firm performance, macroeconomic conditions such as economic growth or decline, and a dynamic political climate can confound the relationship between the outcome and explanatory variables of interests. OLS estimates from this specification are at best indicative of the direction of the relationship between outages and firm performance. Given that the omitted variables in this specification are likely to be negatively correlated with outages but positively correlated with firm performance, we expect estimates from this specification to be negatively biased. Another endogeneity concern is that some firms may locate in regions where outages are infrequent. While we are unable to address this concern directly, we find that in all the 39 regions, there is not a single region where firms do not suffer outages. There are only five regions where more than 90% of all firms did not experience outages in the past year, and only one region with more than 95% of all firms which did not experience outages.[14] This absence of a particularly high degree of concentration of firms that did not experience outages in many regions relieves some concerns of endogeneity resulting from firm placement. To alleviate any remaining concern, we employ city-level controls, which addresses issues of wealth or income differences across different city sizes.[15]

4.2 Instrumental Variables

In this section we discuss possible ways to address endogeneity concerns and potential challenges that may arise. Instrumental variables have been applied widely to estimate the impact of outages or the placement of electricity infrastructure on firm performance and other development outcomes. (Cole et al., 2018; Lipscomb et al., 2013; Allcott et al., 2016) Yet these studies are not without flaws, most notably the validity of the instrument in satisfying the exclusion restriction. We construct a simple instrument not as a main specification but to aid in the comparison of the results with those from our main OLS specification. The IV approach entails estimating a two-stage model, defined as follows:

[14]Note that the total percentage of all firms that did not experience outage in the year preceding survey year is 73. Similarly, there are only five regions in total where the concentration of firms with outages in past year exceeded 50 percent.

[15]Cities are classified into four classes according to the population of the cities: Bigger cities, with a population of above 5 million people, big cities with a population of between 2 and 5 million, medium cities with population below 2 million people, and small cities with population below 500,00 people.

$$\text{Y}_i = \alpha_0 + \mathit{Outage}_i\alpha_1 + \mathbf{X}_i'\alpha_2 + \delta_j + \lambda_r + \phi_t + \mu_i \tag{2}$$

$$\mathit{Outage}_i = \beta_0 + \mathbf{Z}_i\beta_1 + \mathbf{X}_i'\beta_2 + \delta_j + \lambda_r + \phi_t + \varepsilon_i \tag{3}$$

In both equations, $\mathbf{X}_i'$ includes the full set of controls as listed above. Instrument $\mathbf{Z}_i$ represents both instruments for the outage dummy and yearly outage measure is computed as (i) the average of outages dummy for firms other than firm i in district r and (ii) as the average of total outage hours for firms other than firm i in district r:

$$\mathbf{Z}_i = \frac{\sum_{i'} \mathit{Outages}_{i'r}}{n_i} \tag{4}$$

where $\mathit{Outages}_{i'}$ is dummy (or yearly outages) for all firms other than firm i in region r, and n_i is total number of firms in region r. Identification of the IV model requires, first, a strong correlation between the outages measure and the instruments, $\mathbf{Z}_i$, i.e., the condition that Cov $(z,\ \mathit{Outage}) \neq 0$ must be satisfied. This requirement is well satisfied. The results of our first-stage regression in Table 2 shows a strong correlation between the endogenous variable and the instruments. First-stage F-statistics reported in the IV results in Tables 10 through 12 Appendix A are also large enough to avoid weak instruments concerns in most specifications. Secondly, the exclusion restriction, $Cov\ (z, \varepsilon) = 0$ implies that the instruments need to be as good as randomly assigned. More so, the effect of the instruments on the outcome variables should be mediated fully, and only through the endogenous variable. Outages experienced by firm i are correlated with outages experienced by other firms in the same region as firm i. While a more granular geographical level such as a community would have provided an even tighter correlation, our dataset does not provide that granular community-level location of firms. Our identifying assumption should rely on one hand, on the strong correlation between outages and our instruments. On the other hand, the instruments — outages of firms other than firm i in a given region — should not affect the productivity of firm i directly, particularly after controlling for other firm and region characteristics.

Spatial instruments such as the one we employ here have been roundly criticized in the literature for their inability to produce valid inference. Specifically, Betz et al. (2018) caution that if these instruments are strong, they are likely to violate the exclusion restriction, and if they do meet the restriction, they are likely to be irrelevant. To make valid inferences, we require our instruments in this case, i.e., the average outages of firms other than firm i, to impact the productivity of firm i only through the outages of firm i. However, this condition is easily violated as the same unobservable factors that confound the relationship between the outages of firm i and its productivity are plausibly present in the average outages of firms other than firm i. In other words, firms in the same region typical face the similar economic and socio-political environment, hence the outages experienced by firms other than firm i are partly a function the same environment. This violation casts doubt on the validity of our instruments and the results thereof. However, we sample results from this specification in the full sample of all firms for comparison with the OLS estimates, and present country-specific results from the IV in Tables 10 through 12 of Appendix A.

Table 1: Summary Statistics

Variable	Obs.	Mean	Std. Dev	Min	Max
Sales	8,348	118,330.96	970,823.52	8.681	54,663,416
Log Sales	8,348	8.883	2.221	2.161	17.817
Past Sales	8,348	105,304.03	2,033,180.1	0	173,600,000
Log Past Sales	7,788	8.653	2.253	.406	18.972
Value Added	4988	104,894.43	107,6319.7	0	53,848,436
Log Value Added	4,973	1.106	1.255	0.0387	66.60144
TFP	4,939	1.106	1.255	0.038	66.601
Yearly Outages	8,348	8.576	23.972	0	300
Outage Hours	8,348	2.035	13.208	0	360
Manager's Experience	8,164	20.941	11.277	1	70
Permanent Workers	8,333	112.613	346.996	1	8,500
Age of Firm	8,348	58.687	256.068	3	2,030
Outages	8,348	.269	.443	0	1
Finance Access	8,209	.652	.476	0	1
Generator Ownership	8,348	.138	.344	0	1
Foreign Ownership	8,179	5.267	19.210	0	100
Size of Firms	Frequency		Percent		Cummulative
Small	4,079		49.08		49.08
Medium	2,392		28.65		77.73
Large	1,859		22.27		100
Total	8,348		100.00		
Size of Locality	Frequency		Percent		Cummulative
Bigger City	1,386		16.60		16.60
Big City	3,826		45.83		62.43
Medium City	1,600		19.97		81.60
Small City	1,536		18.4		100
Total	8,348		100.00		

Notes: This table provides summary statistics of all key variables in this paper. Sales value are expressed in purchasing power parity 2010 dollars. Our regression tables omit Small City in the city-size categories and Large Firms in the firm-size category in order to serve as the reference group.

Table 2: Effects of Power Outage on Logged Sales and Logged Value Added for All Firms in the Full Sample

	ln Sales				ln Value Added			
	OLS	IV	OLS	IV	OLS	IV	OLS	IV
Outage Hours	−0.000	−0.002			−0.002	−0.003		
	(0.001)	(0.001)			(0.002)	(0.002)		
Outages Dummy (0/1)			0.018	-0.006			0.013	0.052
			(0.055)	(0.078)			(0.054)	(0.081)
Manager's Experience	0.015***	0.015***	0.015***	0.015***	0.011**	0.011**	0.010*	0.010**
	(0.003)	(0.003)	(0.003)	(0.003)	(0.005)	(0.005)	(0.005)	(0.005)
No. Permanent Workers	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Generator	0.711***	0.717***	0.707***	0.712***	0.686***	0.687***	0.677***	0.670***
	(0.087)	(0.084)	(0.087)	(0.085)	(0.090)	(0.093)	(0.093)	(0.089)
Small Firm	−2.115***	−2.113***	−2.116***	−2.115***	−2.263***	−2.262***	−2.269***	−2.271***
	(0.116)	(0.113)	(0.115)	(0.113)	(0.115)	(0.112)	(0.116)	(0.113)
Medium Firm	−1.169***	−1.168***	−1.170***	−1.169***	−1.268***	−1.268***	−1.271***	−1.273***
	(0.069)	(0.067)	(0.068)	(0.067)	(0.085)	(0.083)	(0.086)	(0.083)
Age of Firm	−0.000	−0.000	−0.000	−0.000	−0.000	−0.000	−0.000	−0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Foreign	0.436***	0.438***	0.436***	0.436***	0.673***	0.673***	0.670***	0.671***
	(0.088)	(0.088)	(0.089)	(0.088)	(0.091)	(0.090)	(0.092)	(0.090)
Government	0.068	0.066	0.068	0.068	0.223	0.223	0.227	0.228
	(0.171)	(0.168)	(0.171)	(0.168)	(0.219)	(0.215)	(0.219)	(0.215)
Bigger City	0.230	0.222	0.233	0.229	0.130	0.128	0.138	0.144
	(0.149)	(0.145)	(0.150)	(0.147)	(0.200)	(0.196)	(0.201)	(0.197)
Big City	−0.229*	−0.232*	−0.228**	−0.229*	−0.292*	−0.293*	−0.288*	−0.287*
	(0.128)	(0.124)	(0.128)	(0.126)	(0.165)	(0.160)	(0.167)	(163)
Medium City	−0.036	−0.039	−0.035	−0.037	−0.084	−0.085	−0.082	0.095
	(0.127)	(0.124)	(0.126)	(0.124)	(0.171)	(0.168)	(0.171)	(0.168)
Finance Obstacle	0.080	0.079	0.079	0.080	0.092	0.092	0.094	−0.084
	(0.065)	(0.064)	(0.064)	(0.063)	(0.079)	(0.078)	(0.079)	(0.077)
Observation	8,031	8,031	8,031	8,031	4,848	4,848	4,848	4,848
R-squared	0.473	0.473	0.473	0.473	0.525	0.525	0.525	0.525

Notes: This table shows OLS and IV results for the full sample of firms. Columns 1 – 4 show Logged Sales as a dependent variable, 4 – 8 show Logged Value Added as a dependent variable. Industry and country fixed effects are included in this regression. Robust standard errors are clustered at the 39 different regional levels. *p<0.1; **p<0.05; ***p<0.01

5 Results

Table 2 presents results for the full sample of firms from all four countries, with OLS and IV specifications for both logged Sales and logged Value Added as dependent variables. Tables 3 through 6 present main specification (OLS) results of logged Sales only as the outcome variable.[16] Table 3 presents results by generator ownership status and firm size. Table 4 presents results by country. Tables 5 and 6 present these country-level results separately for firms with and without a generator, for both the outages hours and outages dummy explanatory variables.

5.1 Full Sample Results

Table 2 shows that we find a negative but statistically insignificant relationship between outage hours and both measures of firm performance. Similarly, we find, on average, no significant relationship using the outages dummy variable. The first two columns of Table 3 present OLS and IV results, respectively, for logged Sales with total outage hours as the explanatory variable. Columns 3 and 4 use the outages dummy as the explanatory variable. Columns 4 through 8 repeat this pattern with logged valueadded as the dependent variable. We also present coefficients on the full set of control variables, and while industry, and country fixed effects are included in the regressions their coefficients are not reported. Coefficients on both outage hours and the outages dummy are small in magnitude and not statistically significantly different from zero in all specifications. The control variable coefficients indicate that firms with onsite generators have significantly greater sales and value added than those without, as do foreign-owned firms and those with more managerial experience and more workers. Lastly, firms in the second largest city category have lower sales and value added than firms in the largest city category, and firm size classifications in the data also correspond to sales and value added outcomes.

We also examine how outages affect performance by generator ownership status and firm size categories to determine whether firm performance depends on owning a generator or belonging to a particular size class. Table 3 shows OLS estimates for firms from all four countries split into firm size and generator ownership sub-samples. Panel A shows these

[16]We use the logarithm of value added as the dependent variable only in the full sample of all firms in all four countries in Table 2. Due to missing values of cost of raw materials, there is a significant attrition in the number of firms in each country for which we are able to calculate value added. As a result, we use logarithm of sales as the outcome for country-specific regressions.

results with outage hours as the measure of reliability, while Panel B uses the outage dummy as the measure of reliability. We find no significant negative association between outages and firm performance across generator and size categories. Across firm sizes, the signs on the outage hours variable are expectedly negative for small and medium firms. Overall our results in this category, while not statistically significant have the expected sign in most instances. In other words, in the full sample of all firms from the four countries and across generator ownership and size category, we find no evidence of a negative association between outages and firm performance. This null finding is mirrored in Panel B of Table 3, which shows the results using the outage dummy as the measure of reliability. Table 3 suppresses coefficients on all variables except the reliability measures for reasons of space, but full results with control variables are available upon request.

5.2 Country-specific Results

The results from the full sample conceal some heterogeneity across countries. We now examine country-specific impacts of outages on firm performance, measured by the logarithm of sales as the dependent variable. Country-level OLS estimates are shown in Table 4; coefficients on the full set of controls are suppressed for space. Panel A of Table 4 shows the coefficients on outages hours, while panel B shows the coefficients on the outages dummy, for each of the four countries in our sample. From Panel A, we find no evidence of a negative association between outage hours and firm performance in any of the four countries.

In Panel B, we show that the coefficient on the outages dummy is not significantly different from zero for Egypt, Morocco and Indonesia. However, for Tunisia, the coefficient, -0.116, is both negative and statistically significant at the five percent level. We compare this result with that from the IV specification[17] and find a similar association. This result taking on its own suggests that experiencing outages in Tunisia is, on average, associated with an 11% reduction in total annual sales,[19] or 9% according to the IV estimate relative to firms that do not report outages occurring. This is a significantly high amount of loss for this subset of firms. But a careful look at the data and distribution of outages in Tunisia shows

[17] The Montiel-Pflueger F-stat for this result is greater only than the 20 percent critical value. Technically, this implies that we can reject the null of weak instrument for our two-stage least square regression for a weak instrument threshold of $\tau^{18} = 20\%$.

[19] This figure was calculated following Halvorsen et al. (1980). The form of equation estimated in this paper is as follows: $lnY = \alpha + b_i X_i + c_j D_j$. This equation can be written as $Y = (1+g)^D \exp(\alpha + b_i X_i)$. Thus, the coefficient of the dummy variable in first equation is $c = ln(1+g)$. Subsequently, the relative effect on Y is $g = \exp(c) - 1$, while the percentage effect $= 100 \cdot g = 100 \cdot \exp(c) - 1$.

that the highest percentage of firms that reported experiencing outages in Tunisia are located in the North west region of Tunisia, the poorest region in the country. In this region, out of a total of 119 firms surveyed, 70, i.e., nearly 60% of firms reported experiencing outages, whereas the average number firms experiencing outages in other regions of the country is just over 20%. We also know that our OLS specification, even after controlling for city effects and population, cannot completely solve the omitted variable bias resulting from an inability to accurately capture the economic and political outlook of the different regions where this firms are located. Such a problem can lead to a negative bias in our estimates. Moreover, this result for firms experiencing outages is not robust to other specifications in our study. Using the TFP and valueadded measure, we find no evidence of a negative association between outages and firm performance for firms in Tunisia.

Finally, we also look at country-specific results across generator ownership. These results are shown in Table 5 for outages hour, and Table 6 for the outages dummy as the explanatory variables, respectively. As before, in Table 5, we find no evidence of an association between outage hours and sales except in the case of Tunisia where we find a positive albeit economically insignificant association between outage hours and sales for firms without an onsite generator. This result is counter-intuitive, given that if outages do not negatively impact firm performance, we would expect no positive association at best. But the relationship we see here could be a result of measurement error which is associated with recall bias. Many firms do not keep accurate records of the number of outages the experience or the duration of such outages. More so, many of the firms that claim to have experienced outages have missing data on the duration of these outages. This fact along with the low statistical power that results when country samples are divided into sub-samples are likely to bias our OLS estimate in this case.

In Panel B of Table 6, which considers only firms that do not own a generator, we also find that among the four countries, only firms in Tunisia without a generator are affected. Specifically, the coefficient of -0.145 among firms that do not own a generator in Tunisia, indicates that experiencing outages is associated with about 13 percent reduction in total sales. As we pointed out earlier with respect to the results from the full country sample of firms in Table 4, this estimate is likely biased as a result of endogeneity stemming from an omitted variable bias problem. For other countries in the generator ownership category, we find no evidence of outages affecting firm performance conditional on owning a generator or not.

Table 3: Effect of Power Outage on Logged Sales, by Generator Ownership Status and Firm Size

	Generator Ownership		Firm Size		
	Generator	No Generator	Small	Medium	Large
	(1)	(2)	(3)	(4)	(5)
			Panel A		
Outage Hours	0.002	−0.001	−0.001	−0.002	0.002
	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)
Observation	1,089	6,942	3,508	2,303	1,783
R-squared	0.587	0.447	0.268	0.295	0.371
			Panel B		
Outages Dummy (0/1)	−0.059	0.021	−0.007	0.143	−0.130
	(0.125)	(0.061)	(0.056)	(0.087)	(0.142)
Observation	1,089	6,942	3,508	2,303	1,783
R-squared	0.587	0.447	0.268	0.296	0.371
Firm-Level Controls	Y	Y	Y	Y	Y
City-Level Controls	Y	Y	Y	Y	Y
Region Fixed Effects	Y	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y	Y
Country Fixed Effects	Y	Y	Y	Y	Y

Notes: This table shows OLS estimates for the impact of power outages on firm performance across generator ownership (columns 1 and 2) and firm size categories (columns 3 through 5), for firms in all four countries. Robust standard errors are clustered at the 39 different regional levels in the full sample. The measure of outages in Panel A is Outage Hours, while in Panel B, outages are measured using the Outages Dummy. Both firm-and city-level controls are included in all regressions, including manager's experience, number of permanent workers, size of firm, age of firm, access to finance foreign ownership, government ownership and city size.
*p<0.1; **p<0.05; ***p<0.01

Table 4: Power Outage Effects on Logged Sales by Country

	Morocco	Tunisia	Egypt	Indonesia
	(1)	(2)	(3)	(4)
		Panel A		
Outage Hours	-0.001	0.002	0.003	-0.003
	(0.003)	(0.001)	(0.002)	(0.002)
Observation	1,246	1,081	4,522	1,182
R-squared	0.394	0.739	0.448	0.549
		Panel B		
Outages Dummy (0/1)	-0.094	-0.116^{**}	0.085	0.076
	(0.157)	(0.045)	(0.060)	(0.175)
Observation	1,246	1,081	4,522	1,182
R-squared	0.400	0.547	0.448	0.550
Firm-Level Controls	Y	Y	Y	Y
City-Level Controls	Y	Y	Y	Y
Region Fixed Effects	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y

Notes: This table shows OLS estimates for the impact of power outages on firm performance in each of the four countries (columns 1 through 4). Robust standard errors are clustered at the different regional levels in each country. The measure of outages in Panel A is Outage Hours, while in Panel B, outages are measured using the Outages Dummy. Both firm-and city-level controls are included in all regressions, including manager's experience, number of permanent workers, size of firm, age of firm, foreign ownership, government ownership and city size.

*p<0.1; **p<0.05; ***p<0.01

Table 5: Power Outage Effects on Logged Sales by Generator Ownership Category in Each Country

	Morocco Generator (1)	Tunisia Generator (2)	Egypt Generator (3)	Indonesia Generator (4)
		Panel A		
Outage Hours	0.007	−0.003	0.003	−0.004
	(0.005)	(0.020)	(0.002)	(0.003)
Observation	126	110	561	292
R-squared	0.697	0.726	0.624	0.523
	No Generator	No Generator	No Generator	No Generator
		Panel B		
Outage Hours	−0.001	0.002*	0.006	−0.002
	(0.004)	(0.001)	(0.004)	(0.001)
Observation	1,120	971	3,961	890
R-squared	0.373	0.537	0.405	0.528
Firm-Level Controls	Y	Y	Y	Y
City-Level Controls	Y	Y	Y	Y
Region Fixed Effects	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y

Notes: This table shows OLS estimates for the impact of power outages on firm performance in each of the four countries across generator ownership (columns 1 through 4). Robust standard errors are clustered at the different regional levels in each country. Panel A shows the impact of power outages on firm performance for firms owning a generator, using the Outage Hours measure. Panel B shows the impact of power outages on firm performance for firms without a generator, using the Outage Hours measure. Both firm- and city-level controls are included in all regressions, including manager's experience, number of permanent workers, size of firm, age of firm, foreign ownership, government ownership and city size.
*p<0.1; **p<0.05; ***p<0.01

Table 6: Power Outage Effects on Logged Sales by Generator Ownership Category in Each Country

	Morocco Generator (1)	Tunisia Generator (2)	Egypt Generator (3)	Indonesia Generator (4)
		Panel A		
Ouatges Dummy (0/1)	-0.023	-0.065	-0.052	-0.067
	(0.575)	(0.236)	(0.175)	(0.270)
Observation	126	110	561	292
R-squared	0.695	0.739	0.623	0.521
	No Generator	No Generator	No Generator	No Generator
		Panel B		
Outages Dummy (0/1)	-0.015	-0.145^{**}	0.095	0.035
	(0.176)	(0.045)	(0.082)	(0.163)
Observation	1,120	971	3,961	890
R-squared	0.373	0.538	0.405	0.528
Firm-Level Controls	Y	Y	Y	Y
City-Level Controls	Y	Y	Y	Y
Region Fixed Effects	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y

Notes: This table shows OLS estimates for the impact of power outages on firm performance in each of the four countries across generator ownership (columns 1 through 4). Robust standard errors are clustered at the different regional levels in each country. Panel A shows the impact of power outages on firm performance for firms owning a generator, using the Outages Dummy measure. Panel B shows the impact of power outages on firm performance for firms without a generator, using the Outages Dummy measure. Both firm- and city-level controls are included in all regressions, including manager's experience, number of permanent workers, size of firm, age of firm, foreign ownership, government ownership and city size.
*p<0.1; **p<0.05; ***p<0.01

Table 7: Power Outage Effects on Total Factor Productivity by Country

	All	Morocco	Tunisia	Egypt	Indonesia
	(1)	(2)	(3)	(4)	(5)
	Panel A				
Outage Hours	-0.002^{**}	-0.005	-0.002	-0.000^{**}	-0.002
	(0.001)	(0.003)	(0.001)	(0.000)	(0.002)
Observation	4,819	509	516	2,868	926
R-squared	0.039	0.129	0.282	0.027	0.034
	Panel B				
Outages Dummy (0/1)	-0.040	-0.261	-0.034	-0.008	0.072
	(0.046)	(0.182)	(0.122)	(0.059)	(0.231)
Observation	4,819	509	516	2,868	926
R-squared	0.039	0.465	0.280	0.027	0.034
	Panel C				
Yearly Outages	-0.001	-0.004	-0.002	-0.000	-0.002
	(0.001)	(0.005)	(0.002)	(0.000)	(0.003)
Observation	4,819	509	516	2,868	926
R-squared	0.039	0.128	0.284	0.027	0.034
Firm-Level Controls	Y	Y	Y	Y	Y
City-Level Controls	Y	Y	Y	Y	Y
Region Fixed Effects	Y	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y	Y

Notes: This table shows OLS estimates for the impact of power outages on firm performance in the full sample of all countries (column1) and each of the four countries (columns 2 through 5). Robust standard errors are clustered at the different regional levels in each country. The measure of outages in Panel A is Outage Hours, while in Panel B, outages are measured using the Outages Dummy. Panel C uses the Yearly Outage measure. Both firm-and city-level controls are included in all regressions, including manager's experience, number of permanent workers, size of firm, age of firm, access to finance, foreign ownership, government ownership and city size.
*p<0.1; **p<0.05; ***p<0.01

5.3 Extensions and Robustness

In this section we report the results of a number of further robustness exercises and extensions. For reasons of space, we do not report coefficients on control variables. Specifically, we use total factor productivity (TFP) and the logarithm of valueadded as the dependent variable and both outage hours and yearly outages as intensity measures of outages as well as the dummy indicator of outages. Due to the attrition[20] resulting from computing total factor productivity, we only estimate the relationship between outages and firm performance using, first, the full sample of all firms across the four countries, and secondly, the full sample for each of the four countries in our dataset. We also disaggregate the full sample of all firms across generator ownership and firm size but do not examine country-specific samples across generator ownership due to the attrition in total number of observation.

Our results from this extension shown in Table 7 differ slightly from those of Table 5, where we use sales as the explained variable. We find a minuscule but statistically significant coefficient on the outage hours variable, -0.002, in the full sample of all firms across the four countries we study. This suggests a negative, if economically insignificant relationship, between outage hours and firm performance. In the individual country samples, we find no evidence of a negative association between outages and firm performance. However, the coefficients on both measures of reliability are markedly more negative in this specification. But the coefficient on outages dummy for Tunisia, which is rather large and statistically significant in our earlier specification with sales as explained variable, is smaller and insignificant in the specification using total factor productivity as explained variable. We further examine the robustness of these results using valueadded as the explained variable. The results from this specification, documented in Table 8 of Appendix A, show no significant negative association between outages and firm performance for both the full sample of all firms and the country sub-samples, except for Indonesia with a statistically significant coefficient of -0.005 on the outage hours variable.

Finally, across the generator ownership and size categories we find evidence of a negative relationship between outage hours and firm performance for firms that do not own a generator. This result, shown in Table 9 of Appendix A, again differs from that in our main specification where the coefficients on both measures of reliability are statistically indistinguishable from zero regardless of the generator ownership status of the firm. Across size classification, we also see evidence of a negative relationship between outage hours and

[20]The attrition arises from the fact that the WBES dataset contains some missing information on some of the variables used in the computation of total factor productivity

firm performance for both small and large firms. Again, while the results from our main specification in this category are not statistically significant, they are of similar magnitude with the specification using TFP as outcome variable.

6 Conclusion

We use a nationally representative cross-sectional survey from the WBES, covering a total of $8,348$ firms across four countries to investigate the relationship between outages and firm performance. In the development literature, there is already a thoroughgoing analysis on firm performance and outages in low-electrification, developing countries. However, a potential concern is that even universally-electrified countries have reliability problems. Yet very little is known about the impacts of outages on firm performance in these countries. Understanding this impact is important as many developing, low-electrification countries now pursue the goal of universal electrification.

We find only weak evidence of a negative association between outages and firm performance across all firms in our sample. This finding holds across sub-samples with and without onsite generators as well as different firm size categories. This result suggests that universal electrification may have been effective towards meeting its policy goals, even in the presence of imperfect reliability. While we find some negative association between outages and firm performance for firms in Tunisia, using sales as the explained variable, the finding is not robust to other specifications using total factor productivity and valueadded as the explained variable. Therefore, given this mixed results and the likely biases in our estimates, we assert that outages in the countries we study do not necessary result in economically significant productivity losses.

Reliable supply of electricity is widely acknowledged as an important input for satisfactory firm performance and economic growth. Yet it is possible for firms, especially the ones in the country we study to adapt to challenges posed by outages — which are relatively infrequent in these countries — such that their productivity is not significantly impacted. It is important to stress this finding as many development institutions and agencies frame universal access to electricity as the pinnacle of electrification goals for developing countries. While universal electrification on its own does not necessarily imply reliable power supply, countries that have attained universal electrification have expended huge capital in reaching the so-called last mile. Usually, these countries have invested in power infrastructure and reliability in urban areas, hence they tend to have a fairly reliable power system relative to countries that have yet to achieve universal electrification. Still, the optimal allocation of electricity sector investment is more nuanced and depends not only on electrification rates and average reliability but also on country-specific conditions. Defining and understanding the country-specific conditions that drive these differences in reliability impacts requires further study.

The results from the overall sample across all four countries in this study intimate that power outages may not be a problem for the average firm operating under conditions of universal electrification, as we find no consistently negative and significant association between outages and firm performance. However, examining country-specific cases indicates that the overall result may conceal some differences across countries and firms. We conclude that while some countries with universal electrification may well have reliable power supply to industry as a result of adequate investments in maintaining grid infrastructure, other universally-electrified countries that have yet to make equally significant investments may still grapple with reliability. Whether this unreliability can effectively impact firm performance still requires further study. What is clear from existing literature is that for countries with low electrification rates and correspondingly poor reliability, outages have marked impacts of firm performance. Taking the full sample of firms into consideration, we submit that in countries that have attained universal electrification, there is insufficient evidence of a negative association between outages and productivity. In the case of Tunisia, our results are mixed; the difference we see in total sales between firms experiencing outages and those that do not could be driven by economic outlook faced by affected firms. This finding has implications for the United Nations goal of universal electrification for all countries by 2030. A binary metric has long been used to assess electrification rates in developing countries. But several newer metrics that emphasize reliability have been proposed with the realization that access rates measures fail to embody the extent of reliability. While access rates are a poor measure of reliability, our findings suggest that countries that have achieved and maintained universal electrification over the years tend to have a fairly reliable power systems. Admittedly, having a 100% rate of electrification does not translate to a fail-safe power system, but attaining universal electrification frees up capital for building a more robust power system in business centers and cities where electricity is in high demand by both the industrial and service sector.

Finally, our results suggest policymakers should encourage the development of new measures that consider the vulnerability or adaptation capability of a population to limited access and poor reliability. Our findings also show cause for optimism; the weak evidence of a negative association between outages and firm performance that we find in the overall sample suggests that it is possible for firms in countries with universal electrification to successfully adapt to any remaining reliability problems such that performance is not hindered by power outages. Our findings in particular underscore the need for future research to unpack any remaining cross-country heterogeneity in the effects of reliability. With limited data, our study is not able to clearly delineate the factors that make firms in some regions more susceptible to the effects of power outages than firms in other regions. Doing so, however, is the next logical step for helping policymakers to understand when and where reliability investments are most needed.

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7 Appendix

We provide here additional regression tables detailing other results of interest

Table 8: Power Outage Effects on Valueadded by Country

	All	Morocco	Tunisia	Egypt	Indonesia
	(1)	(2)	(3)	(4)	(5)
			Panel A		
Outage Hours	−0.002	−0.003	0.002	−0.000	−0.005*
	(0.002)	(0.003)	(0.001)	(0.002)	(0.003)
Observation	4,848	510	550	2,862	926
R-squared	0.525	0.417	0.563	0.506	0.562
			Panel B		
Outages Dummy (0/1)	0.013	−0.196	−0.007	0.067	−0.015
	(0.054)	(0.166)	(0.198)	(0.053)	(0.195)
Observation	4,848	510	550	2,862	926
R-squared	0.525	0.418	0.563	0.506	0.560
Firm-Level Controls	Y	Y	Y	Y	Y
City-Level Controls	Y	Y	Y	Y	Y
Region Fixed Effects	Y	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y	Y

Notes: This table shows OLS estimates for the impact of power outages on firm performance in each of the full sample of firms in all countries (column 1) and each of the four countries (columns 2 through 5). Robust standard errors are clustered at the different regional levels in each country. The measure of outages in Panel A is Outages hours, while in Panel B, outages are measured using the Outages Dummy. Both firm-and city-level controls are included in all regressions, including manager's experience, number of permanent workers, size of firm, age of firm, foreign ownership, government ownership and city size.
*p<0.1; **p<0.05; ***p<0.01

Table 9: Effect of Power Outage on TFP, by Generator Ownership Status and Firm Size

	Generator Ownership		Firm Size		
	Generator	No Generator	Small	Medium	Large
	(1)	(2)	(3)	(4)	(5)
			Panel A		
Outage Hours	−0.000	−0.003**	−0.001***	−0.001	−0.002**
	(0.001)	(0.001)	(0.000)	(0.002)	(0.001)
Observation	759	4060	1,926	1,424	1,256
R-squared	0.222	0.035	0.141	0.036	0.125
			Panel B		
Outages Dummy (0/1)	0.033	−0.061	−0.060	−0.034	−0.057
	(0.222)	(0.034)	(0.037)	(0.080)	(0.114)
Observation	759	4060	1,926	1,424	1,256
R-squared	0.587	0.447	0.141	0.036	0.124
Firm-Level Controls	Y	Y	Y	Y	Y
City-Level Controls	Y	Y	Y	Y	Y
Region Fixed Effects	Y	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y	Y

Notes: This table shows OLS estimates for the impact of power outages on firm performance across generator ownership (columns 1 and 2) and firm size categories (columns 3 through 5), for firms in all four countries. Robust standard errors are clustered at the 39 different regional levels in the full sample. The measure of outages in Panel A is Outages Hours, while in Panel B, outages are measured using the Outages Dummy. Both firm-and city-level controls are included in all regressions, including manager's experience, number of permanent workers, size of firm, age of firm, access to finance foreign ownership, government ownership and city size.
*p<0.1; **p<0.05; ***p<0.01

Table 10: First Stage OLS

	Outages	
	(Outage Hours)	(Outages Dummy (0/1)
Mean Outage Hours	0.676***	
	(0.092)	
Mean Outages Dummy (0/1)		0.940***
		(0.035)
Manager's Experience	0.041***	−0.000
	(0.014)	(0.000)
No. Permanent Workers	−0.000	−0.000*
	(0.001)	(0.000)
Generator	2.976***	0.885***
	(0.490)	(0.016)
Small Firm	0.433	−2.135***
	(0.459)	(0.077)
Medium Firm	0.428	−1.227***
	(0.483)	(0.813)
Age of Firm	0.001	−0.000
	(0.001)	(0.000)
Foreign Ownership	0.922	0.792
	(0.585)	(0.101)
Government Ownership	−0.021	−0.046
	(1.144)	(0.190)
Bigger City	−0.181**	−0.176
	(0.553)	(0.093)
Big City	−1.123***	−0.819***
	(0.453)	(0.079)
Medium City	−0.456	−0.344***
	(0.526)	(0.087)
Finance Obstacle	−0.456	0.085**
	(0.526)	(0.045)
Observation	8,031	8,031
Montiel-Pflueger F-Stat	53.26	674
R^2	0.014	0.110

Notes: Robust standard errors in parenthesis. In columns 1 and 2, standard errors are clustered at the 39 different regional levels. F-Stat is the IV First Stage F-test of instrument strength. Outage Hours is the total duration of outages a firm experienced in a month. Outages Dummy (0/1) is defined as 1 if a firm experienced an outage in the past year, and 0 otherwise. The instruments are: Mean Outage Hours and Mean Outages Dummy. Small City is omitted in the city-size category, while Large Firm is omitted in the firm-size category.

p<0.1; p<0.05; **p<0.01

Table 11: Power Outage Effects on Logged Sales by Country — IV Estimates

	Morocco	Tunisia	Egypt	Indonesia
	(1)	(2)	(3)	(4)
		Panel A		
Outage Hours	−0.001	0.002	0.004***	−0.003*
	(0.003)	(0.001)	(0.001)	(0.002)
Montiel-Pflueger F-Stat	46.87	17.79	6.173	33.38
Observation	1,246	1,081	4,522	1,194
R-squared	0.394	0.547	0.448	0.550
		Panel B		
Outages Dummy (0/1)	−0.094	−0.099**	0.068	0.058
	(0.157)	(0.040)	(0.089)	(0.184)
Montiel-Pflueger F-Stat	54.96	19.98	6.14	75.09
Observation	1,246	1,081	4,522	1,182
R-squared	0.400	0.548	0.448	0.550
Firm-Level Controls	Y	Y	Y	Y
City-Level Controls	Y	Y	Y	Y
Region Fixed Effects	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y

Notes: This table shows instrumental variable estimates for the impact of power outages on firm performance in each of the four countries (columns 1 through 4). Robust standard errors are clustered at the different regional levels in each country. The measure of outages in Panel A is Outage Hours, while in Panel B, outages are measured using the Outages Dummy. Both firm-and city-level controls are included in all regressions, including manager's experience, number of permanent workers, size of firm, age of firm, access to finance, foreign ownership, government ownership and city size.
*p<0.1; **p<0.05; ***p<0.01

Table 12: Power Outage Effects on Logged Sales by Generator Ownership Category in Each Country — IV Estimates

	Morocco	Tunisia	Egypt	Indonesia
	Generator	Generator	Generator	Generator
	(1)	(2)	(3)	(4)
		Panel A		
Ouatges Dummy (0/1)	0.135	−0.266	−0.257	−0.037
	(0.423)	(0.345)	(0.166)	(0.250)
Montiel-Pflueger F-Stat	26.05	14.05	25.08	91.37
Observation	126	110	561	292
R-squared	0.694	0.738	0.621	0.521
	No Generator	No Generator	No Generator	No Generator
		Panel B		
Outages Dummy (0/1)	0.145	−0.113**	0.091	0.009
	(0.180)	(0.054)	(0.121)	(0.165)
Montiel-Pflueger F-Stat	59.35	19.40	5.479	71.95
Observation	1,120	971	3,961	890
R-squared	0.372	0.538	0.405	0.528
Firm-Level Controls	Y	Y	Y	Y
City-Level Controls	Y	Y	Y	Y
Region Fixed Effects	Y	Y	Y	Y
Year Fixed Effects	Y	Y	Y	Y

Notes: This table shows instrumental variable estimates for the impact of power outages on firm performance in each of the four countries across generator ownership (columns 1 through 4). Robust standard errors are clustered at the different regional levels in each country. Panel A shows the impact of power outages on firm performance for firms owning a generator, using the Outages Dummy measure. Panel B shows the impact of power outages on firm performance for firms without a generator, using the Outages Dummy measure. Both firm- and city-level controls are included in all regressions, including manager's experience, number of permanent workers, size of firm, age of firm, access to finance, foreign ownership, government ownership and city size.
*p<0.1; **p<0.05; ***p<0.01

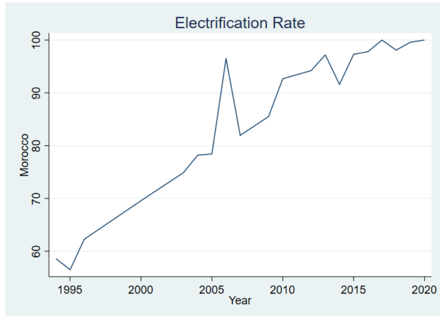

Figure 9: This figure shows the electrification rate for Morocco, which grew rapidly in the 90s and 2000s, but only reached 100% in 2020.

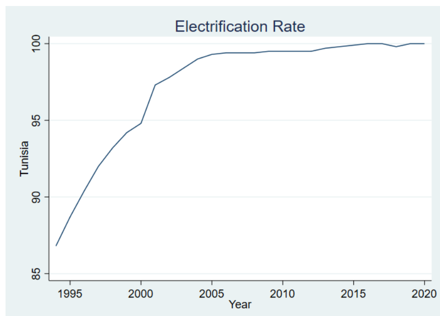

Figure 10: This figure shows the electrification rate for Tunisia. While electrification rate has peaked since the mid 2000s, it reached 100% in 2016.

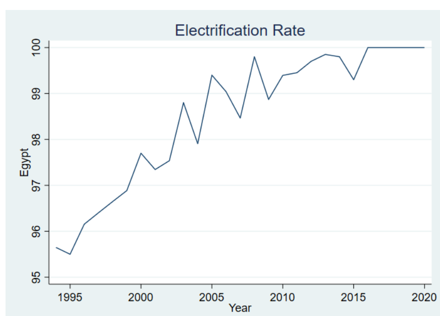

Figure 11: This figure the electrification rate for Egypt, which has been as high as 95% since 1994, but only reached a 100% in 2016

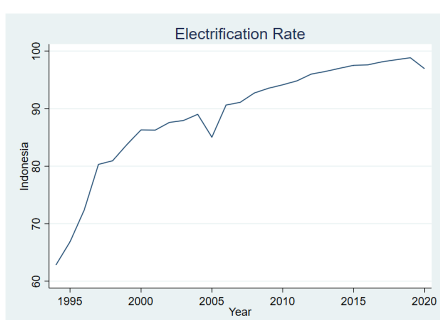

Figure 12: This figure shows the electrification rate of Indonesia, which grew rapidly in the 90s, and reached a peak of 99%

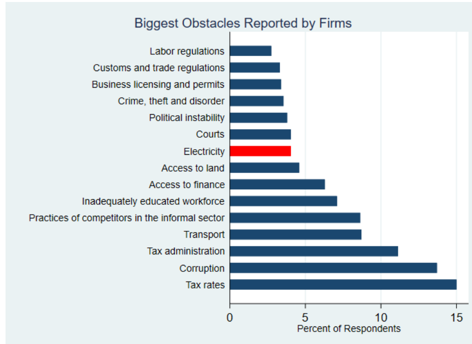

Figure 13: This figure shows the self-ranking of the biggest obstacles faced by firms in Morocco. Tax rates is ranked as the biggest obstacle while electricity, marked in red, is ranked 9^{th} amid the 15 obstacles identified from firms responses.

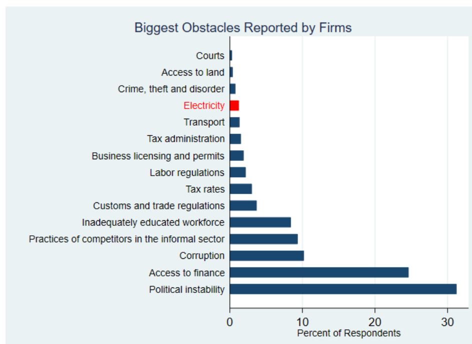

Figure 14: This figure shows the self-ranking of the biggest obstacles faced by firms in Tunisia. Political instability is ranked as the biggest obstacle while electricity, marked in red, is ranked 12^{th} amid the 15 obstacles identified from firms responses.

Figure 15: This figure shows the self-ranking of the biggest obstacles faced by firms in Egypt. Political instability is ranked as the biggest obstacle while electricity, marked in red, is ranked 7^{th} amid the 15 obstacles identified from firms responses.

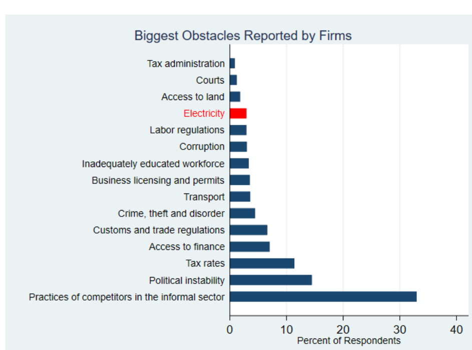

Figure 16: This figure shows the self-ranking of the biggest obstacles faced by firms in Indonesia. Practices of competitors is ranked as the biggest obstacle while electricity, marked in red, is ranked 12^{th} amid the 15 obstacles identified from firms responses.

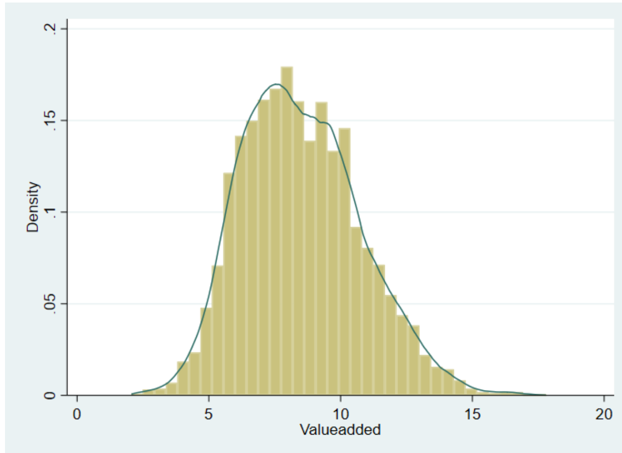

Figure 17: This figure shows the distribution of valueadded among all firms across the countries we study, which, overall follows a normal distribution.

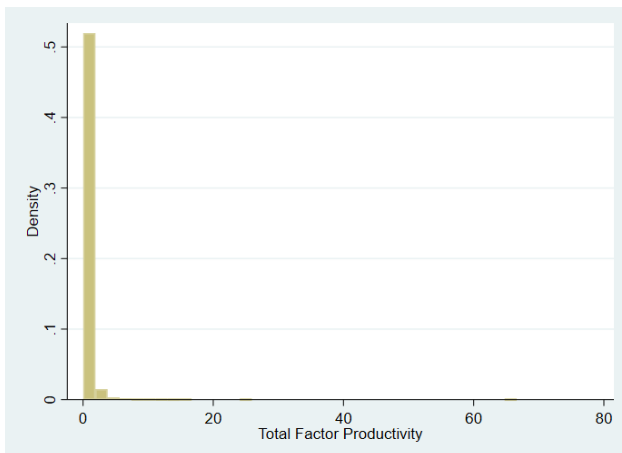

Figure 18: This figure shows the distribution of total factor productivity among all firms across the countries we study. The distribution appears to be skewed to the left, but for most firm the TFP values fall between 0 and 2, with some outliers above 20 .

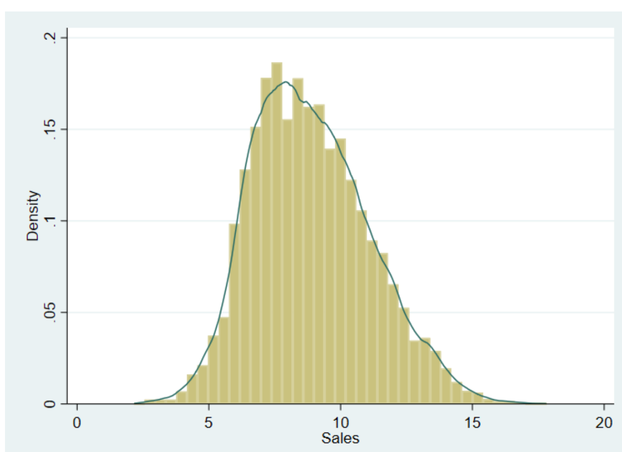

Figure 19: This figure shows the distribution of sales among all firms across the countries we study, which also follows a normal distribution.