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Power Constraints and Firm-Level Total Factor Productivity in Developing Countries

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Abstract

This paper analyzes the effects of power outages and constraints on manufacturing firms' revenue-based total factor productivity in developing countries. The empirical analysis is based on the World Bank Enterprise Surveys dataset for 84 countries over 2006–2019. The paper starts by showing statistically that firms facing power outages differ and operate in very different environments compared to firms not facing power outages, underlining a potential nonrandom issue of the treatment variable. The matching-based approach (entropy balancing) is designed to contain this type of bias. It shows that power outages negatively and significantly affect firm-level revenue-based total factor productivity, with a 9 percent lower unconditional average productivity for exposed firms compared to nonexposed firms. Moreover, the estimates suggest a connection between the severity of self-reported power constraints or obstacles by firms and the magnitude of revenue-based total factor productivity loss. The results also indicate that the effect of power outages on firm-level revenue-based total factor productivity could be influenced by the stage of economic development (low-income countries, lower-middle-income countries, upper-middle-income countries), and the ability of firms to engage in research and development and purchase backup generators. These findings suggest that to ensure economic development, the government should provide a stable power supply that can mitigate the negative shocks faced by manufacturing firms and enhance their productivity and competitiveness, allowing them to drive economic growth.

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Power Constraints and Firm-Level Total Factor Productivity in Developing Countries*

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1 Introduction

Low levels of infrastructure development and poor quality services within a country can increase production costs for domestic firms and divert their technological choices to sub-optimal solutions. This reduces their level of competitiveness compared to foreign competitors in general. Furthermore, the economic literature suggests that better power infrastructure significantly stimulates economic growth and improves a range of development outcomes. However, in developing countries, firms generally have difficulty connecting to the power grid or, when they are connected, they face frequent scheduled or unscheduled power outages (Alam, 2013). Voltage fluctuations and the frequency of power outages therefore lead to material losses and have a negative effect on manufacturing costs and production.

As drivers of economic growth, a major part of the firms in these developing countries cite power as the major obstacle or one of the main constraints to their activities (Asiedu et al., 2021). Indeed, power is the second most important constraint after access to finance. Two regions are particularly affected, namely South Asia and Sub-Saharan Africa. In fact, about 45.9% of firms in Sub-Saharan Africa and 41.2% of firms in South Asia report that power is a major or severe constraint to their operations. The issue of power thus appears to be of greater concern to these firms than many other issues such as corruption and transport in most of these regions.

Given the major role of manufacturing firms in developing countries and the gradual improvement of firm-level data availability and quality, a recent literature is emerging on the empirical assessment of the effect of power constraints on firms' performance. However, this literature on power constraints and firms' productivity is still scarce and the results remain rather inconsistent when compared to each other. For example, some studies find a statistically significant negative effect of these constraints on the performance of firms (Hardy and McCasland, 2021; Abeberese et al., 2021), other studies find a statistically significant but weak effect (Grainger and Zhang, 2017) and still others do not find a statistically significant relationship between these power obstacles and the productivity of firms (Scott et al., 2014). This lack of consistency in the previous results from the literature could reflect the potential limitations of the different empirical approaches adopted in this literature so far. For example, Xiao et al. (2022) consider power outages or constraints as a completely exogenous explanatory variable. Meanwhile, authors like Fisher-Vanden et al. (2015); Allcott et al. (2016); Cole et al. (2018) or Elliott et al. (2021) consider this variable as potentially endogenous and propose an instrumental variables technique based on variations in the power supply from hydroelectric generation as an instrument.

This paper contributes to the empirical literature on the potential effects of power outages or constraints on firm-level TFP by proposing a new matching-based approach (Entropy Balancing) and by extending the previous results from the literature to the degree of severity of the power constraints. First, contrary to Xiao et al. (2022) who present the power outages variable as an exogenous energy shock, we show statistically that the outages treatment variable is not random for manufacturing firms in developing countries. Second, in order to compensate for the limits linked to the instrumentation technique by the hydroelectric variable in some analysis of this literature (as in Fisher-Vanden et al., 2015; Allcott et al., 2016; Cole et al., 2018; Elliott et al., 2021) and to properly account for potential endogeneity with respect to exposure to power constraints, but also to address the lack of a balanced panel structure (survey data), we use a matching-based approach (Entropy Balancing). Our analysis is based on the idea that exposure to constraints represents a treatment. The firms exposed to the constraints constitute the treatment group, the unexposed firms constitute a potential control group. Third, we establish a strong link between the severity of self-reported power constraints or obstacles by firms (minor, moderate, major, severe, and biggest) and the magnitude of productivity loss for firms. In other words, the greater the level of power constraints self-reported by a firm, the greater the effect of these constraints on its productivity, and vice versa.

Broadly, our approach shows that the overall effect of power outages on revenue-based total factor productivity (TFPR) is negative and statistically significant. Additionally, we show that other mechanisms such as the acquisition of back-up generators, or investment in R&D allow firms to fight against the severe constraints encountered in the power sector. We also show that constraints in the power sector affect firm revenue-based total factor productivity mainly through the channel of non-optimal reorganization of firm operations (reduced capacity utilization) and through the channel of production losses due to power outages.

The rest of the paper is as follows: the literature review in section 2, the theoretical framework in section 3, data and model in section 4, empirical results in section 5 and section 6 concludes.

2 Related literature

Some analyses have focused on the effect of inputs market constraints on productivity (Prescott, 2002; Hsieh and Klenow, 2009; Jones, 2011). These analyses suggest that input market constraints prevent the achievement of an efficient allocation of resources, thus reducing total factor productivity. In the same vein, Brandt et al. (2013) find that TFP losses due to input market constraints are still high in many countries. More specifically in our field of research, energy market constraints are also assessed. Indeed, Shi and Sun (2017) find that energy price instability negatively affects output growth in the short and long run. As for Bernanke (1983), he shows that uncertainty about energy prices can induce firms to postpone their investment decisions, thus leading to a decline in overall output. Similarly, Elder and Serletis (2009) suggest that oil price uncertainty may tend to reinforce the negative response of production to oil shocks. Finally, Cheng et al. (2019) show that an increase in oil price volatility reduces real GDP and investment, while a decrease stimulates the economy.

With respect to power sector constraints, Cole et al. (2018) find that power outages have a negative and significant effect on firm sales in 14 African countries. The effect found is larger when endogeneity is taken into account.[1] They also find that power outages affect firm profits and total factor productivity. Furthermore, also using a hydro-instrumental variable strategy, Elliott et al. (2021) show that Vietnamese firms with less reliable power have lower productivity in 2005 and 2015. They conclude that reducing the length of power outages by 1% would have increased overall revenues by 4.66 billion USD. In the same line of instrumental variables, Allcott et al. (2016) also use changes in power supply from hydroelectric generation as an instrument to estimate the effect of power outages on the Indian manufacturing sector. Finally, a similar approach is taken by Fisher-Vanden et al. (2015) who examine the effects of power outages on firm performance in China.

Meanwhile, the economic literature remains relatively well-supplied on the other common determinants of firm-level performance. Among these determinants, we can mention international development aid, financial inclusion, bank concentration, financial innovation, inflation, or taxation. International aid is a key

[1] Use of a hydro-instrumental strategy.

factor in improving the performance of firms by alleviating infrastructure and financing constraints in developing countries. In this sense, Chauvet and Ehrhart (2018) find a positive effect of foreign aid on the growth of firms' sales. Furthermore, Chauvet and Jacolin (2017) find that financial inclusion, i.e. the distribution of financial services in firms, has a positive effect on firm growth. This positive effect is amplified when there is greater competition between banks. In the same vein, Lee et al. (2020) show that financial inclusion helps firms to increase their sales growth. On the other hand, they paradoxically find that financial innovation has a negative effect on the growth rate of firms' sales. In their paper, Bambe et al. (2022) show that inflation targeting increases the growth and productivity of firms in targeted countries compared to non-targeted countries. Indeed, inflation targeting improves the performance of developing countries by reducing the level and volatility of inflation (Lin and Ye, 2009). Finally, Chauvet and Ferry (2021) show that tax revenues boost the performance of firms through the financing of essential infrastructure for business development.

In this paper, we mainly contribute to this literature on the effects of power outages or constraints by proposing a new matching-based approach (Entropy Balancing) and by extending the previous results from the literature to the degree of severity of the power constraints.

3 Theoretical framework

The main purpose of this theoretical framework is twofold. First, we highlight the difficulty of directly drawing conclusions about how energy shocks would affect firm-level total factor productivity from a theoretical framework. The second main objective is to establish theoretically that productivity loss increases with the severity of energy constraints facing manufacturing firms.

Although some of the studies in this literature point out that economic growth, for instance, decreases in the event of an energy shock (Cheng et al., 2019; Sadorsky, 1999), we show in this theoretical framework that this could have rather contrasting effects on the total factor productivity of manufacturing firms depending on the market structure. Since power constraints are an important manifestation of input market distortion, our theoretical framework is closely related to the literature on the relationship between input market distortion and firm-level total factor productivity.

This theoretical framework of intermediate goods and output price adjustment caused by an energy shock is based on that of Hsieh and Klenow (2009) and Xiao et al. (2022). We derive the expression for total factor productivity at the firm-level and analyze the effect of energy shocks on firm-level TFP.

We assume monopolistic competition with heterogeneous firms that face different degrees of energy constraints. Indeed, there are several reasons why we consider power constraints to be firm-specific rather than sector-specific in this framework. First, the power infrastructure of a country or region can vary considerably in terms of reliability and quality. Some firms may be located in areas with better power infrastructure, while others may suffer frequent constraints like outages due to inadequate infrastructure or maintenance. Second, some firms may have invested in backup generators or alternative power sources to mitigate the impact of power constraints. These firms would be less affected by general disruptions to the power supply than those without such back-up systems. Third, firms in the same sector may have different operational requirements and production processes. Some firms may be highly dependent on a continuous power supply, such as those involved in refrigeration or other electricity-intensive operations. On the other hand, some firms may have more flexible production processes that can adapt to temporary power supply interruptions. Finally, firms may adopt different mechanisms to cope with power constraints. For instance, some firms may adjust their production schedules, switch to off-peak hours or implement energy-saving measures during outages, helping them to minimize the negative impact of power disruptions.

In a fully competitive final output market, there is a single final product Y, and it is aggregated from the output Y_s of S manufacturing industries (or branches) by the following production function:

$$Y = \prod_{s=1}^{S} {Y_s}^{\theta_s}, \text{ where } \sum_{s=1}^{S} \theta_s = 1 \tag{1}$$

where θ_s is an output elasticity parameter for industry s. Minimizing production costs implies:

$$P_s Y_s = \theta_s P Y \tag{2}$$

P_s is the price of the output Y_s of the industry s, and the price of the final product is $P \equiv \prod_{s=1}^{S} \left(\frac{P_s}{\theta_s}\right)^{\theta_s}$. The output Y_s of the industry s is the CES aggregate of M_s types of differentiated products:

$$Y_s = \left(\sum_{i=1}^{M_s} {Y_{si}}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} \tag{3}$$

where σ is the elasticity of substitution between the differentiated products within the industry s.

The production function of each differentiated product is given by a Cobb-Douglas function of the firm's TFP and three production inputs, including capital, labor and energy:

$$Y_{si} = A_{si} K_{si}^{\alpha_s} L_{si}^{\beta_s} E_{si}^{1-\alpha_s-\beta_s} \tag{4}$$

where α_s denotes the capital share of industry s, β_s denotes the labor share of industry s, $(1-\alpha_s-\beta_s)$ denotes the share of intermediate products or the share of energy of industry s, and A_{si} denotes the level of TFP of firm i. Note also that this framework allows input shares to differ between different industries but not between firms in the same industry.

The profit maximization program for monopolistically competitive firms with respect to K_{si}, L_{si}, and E_{si} is as follows:

$$\begin{gathered} \max \pi_{si} = P_{si} Y_{si} - r K_{si} - w L_{si} - (1+\tau_{E_{si}}) P_E E_{si} \\ \text{s.t. } Y_{si} = A_{si} {K_{si}}^{\alpha_s} {L_{si}}^{\beta_s} {E_{si}}^{1-\alpha_s-\beta_s} \end{gathered} \tag{5}$$

where r represents the price of capital, w represents the labour cost, P_E represents the cost of intermediate inputs, i.e. energy. $\tau_{E_{si}}$ represents the energy constraints (increase in the cost of energy, power outages leading to additional costs for back-up generators, increase in losses for firms, etc.) facing a representative firm i.

The maximization of the profit (5) using the Lagrangian method of optimization combined with the first order conditions yields:

$$
\begin{cases}
\lambda A_{si}\alpha_s K_{si}{}^{\alpha_s-1}L_{si}{}^{\beta_s}E_{si}{}^{1-\alpha_s-\beta_s}-r=0 \quad \text{where } \lambda=\frac{\sigma-1}{\sigma}P_{si} & (6)\\
K_{si}=\frac{w}{r}\frac{\alpha_s}{\beta_s}\times L_{si} & (7)\\
E_{si}=\frac{w}{P_E}\frac{1-\alpha_s-\beta_s}{\beta_s}\frac{1}{(1+\tau_{E_{si}})}\times L_{si} & (8)
\end{cases}
$$

By substituting the equations (7) and (8) into the equation (6), we obtain the standard condition that the firm's output price is a fixed markup over its marginal cost (r, w, P_E):

$$
P_{si}=\frac{\sigma}{\sigma-1}\left(\frac{r}{\alpha_s}\right)^{\alpha_s}\left(\frac{w}{\beta_s}\right)^{\beta_s}\times\left(\frac{P_E}{1-\alpha_s-\beta_s}\right)^{1-\alpha_s-\beta_s}\times\frac{(1+\tau_{E_{si}})^{1-\alpha s-\beta_s}}{A_{si}} \tag{9}
$$

The output price is increasing with the energy constraints $\tau_{E_{si}}$ facing the representative firm. Under the assumption that the output price increases with the level of energy constraint facing the representative firm, this could lead to a generalized price increase in the output market if a significant number of firms face energy constraints in the economy. Indeed, many analyses point out that energy shocks generate output prices adjustment by producers in the economy (Barth III and Ramey, 2001; Bodenstein et al., 2011; Choi et al., 2017).[2] This is called cost-push inflation or output market distortion. Depending on the strength of the interactions between the different sectors of the economy, a distortion of the output market as a result of energy constraints may lead to distortions of the labor, capital and even energy markets again, thus leading to a dangerous vicious circle.

Now, let us recall our definition of the TFP. We opted for the revenue-based TFP (TFPR). Here, the TFP is measured by revenue productivity or revenue-based productivity such that $\text{TFPR}_{si}=A_{si}P_{si}$ (as in Hsieh and Klenow, 2009). From equation (9), we can therefore express the TFPR_{si} of firm i in the sector s as follows:

$$
\text{TFPR}_{si}=\frac{\sigma}{\sigma-1}\left(\frac{r}{\alpha_s}\right)^{\alpha_s}\left(\frac{w}{\beta_s}\right)^{\beta_s}\times\left(\frac{P_E}{1-\alpha_s-\beta_s}\right)^{1-\alpha_s-\beta_s}\times(1+\tau_{E_{si}})^{1-\alpha_s-\beta_s} \tag{10}
$$

The analysis of the effect of energy constraints $\tau_{E_{si}}$ on the equation (10) revenue-based TFP leads to:

$$
\frac{\partial\text{TFPR}_{si}}{\partial\tau_{E_{si}}}=\frac{\sigma}{\sigma-1}\left(\frac{r}{\alpha_s}\right)^{\alpha_s}\left(\frac{w}{\beta_s}\right)^{\beta_s}\times\left(\frac{P_E}{1-\alpha_s-\beta_s}\right)^{1-\alpha_s-\beta_s}\times\frac{1-\alpha_s-\beta_s}{(1+\tau_{E_{si}})^{\alpha_s+\beta_s}} \tag{11}
$$

Based on the value taken by the elasticity of substitution σ in monopolistic competition, the final expression obtained in equation (11) is either negative (when $\sigma<1$), positive (when $\sigma>1$), or indefinite (when $\sigma\to1$). Therefore, it is not possible to draw here any conclusion about how energy shocks will affect total factor productivity at the firm-level from a theoretical perspective (H_1). That means for instance, the analysis of the effect of power constraints on the productivity of firms thus remains an empirical question that we will analyze in the next section 4.

Furthermore, as the $\lim_{\tau_{E_{si}}\to+\infty}\frac{\partial\text{TFPR}_{si}}{\partial\tau_{E_{si}}}$ converges toward zero, we can also hypothesize that the greater the energy constraints facing firms ($\tau_{E_{is}}$ is large), the more the reverse effects of power constraints on TFP are significant (H_2). For instance, this would mean that the greater the level of power constraints faced by a firm, the greater the effect of these constraints on its productivity, and vice versa.

[2] For example, for Choi et al. (2017), a 10% increase in international oil prices raises inflation by 0.4 percentage points on average.

The main purpose of our following empirical approach will be to test these two main hypotheses (H_1 and H_2) put forward through this theoretical framework.

4 Empirical strategy and data

4.1 Empirical strategy

One of the main challenges in quantifying the effect of power sector constraints on firm performance is that facing or not power constraints might be non-random (Alam, 2013; Cole et al., 2018; Elliott et al., 2021). Indeed, the power constraints faced by firms in a country can be explained by the macroeconomic/institutional phenomena of the country in question (low quality of regulation, lack of financing, political instability, etc.) and/or firm characteristics such as size, maturity, quality of management or even ownership (public or private, domestic or foreign). These realities can also explain the low level of performance of firms operating in that country. Even within the same country, we can mention targeted public investment in energy infrastructure near the best performing firms to support their operations, and public investment in infrastructure (roads and railways) that can both improve the reliability of power supply (ease of maintenance of power transmission lines) and the transportation of products for firms.

To deal with this identification issue, some authors in this literature have opted for the instrumental variables technique based on variations in the power supply from hydroelectric generation as an instrument (Fisher-Vanden et al., 2015 in China; Allcott et al., 2016 in India; Cole et al., 2018 in 14 selected Sub-Saharan African countries; Elliott et al., 2021 in Vietnam). Meanwhile, we believe that this identification strategy might potentially have three major limitations:

First, it is not applicable to a larger sample, as not all countries have an energy mix based mainly on hydropower. As a result, studies using this identification strategy frequently focus on a single country, or on a small number of countries similar in terms of energy mix mainly based on hydro-generation of the electricity, thus reducing the external validity of their conclusions.

The second and more fundamental limitation might be that very often, these countries that are largely dependent on hydro-generation set up substitute generators or fossil power plants ready to take over following the fluctuations in dam water (climate shocks). This reality could cut the link between hydro-generation (the instrument) and power constraints (treatment). The validity of this type of instrument would therefore be partly questioned.

Finally, even when a valid instrument is available, the fact that the exposure to the treatment is non-random could result in poor estimates when using an instrumental variable strategy approach, as pointed out by Ertefaie et al. (2016) and Canan et al. (2017), who stress the relevance of the matching approach in the presence of this specific source of endogeneity.

So, to overcome these potential limitations described above and to properly account for potential endogeneity issue with respect to exposure to power constraints, but also to address the lack of a balanced panel structure (survey data), we propose a matching-based approach (Entropy Balancing). Our analysis is based on the idea that exposure to constraints represents a treatment. Firms exposed to the constraints constitute the treatment group, while firms not exposed constitute a potential control group. The average treatment effect on treated firms (ATT) is defined as follows:

$$\tau_{\text{ATT}} = E[y(1) \mid T = 1] - E[y(0) \mid T = 1] \tag{12}$$

$y(\cdot)$ is the outcome variable (the TFPR). T indicates whether a unit or firm is exposed to treatment/constraints ($T = 1$) or not ($T = 0$). Therefore, $E[y(1) \mid T = 1]$ is the expected outcome after treatment and $E[y(0) \mid T = 1]$ is the counterfactual outcome, i.e. the outcome that a unit exposed to treatment would have obtained if it had not experienced to treatment. As the counterfactual outcome is not observable, we need an appropriate proxy to identify the ATT. If the treatment is randomly assigned, then the average outcome of the units not exposed to the treatment, $E[y(0) \mid T = 0]$, is an appropriate proxy. However, as we saw earlier, exposure to the constraints and hence selection into the treatment could be endogenous due to the potential confounding factors we mentioned earlier.

The idea of matching-based estimators is to mimic randomization with respect to treatment assignment. The unobserved counterfactual outcome is imputed by matching treated units with untreated units that are as similar as possible with respect to all observable characteristics that: (i) are associated with selection into treatment (i.e. the probability of being exposed to constraints), and (ii) influence the outcome of interest. The realizations of the productivity gap measure for these matches are then used as an empirical proxy for the unobserved counterfactual. Formally, the matching-based ATT estimate is defined as follows:

$$\tau_{\text{ATT}}(x) = E[y(1) \mid T = 1, X = x] - E[y(0) \mid T = 0, X = x] \tag{13}$$

where x is a vector of relevant observable characteristics (see the description of the firm-level and country-level control variables in subsection 4.2), $E[y(1) \mid T = 1, X = x]$ is the expected outcome for the units that received the treatment, and $E[y(0) \mid T = 0, X = x]$ is the expected outcome for the best matches of the treated units. Entropy balancing estimates the causal effect under the unconfoundedness assumption or conditional independence assumption (CIA). The CIA implies that the selection into the treatment group is only conditional to a set of observed covariates. Specifically, it assumes that conditional on the observed covariates (after controlling-for the covariates), the treatment assignment is independent of the potential outcomes.[3]

In this study, as Neuenkirch and Neumeier (2016) in the analysis of the effect of US sanctions on the poverty gap in the target countries and Apeti (2023a) in the analysis of the effects of mobile money on household consumption volatility, we use Entropy Balancing to select matches for units exposed to the treatment and to estimate the ATT.[4] Entropy Balancing is a method proposed by Hainmueller (2012). This method is implemented in two steps. First, weights are calculated and assigned to the units not subject to treatment. These weights are chosen to satisfy prespecified equilibrium constraints involving sample moments of the observable features while at the same time remaining as close as possible to the uniform base weights. In our analysis, the equilibrium constraints require equal covariate means between the treatment and control groups, which ensures that the control group contains, on average, non-treatment units that are as similar as possible to the treatment units. Second, the weights obtained in the first step are used in a regression analysis with the treatment indicator as an explanatory variable. This yields an estimate of the ATT, i.e. the conditional difference in the means of the outcome variable between the treatment group and

[3] In other words, CIA implies that after conditioning on the observed covariates, there are no unobserved confounding factors that influence both the treatment assignment and the potential outcomes. We empirically test the CIA in our subsection 5.2.

[4] See also Apeti and Edoh (2023); Apeti (2023b); Apeti et al. (2023).

the control group.[5] Broadly, the idea of Entropy Balancing here is to compare the productivity gap of firms exposed to power constraints with that of unexposed firms that are as similar as possible to the exposed firms. The average difference in productivity between the exposed firms and the ”closest” unexposed firms must then be due to the treatment, i.e. the exposure to the power constraints. In this sense, the empirical approach mimics a randomized experiment by balancing the treatment and control groups on the basis of observable characteristics.

By combining matching and regression analysis, Entropy Balancing has some advantages over other treatment effect estimators. A particularly important advantage over regression-based approaches (including DiD estimation) as well as propensity score-based matching methods is that Entropy Balancing is non-parametric in the sense that no empirical model for the outcome variable or selection into treatment needs to be specified. Moreover, unlike regression-based analyses, there is no multicollinearity, as the reweighting scheme orthogonalizes the covariates to the treatment variable. Furthermore, unlike other matching methods, Entropy Balancing ensures a high balance of covariates between treatment and control groups, even in small samples.

Then, by combining a reweighting scheme with regression analysis, Entropy Balancing allows us to control for both country fixed effects and year fixed effects in the second step of the matching approach, i.e. the regression analysis.[6] The inclusion of country fixed effects is particularly useful to account for the potential unobserved heterogeneity between firms from different countries and to control for time-invariant country-specific conditions that could lead to differences in the productivity gap between firms. Also, knowing that productivity varies with firm and economic characteristics (Syverson, 2011), we include a large set of control variables at the firm and country level.

Finally, as recalled by Chauvet and Ehrhart (2018), the statistical bias resulting from the attempt to measure the effect of macro variables on micro-units was underlined by Moulton (1990).[7] Therefore, as in Chauvet and Ehrhart (2018) and Bambe et al. (2022), the standard errors are clustered at the country level (as we have country level control variables such as economic growth, bank concentration, inflation, etc.).[8]

4.2 Data and variables

In this analysis, we consider 31,406 manufacturing firms in 84 developing countries from 2006 to 2019, 30 of which are in Sub-Saharan Africa (AFR), 8 in East Asia and Pacific (EAP), 14 in Europe and Central Asia (ECA), 20 in Latin America and the Caribbean (LAC), 6 in the Middle East and North Africa (MNA), and 6 in South Asia (SAR).

4.2.1 Firm-level data

We mainly use the World Bank Enterprise Survey (WBES) data in this analysis. The strata of the enterprise surveys are firm size, industry and geographical region within a country. The firm size levels are 5-19 (small), 20-99 (medium), and 100+ employees (large). It is important to note, however, that these surveys

[5]In the regression step, we additionally control for the covariates used in the first step. This is equivalent to including control variables in a randomized experiment to increase the efficiency of the estimation.

[6]We also include region and income group fixed effects in our econometric specification.

[7]Random disturbances in the correlated regression within the groupings that are used to merge the aggregate data with the micro data can lead to a downward bias in the ordinary least squares standard errors (Moulton, 1990).

[8]Clustering the standard errors at the industry level also yields similar results as the country level clustering (see robustness check in the subsection 5.3).

are limited to formal firms with five or more employees and with over 1% private ownership or participation. In this analysis, we start with the year 2006 because most surveys from this year onwards use stratified sampling and contain weights based on this information. Earlier surveys may not contain any information on weights. All monetary variables are adjusted to 2009 levels using a World Bank GDP deflator and then transformed to US dollars using the International Monetary Fund's purchasing power parity (PPP) index.

Our treatment variables (dummy variables taking 0 or 1) characterize the different levels of power constraints that firms report being exposed to. One advantage of this measure is that it reflects firms' perceptions of the extent to which power constrains their operations. This is important because the firm's perception is one of the most important factors influencing their operational and investment decisions (Asiedu and Freeman, 2009).

To approximate the level of performance of each firm, we opt for total factor productivity (TFP), the part of output that is not explained by the quantity of inputs used.[9] The productivity of firms, i.e. the ability to generate greater output with fewer inputs, is one of the key elements of economic growth. As a reminder, productivity is estimated from a Cobb-Douglas VA (value added) function of the following form:

$$VA_i = A_i K_i^{\alpha_k} L_i^{\alpha_l} \tag{14}$$

where value added at the firm-level VA_i is a function of the inputs of capital (K_i) and labour (L_i).[10] The efficiency of firms' production is measured by the term A_i which is the part of output that cannot be directly attributed to inputs used. Equation (14) could be rewritten as:

$$log(VA_i) = \alpha_0 + \alpha_k log(K_i) + \alpha_l log(L_i) + \varepsilon_i \tag{15}$$

log(TFP$_i$) is estimated as a sum of the constant and the residual, i.e., log(TFP$_i$)=$\hat{\alpha}_0 + \hat{\varepsilon}_i$.[11] Therefore, the TFP is the part of output that is not explained by the quantity of inputs used.

In equation (14), TFP A_i is estimated separately for each industry. This avoids the assumption of a common production technology (i.e. α_k and α_l are the same within the sample). In addition, wherever possible, the elasticities of output with respect to capital and labor (i.e. α_k and α_l) can vary according to the income level group of the corresponding economy. Finally, as in Halvorsen et al. (1980), the country and year effects are controlled via dummy variables for each country and year. The table (1) shows an average log(TFP) of 2.46 for our sample of firms. However, we have a large heterogeneity between our firms as it varies from -3.23 for the least productive firms to 8.83 for the best performing firms.

At the firm-level, we control for the age of the firm, the size of the firm, whether or not the firm has a website, and most importantly, the ownership of the firm.[12] Indeed, over time, firms tend to find ways to solve or mitigate the problem of power constraints. In addition, older firms are found to be more productive (Majumdar, 1997). Moreover, a positive relationship between firm size and TFP is found in the manufacturing sector in general (Leung et al., 2008; Tovar et al., 2011). Also, we use the possession of a website by a firm as a good signal of the quality of the firm's marketing, it can influence its productivity. Finally,

[9] World Bank Group, Enterprise Analysis Unit. 2017. "firm-level Productivity Estimates".

[10] VA is represented by the difference between the establishment's total annual sales and the total annual cost of inputs, K is represented by the replacement value of machinery, vehicles and equipment; L is represented by the total annual labor cost.

[11] Where log(A$_i$)=log(TFP$_i$)

[12] We include both age and size because, contrary to popular belief, St-Pierre et al. (2010) have shown that firm size and age are not substitutes in an exploratory study of 288 Quebec manufacturing firms.

Table 1: Summary statistics on our main variables

	Mean	SD	Min	Max	N
Panel A: Firm-level controls					
Firm's longevity (Years)	29.72	16.77	3.00	351.00	31406
Firm size (Small=1, Medium=2 or Large=3)	1.81	0.77	1.00	3.00	31406
Own website (No=0, Yes=1)	0.42	0.49	0.00	1.00	31406
Foreign private participation (%)	7.75	24.93	0.00	100.00	31406
Panel B: Country-level controls					
Regulatory Quality, Percentile Rank (0-100)	42.67	18.55	5.21	91.75	31406
Financial development index	0.28	0.14	0.03	0.70	31406
Bank concentration (%)	61.49	20.04	22.60	100.00	31406
Net ODA received (% of GNI)	2.42	4.16	0.01	37.37	31406
Inflation, consumer prices (annual %)	7.58	8.58	-1.05	84.86	31406
GDP growth (annual %)	4.34	4.44	-25.91	14.01	31406
GDP per capita (constant 2015 USD)	3976.76	3208.01	302.07	14086.02	31406
Panel C: Outages related variables					
Outages frequency (occurrences per month)	7.31	8.69	0.00	31.00	16821
Outages intensity (hours per occurrence)	4.45	6.98	0.00	96.00	16416
Panel D: Performance related variables					
Log revenue-based TFP (TFPR)	2.46	1.50	-3.23	8.83	31406
Cost of inputs per unit of sales (2009 USD)	0.40	0.22	0.00	0.99	31406
Sales per labor cost (2009 USD)	11.71	21.32	0.11	646.50	31406
Capacity Utilization (%)	73.48	21.12	0.00	100.00	30714
Losses due to Outages (% of annual Sales)	8.12	11.85	0.00	100.00	12813

Asiedu et al. (2021) find that the probability of facing power constraints is lower for state-owned firms with majority ownership. However, a high level of private participation in a firm could reveal significant levels of firm attractiveness or performance.

Further details on the firm-level variables can be found in the Appendix (Table 16).

4.2.2 Country-level data

At the country level, we control the quality of regulation, financial development, bank concentration, foreign aid, inflation, economic growth, and the level of wealth. Indeed, Agostino et al. (2020) establish strong evidence that better local institutions (the rule of law and government efficiency) help small and medium-sized firms become more productive in Europe over the period 2010-2014. We also have evidence of a positive effect of foreign aid on firm sales growth (Chauvet and Ehrhart, 2018). Furthermore, financial development and greater competition between banks (strong bank concentration) favor the performance of firms (Chauvet and Jacolin, 2017; Lee et al., 2020). Finally, Bambe et al. (2022) show that inflation targeting increases the growth and productivity of firms in targeted countries compared to non-targeted countries. Indeed, inflation targeting improves the performance of developing countries by reducing the level and volatility of inflation (Lin and Ye, 2009).

Further details on the country-level variables can be found in Appendix Table (16).

5 Empirical results

5.1 Descriptive statistics

Table (2) presents a summary of our treatment variables (power constraints) in this study. With respect to power outages, 16,816 firms out of 30,403 firms faced power outages, or about 53.6% of the firms in our sample. In addition, for 19,551 firms, power is an obstacle, representing 62.3% of firms. Of these firms, 17.6% faced minor obstacles in the power sector, 15.1% faced moderate obstacles, 16.2% faced major obstacles, 13.2% faced severe obstacles, and 11.7% considered power to be the major challenge in their operations. Finally, while outages are one of the main manifestations of constraints in the power sector in these countries, there are a number of other constraints (high cost of power, voltage fluctuations, connection problems, etc.) that are not readily observable through the survey data. Indeed, we can see here that 32.7% of the firms that faced obstacles did not experience any outages. Similarly, 39.1% of firms that experienced minor obstacles, 28.3% of firms that experienced moderate obstacles, 28.9% of firms that experienced major obstacles, 33.8% of firms that experienced severe obstacles, and 27.2% of firms that reported power as their greatest challenge.

Table 2: Summary statistics on the treatment variables

	No Outages	Outages	Total	No Outages	Outages	Total	No Outages	Outages	Total
	Count			Row percentages			Column percentages		
Power is an obstacle									
No	8,198	3,654	11,852	69.2%	30.8%	100.0%	56.2%	21.7%	37.7%
Yes	6,388	13,163	19,551	32.7%	67.3%	100.0%	43.8%	78.3%	62.3%
Total	14,587	16,816	31,403	46.4%	53.6%	100.0%	100.0%	100.0%	100.0%
Power as minor obstacle									
No	12,420	13,446	25,865	48.0%	52.0%	100.0%	85.1%	80.0%	82.4%
Yes	2,167	3,371	5,538	39.1%	60.9%	100.0%	14.9%	20.0%	17.6%
Total	14,587	16,816	31,403	46.4%	53.6%	100.0%	100.0%	100.0%	100.0%
Power as moderate obstacle									
No	13,242	13,406	26,648	49.7%	50.3%	100.0%	90.8%	79.7%	84.9%
Yes	1,345	3,410	4,755	28.3%	71.7%	100.0%	9.2%	20.3%	15.1%
Total	14,587	16,816	31,403	46.4%	53.6%	100.0%	100.0%	100.0%	100.0%
Power as major obstacle									
No	13,114	13,191	26,305	49.9%	50.1%	100.0%	89.9%	78.4%	83.8%
Yes	1,472	3,625	5,098	28.9%	71.1%	100.0%	10.1%	21.6%	16.2%
Total	14,587	16,816	31,403	46.4%	53.6%	100.0%	100.0%	100.0%	100.0%
Power as severe obstacle									
No	13,182	14,060	27,242	48.4%	51.6%	100.0%	90.4%	83.6%	86.8%
Yes	1,404	2,756	4,161	33.8%	66.2%	100.0%	9.6%	16.4%	13.2%
Total	14,587	16,816	31,403	46.4%	53.6%	100.0%	100.0%	100.0%	100.0%
Power as biggest obstacle									
No	13,097	13,835	26,932	48.6%	51.4%	100.0%	93.1%	84.2%	88.3%
Yes	968	2,588	3,556	27.2%	72.8%	100.0%	6.9%	15.8%	11.7%
Total	14,065	16,423	30,488	46.1%	53.9%	100.0%	100.0%	100.0%	100.0%
N	11,808	18,680	30,488						

Table (3) shows that 52.9% of our firms are small firms employing fewer than 20 people, and 35.3% are intermediate firms employing between 20 and 99 people. Finally, large firms (more than 100 employees) represent 11.8% of firms. For each category of these firms, the frequency of experiencing outages exceeds 50 percent. On the other hand, only 19.1% of firms invest in R&D, and of these, a significant 62.3% are roughly firms that suffer from power constraints. Similarly, of the 21.5% of firms that own back-up generators, 77.2% are actually firms that face power constraints.

The next figures present some stylized facts. In Figure (1), the white lines in the middle of the boxes

Table 3: Summary statistics on our main categorical variables

	No Outages	Outages	Total	No Outages	Outages	Total	No Outages	Outages	Total
	Count			Row percentages			Column percentages		
Firm size									
Small(<20)	7,974	8,639	16,613	48.0%	52.0%	100.0%	54.7%	51.4%	52.9%
Medium(20-99)	4,984	6,087	11,071	45.0%	55.0%	100.0%	34.2%	36.2%	35.3%
Large(100 And Over)	1,629	2,091	3,719	43.8%	56.2%	100.0%	11.2%	12.4%	11.8%
Total	14,587	16,816	31,403	46.4%	53.6%	100.0%	100.0%	100.0%	100.0%
R&D									
No	8,726	9,492	18,219	47.9%	52.1%	100.0%	84.4%	78.0%	80.9%
Yes	1,617	2,672	4,289	37.7%	62.3%	100.0%	15.6%	22.0%	19.1%
Total	10,344	12,164	22,508	46.0%	54.0%	100.0%	100.0%	100.0%	100.0%
Generator									
No	13,016	11,596	24,612	52.9%	47.1%	100.0%	89.5%	69.0%	78.5%
Yes	1,533	5,202	6,735	22.8%	77.2%	100.0%	10.5%	31.0%	21.5%
Total	14,549	16,798	31,347	46.4%	53.6%	100.0%	100.0%	100.0%	100.0%
Own website									
No	9,327	10,983	20,309	45.9%	54.1%	100.0%	63.9%	65.3%	64.7%
Yes	5,260	5,834	11,094	47.4%	52.6%	100.0%	36.1%	34.7%	35.3%
Total	14,587	16,816	31,403	46.4%	53.6%	100.0%	100.0%	100.0%	100.0%
WB income group									
Low Income	281	1,386	1,666	16.8%	83.2%	100.0%	1.9%	8.2%	5.3%
Lower Middle Income	7,634	10,411	18,045	42.3%	57.7%	100.0%	52.3%	61.9%	57.5%
Upper Middle Income	6,672	5,020	11,692	57.1%	42.9%	100.0%	45.7%	29.9%	37.2%
Total	14,587	16,816	31,403	46.4%	53.6%	100.0%	100.0%	100.0%	100.0%
Region									
AFR	2,542	3,075	5,616	45.3%	54.7%	100.0%	17.4%	18.3%	17.9%
EAP	3,790	4,315	8,105	46.8%	53.2%	100.0%	26.0%	25.7%	25.8%
ECA	1,605	967	2,573	62.4%	37.6%	100.0%	11.0%	5.8%	8.2%
LAC	2,993	2,747	5,740	52.1%	47.9%	100.0%	20.5%	16.3%	18.3%
MNA	2,076	2,487	4,563	45.5%	54.5%	100.0%	14.2%	14.8%	14.5%
SAR	1,581	3,225	4,806	32.9%	67.1%	100.0%	10.8%	19.2%	15.3%
Total	14,587	16,816	31,403	46.4%	53.6%	100.0%	100.0%	100.0%	100.0%
N	12,317	19,086	31,403						

indicate the respective medians. After a quasi-constant evolution within minor and moderate obstacles, we observe a drop in median total factor productivity as soon as the constraints become major for the firms (box plots 1). It can be seen that this deterioration in the power sector lowers the median total factor productivity of firms. Similarly, the box plots 2 shows a decrease in median firms' capacity utilization with the level of power constraints. We can see that this deterioration in the power sector reduces the median capacity utilization. The box plots 3 shows that the median losses incurred by firms increases with the level of constraints encountered in the power sector. The deterioration in the power sector increases median losses.

Figure (2) shows the effects of constraints on losses with a breakdown by geographical region. We can see that the negative effects of power constraints on losses by region are reinforced when the constraints become major or severe, especially for the Sub-Saharan Africa, MENA and South Asia regions.

Figure (3) highlights the combined effect of outages and other constraints. When the outages are not associated with the highest level of constraints, we can see the decrease in productivity only for two regions (EAP and LAC). However, when the outages are associated with the highest level of constraints, then we find the decrease in productivity in four regions (AFR, EAP, ECA, SAR). Moreover, intra-regional volatility in total factor productivity becomes more important between firms within the same region.

Table (4) shows the sample means of all matching covariates, divided into two groups: observations of firms facing power constraints (outages) or the treatment group (column 1) and observations of firms not facing power constraints or the potential control group (column 2).[13] The last column shows the standard-

[13] As Asiedu et al. (2021), we log some of our macroeconomic variables to mitigate the effect of outliers.

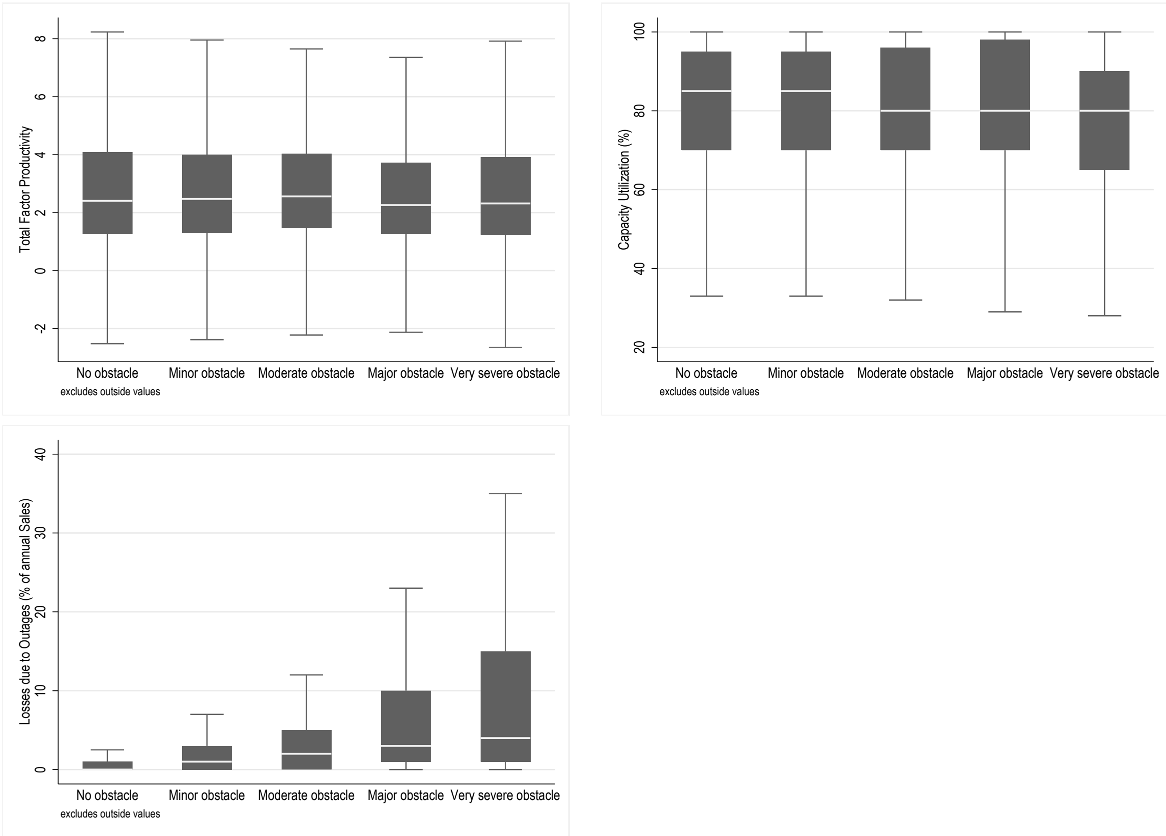

Figure 1: Degree of power constraints, declining total factor productivity and capacity utilization in %, and increasing losses in % of total sales

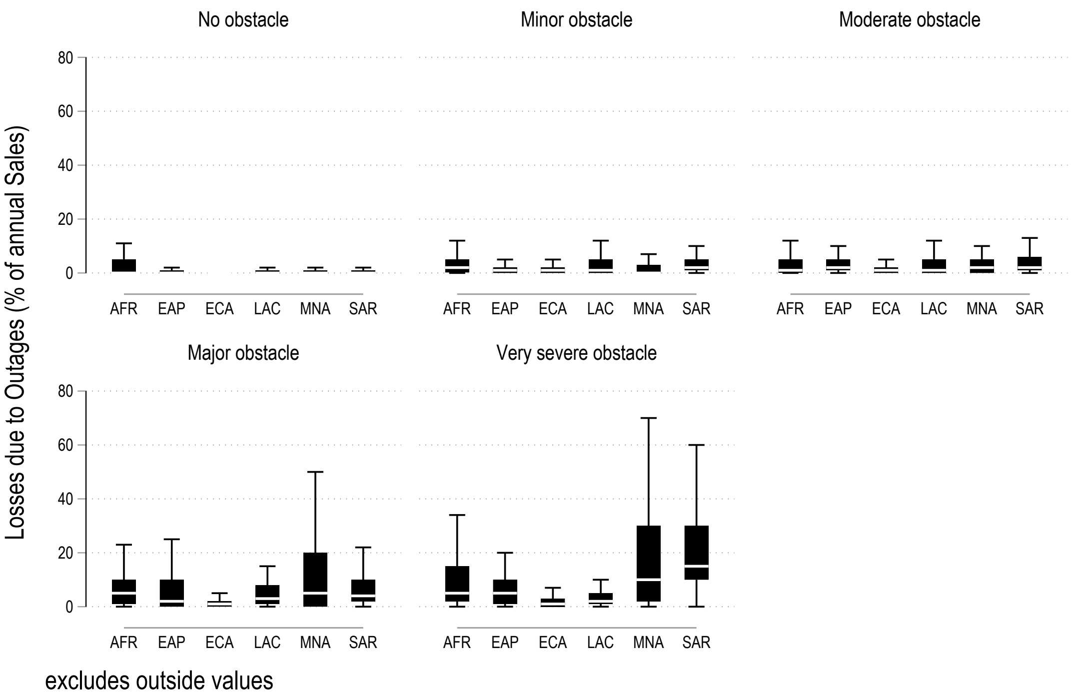

Figure 2: Breakdown losses by degree of power constraints and by region

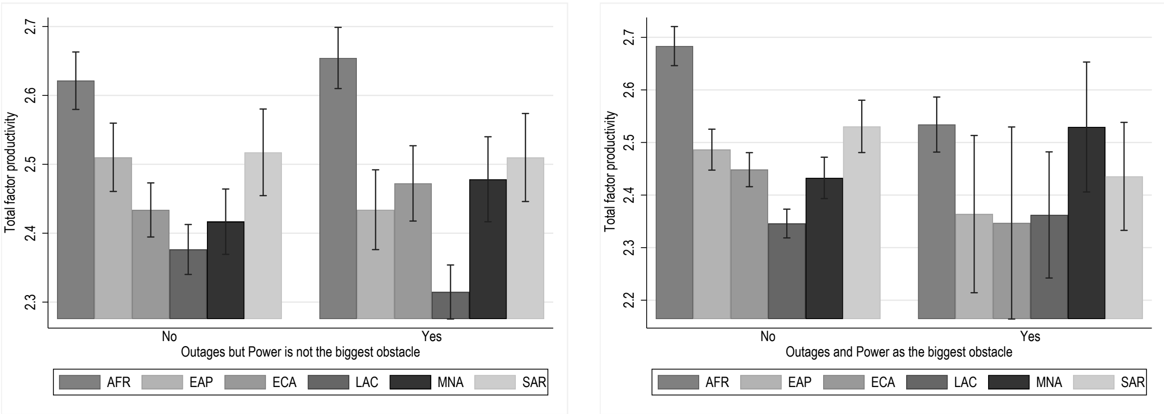

Figure 3: The combined effects of outages and other power constraints

ized differences in means between these two groups with the corresponding level of significance in each case.

Table 4: Descriptive Statistics (T=Power Outages)

	[1]	[2]	[1] − [2]
	Outages	No Outages	Diff.
Firm size	1.802	1.831	-0.038***
Firm's longevity	29.690	29.737	-0.003**
Own website	0.386	0.471	-0.173***
Foreign private participation	8.082	7.222	0.034**
GDP growth (annual %)	3.321	4.995	-0.511***
Inflation (annual %)	7.726	7.480	0.043***
log(Bank concentration in %)	4.047	4.084	-0.108***
log(FD index)	-1.496	-1.243	-0.436***
log(GDP per capita)	7.771	8.231	-0.542***
log(Net ODA in % of GNI)	-0.185	-0.883	0.392***
log(Regulatory Quality)	3.601	3.784	-0.370***
Observations	19086	12317	

Notes: This Table shows the sample means of all matching covariates, divided into two groups: observations of firms facing outages or the treatment group (column 1) and observations of firms not facing outages or the potential control group (column 2). The last column shows the standardized differences in means between these two groups with the corresponding level of significance in each case. The analysis of the results for all the relevant observable characteristics reveals that firms facing outages differ drastically compared to firms not facing outages.

The analysis of the results for all relevant observable characteristics reveals that firms facing power constraints differ drastically and operate in very different environments compared to firms not facing power constraints. Indeed, we find that firms facing power constraints are on average smaller than those not facing power constraints. In the same vein, these firms facing the constraints are on average younger than those not facing the constraints. We also note that firms not facing constraints have on average a better marketing management (approximated by the possession of a website). Finally, we also notice that the firms that face constraints more often in terms of power services are the firms that are mostly owned by foreign private actors.

Furthermore, the economic and policy environment in which these power-constrained firms operate is generally worse. Economic growth is lower, inflationary pressures are higher, financial development and banks concentration are lower, and the quality of regulation is weaker. These firms are also found to be located in poorer and less resilient countries and therefore receive more international development assistance and aid. These descriptive results illustrate the importance of selecting an appropriate control group using a matching-based approach before calculating treatment effects, as otherwise the effect of power constraints on firms' total factor productivity could be miss-estimated.

Table (5) compares the sample means of all matching covariates in the treatment group (column 1) and the synthetic control group obtained via Entropy Balancing (column 2). The last column shows the standardized differences in means with the corresponding significance level in each case. The comparison of the average realizations of the observable characteristics of the treatment group with those of the synthetic control group reveals the effectiveness of Entropy Balancing. All covariates are perfectly balanced and no statistically significant differences remain. Furthermore, Figures (4 and 5) display the kernel densities of our covariates for the treatment and control group and show how balancing constraints have affected the reweighted covariate distributions. Therefore, we can say that the control groups in the subsequent empirical analysis are composed of relevant counterfactuals for the sample of firms facing power constraints.

Table 5: Covariate balancing (T=Power Outages)

	[1]	[2]	[1] − [2]
	Outages	Control	Diff.
Firm size	1.802	1.802	0.000
Firm's longevity	29.737	29.736	0.000
Own website	0.386	0.386	-0.000
Foreign private participation	8.082	8.082	0.000
GDP growth (annual %)	4.995	4.994	0.000
Inflation (annual %)	7.480	7.482	-0.000
log(Bank concentration in %)	4.047	4.047	-0.000
log(FD index)	-1.496	-1.496	-0.000
log(GDP per capita)	7.771	7.771	-0.000
log(Net ODA in % of GNI)	-0.185	-0.185	-0.000
log(Regulatory Quality)	3.601	3.601	-0.000
Weighted observations	19086	19086	

Notes: This Table compares the sample means of all matching covariates in the treatment group (column 1) and the synthetic control group obtained via Entropy Balancing (column 2). The last column shows the standardized differences in means with the corresponding significance level in each case. The comparison of the average realizations of the observable characteristics of the treatment group with those of the synthetic control group reveals the effectiveness of Entropy Balancing. All covariates are perfectly balanced and no statistically significant differences remain.

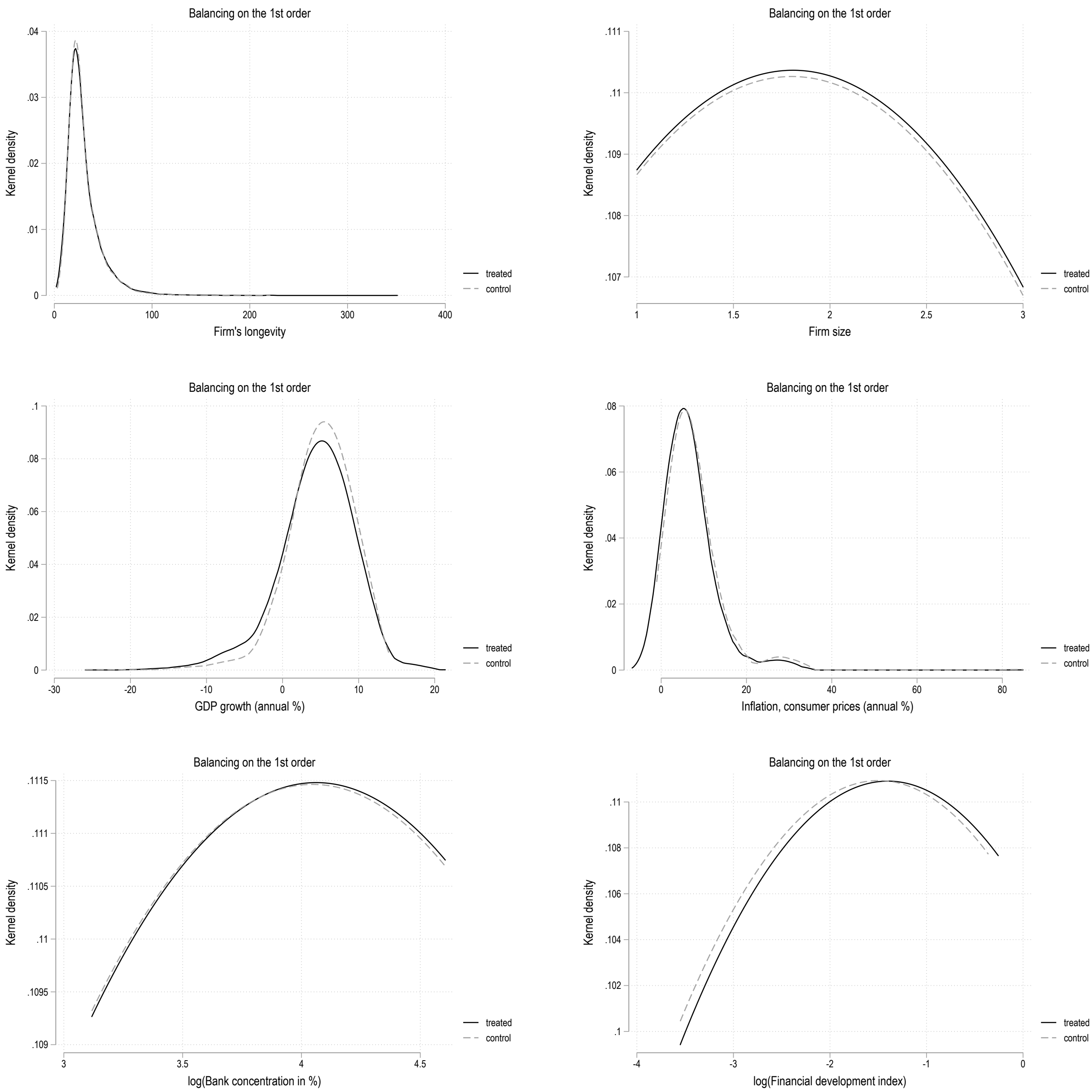

Figure 4: Kernel densities of the covariates for the treatment and control group (Set 1)

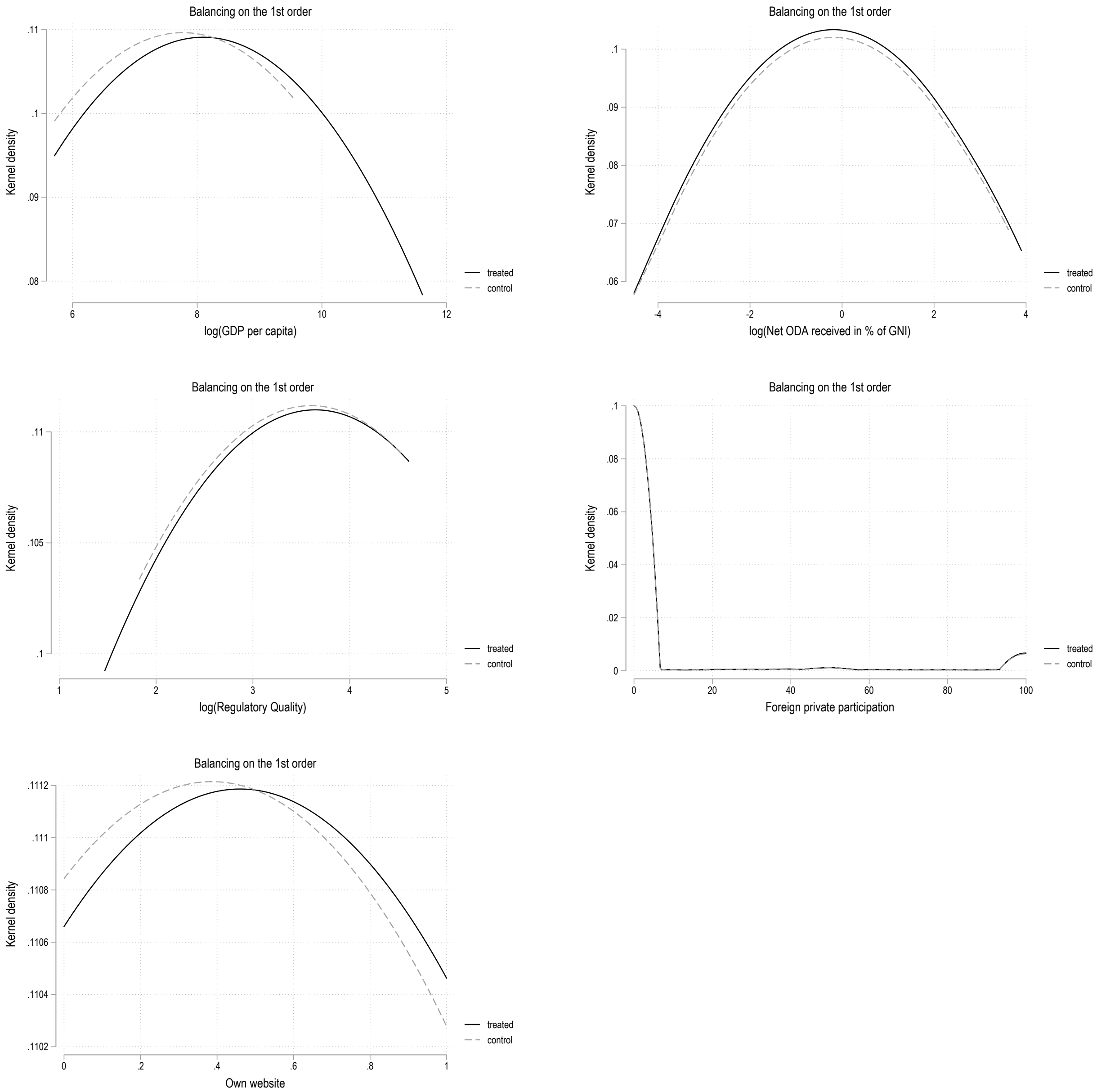

Figure 5: Kernel densities of the covariates for the treatment and control group (Set 2)

5.2 Treatment effects

Based on the treatment effects for endogenous treatments described in Wooldridge (2010), we performed an endogeneity test to ensure that the conditional independence assumption (CIA) is respected before running the regressions based on entropy balancing. The results shows that conditional on our covariates, the treatment and outcome unobservables are uncorrelated (H0).[14] We can be sure that our estimates below from entropy balancing represent the consistent treatment effects on the treated (ATT).

The results of the Table (6) indicate that power constraints characterized by outages negatively affect exposed firms, since we observe a negative and significant coefficient associated with power outages dummy variable of 0.102, i.e., 1.1 percentage points or 9% of the unconditional average productivity (column 1). This first result supports those found by a large part of this literature (Cole et al., 2018; Abdisa, 2018; Elliott et al., 2021; Xiao et al., 2022). However, we note that the effects of the constraints are not statistically significant when the levels of constraints are not severe (columns 2 to 5), even if they are gradually increasing. As soon as the constraints become very important (severe), the effect becomes negative and statistically significant (column 6). In column (7), the adverse effect is greatest when power proves to be the firm's biggest obstacle (ahead of factors such as access to finance, problems with the tax administration, transport problems or problems related to corruption). The visualization of these coefficients are shown in Figure (6).

Table 6: The effect of power outages and constraints on the firm's revenue-based TFP

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Power Outages	-0.102***						
	(0.032)						
Power is not an obstacle		0.041					
		(0.027)					
Power as minor obstacle			0.040				
			(0.026)				
Power as moderate obstacle				0.004			
				(0.031)			
Power as major obstacle					-0.032		
					(0.028)		
Power as severe obstacle						-0.044*	
						(0.025)	
Power as biggest obstacle							-0.148***
							(0.025)
Observations	31403	31406	31406	31406	31406	31406	30491

Notes: Table shows the average treatment effects on the treated obtained by weighted least squares regressions (Entropy Balancing). The dependent variable is the logarithm of the firm-level revenue-based total factor productivity for all regressions (1-7). In each regression, the treatment variable represents a specific degree of power constraints for firms. Firm-level controls variables are: Firm size, Firm's longevity, Own website, Foreign private participation. Country-level controls variables are: GDP growth (annual %), Inflation (annual %), log(Bank concentration in %), log(FD index), log(GDP per capita), log(Net ODA in % of GNI), log(Regulatory Quality). Each estimate includes Year FE, Country FE, Region FE, Income group FE and a Constant. The variation in the number of observations is related to the fact that the treatment variables are derived from three separate survey questions. Standard errors in parentheses are clustered at country level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

In Table (7), we consider the interaction of the outages treatment variable with each specific level of obstacles encountered by firms in the power sector (the other treatment variables in our analysis). In column (1), when we consider the outages treatment variable and no constraints or obstacles, we have no effect of

[14] Test of endogeneity. H0: Treatment and outcome unobservables are uncorrelated. chi2(2) = 0.40 ; Prob > chi2 = 0.8191). We cannot reject H0.

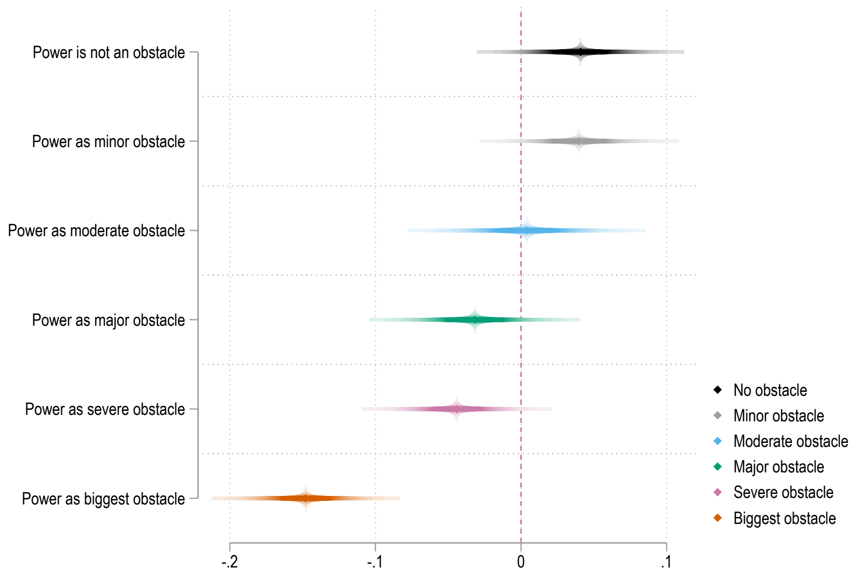

Figure 6: The effect of power constraints on the firm's revenue-based TFP

Notes: Figure shows the coefplots with the smoothed confidence intervals (1, 3, 5, ..., 99) of the average treatment effects on the treated obtained by weighted least squares regressions (Entropy Balancing) from the Table (6). The dependent variable is the logarithm of the firm-level revenue-based total factor productivity for all regressions. In each regression, the treatment variable represents a specific degree of power constraints for firms. Firm-level controls variables are: Firm size, Firm's longevity, Own website, Foreign private participation. Country-level controls variables are: GDP growth (annual %), Inflation (annual %), log(Bank concentration in %), log(FD index), log(GDP per capita), log(Net ODA in % of GNI), log(Regulatory Quality). Each estimate includes Year FE, Country FE, Region FE, Income group FE and a Constant. Standard errors are clustered at country level.

outages on firms' productivity. This implies that most firms manage to deal with outages when other sources of constraints in the power sector are absent (voltage problems, high cost of service, connection difficulties, etc.). In column (2), the effect becomes negative when we consider the presence of minor constraints. The negative effect becomes progressively stronger when we consider the presence of moderate and major obstacles, until it becomes significant when we consider the presence of severe obstacles for firms. This negative effect is reinforced and becomes very significant when power becomes the greatest obstacle for firms.

5.3 Robustness tests

The World Bank study suggests clustering by industry when each industry has at least 500 observations.[15] Otherwise, the appropriate clustering is by economies or countries as we have done so far. However, in order to test the sensitivity of our results to this, we have repeated our regressions by clustering by industry (see Table 8) even though we have fewer than 500 observations for some industries in our sample. Although we have some small variations in our standard errors, the results remain almost the same (in quality and magnitude) as our initial results with the clustering by country.

We also wanted to test the robustness of our results using the ordinary least squares (OLS) estimator in Table (9) to reassure that our results are not highly influenced or biased by our choice of Entropy Balancing estimator. Obviously, we have some small differences in magnitudes for some of the coefficients due to the downward bias of the OLS estimates in presence of endogeneity (Neuenkirch and Neumeier, 2016), but

[15] World Bank Group, Enterprise Analysis Unit. 2017. "firm-level Productivity Estimates".

Table 7: The combined effect of power outages with each level of power constraints on the firm's revenue-based TFP

	(1)	(2)	(3)	(4)	(5)	(6)
Outages × No obstacle	0.016					
	(0.027)					
Outages × Minor obstacle		-0.014				
		(0.037)				
Outages × Moderate obstacle			-0.035			
			(0.040)			
Outages × Major obstacle				-0.044		
				(0.028)		
Outages × Severe obstacle					-0.079**	
					(0.031)	
Outages × Biggest obstacle						-0.173***
						(0.026)
Observations	31406	31406	31406	31406	31406	31406

Notes: Table shows the average treatment effects on the treated obtained by weighted least squares regressions (Entropy Balancing). The dependent variable is the logarithm of the firm-level revenue-based total factor productivity for all regressions (1-6). In each regression, the treatment variable represents a specific degree of power constraints for firms and outages dummy variable. Firm-level controls variables are: Firm size, Firm's longevity, Own website, Foreign private participation. Country-level controls variables are: GDP growth (annual %), Inflation (annual %), log(Bank concentration in %), log(FD index), log(GDP per capita), log(Net ODA in % of GNI), log(Regulatory Quality). Each estimate includes Year FE, Country FE, Region FE, Income group FE and a Constant. Standard errors in parentheses are clustered at country level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 8: Robustness tests – The effect of power outages and constraints on the firm's revenue-based TFP by clustering standards errors at industry level

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Power Outages	-0.102***						
	(0.018)						
Power is not an obstacle		0.041					
		(0.025)					
Power as minor obstacle			0.040				
			(0.029)				
Power as moderate obstacle				0.004			
				(0.025)			
Power as major obstacle					-0.032		
					(0.022)		
Power as severe obstacle						-0.044*	
						(0.022)	
Power as biggest obstacle							-0.148***
							(0.042)
Observations	31403	31406	31406	31406	31406	31406	30491

Notes: Table shows the average treatment effects on the treated obtained by weighted least squares regressions (Entropy Balancing). The dependent variable is the logarithm of the firm-level revenue-based total factor productivity for all regressions (1-7). In each regression, the treatment variable represents a specific degree of power constraints for firms. Firm-level controls variables are: Firm size, Firm's longevity, Own website, Foreign private participation. Country-level controls variables are: GDP growth (annual %), Inflation (annual %), log(Bank concentration in %), log(FD index), log(GDP per capita), log(Net ODA in % of GNI), log(Regulatory Quality). Each estimate includes Year FE, Country FE, Region FE, Income group FE and a Constant. Standard errors in parentheses are clustered at industry level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

they remain qualitatively unchanged. As Entropy Balancing, the OLS estimator also allows us to see the adverse and progressive effect of power sector constraints on firm productivity in developing countries.

Table 9: Robustness tests – The effect of power outages and constraints on the firm's revenue-based TFP by using least squares regressions (without entropy balancing re-weighting scheme)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Power Outages	-0.083***						
	(0.028)						
Power is not an obstacle		0.041					
		(0.026)					
Power as minor obstacle			0.031				
			(0.022)				
Power as moderate obstacle				-0.000			
				(0.029)			
Power as major obstacle					-0.028		
					(0.028)		
Power as severe obstacle						-0.047**	
						(0.024)	
Power as biggest obstacle							-0.131***
							(0.027)
Observations	31403	31406	31406	31406	31406	31406	30491

Notes: Table shows the coefficients obtained by least squares regressions. The dependent variable is the logarithm of the firm-level revenue-based total factor productivity for all regressions (1-7). In each regression, the treatment variable represents a specific degree of power constraints for firms. Firm-level controls variables are: Firm size, Firm's longevity, Own website, Foreign private participation. Country-level controls variables are: GDP growth (annual %), Inflation (annual %), log(Bank concentration in %), log(FD index), log(GDP per capita), log(Net ODA in % of GNI), log(Regulatory Quality). Each estimate includes Year FE, Country FE, Region FE, Income group FE and a Constant. Standard errors in parentheses are clustered at country level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

In table (10), we opt for alternative measures of firm productivity. Although our main variable (TFPR) is suitable to approximate the level of performance of manufacturing firms in developing countries, it also faces some criticism in the literature. Indeed, the estimation of the TFPR can potentially be problematic for certain reasons such as selection, simultaneity or problems related to the use of monetary measures (as opposed to physical measures) of production and inputs (Levinsohn and Petrin, 2003, Foster et al., 2008, Hsieh and Klenow, 2009). To ensure that our results are not biased or influenced by the choice of this measure, we also test the robustness of our results using alternative measures to approximate the productivity of firms (in the form of factor ratios). These are simple ratios of the corresponding variables. These measures of firm performance based on factor shares also have the advantage of being simple and very informative. In column (1), we repeat the estimation with our main variable (TFPR). In column (2), we estimate the effect of the power constraints on labor costs per USD of sales. The result suggests that the constraints induces an increase in production costs for the treated firms. Finally, in column (3), the constraints lead to a decrease in the amount of total sales per worker (in 2009 USD).

In Table (17) in Appendix, we added additional potentially relevant control variables to minimize potential bias due to unobserved confounding factors. These variables are exports, size of the locality of firms, public ownership versus other actors' ownership, gender of the top manager, quality certification, informal payment, investment in fixed assets, bank account and access to credit. These variables are potentially relevant variables in our model according to this literature. For each case, our results remain statistically significant. This further demonstrates the stability of our main results.

Table 10: Robustness tests – The effect of power outages on the firm's revenue-based TFP and factor share based estimates of productivity

	(1) revenue-based TFP	(2) Cost of inputs per unit of sales	(3) Sales per labor cost
Power Outages	-0.102***	0.010**	-1.193***
	(0.032)	(0.005)	(0.439)
Observations	31403	31403	31403

Notes: Table shows the average treatment effects on the treated obtained by weighted least squares regressions (Entropy Balancing). The dependent variable is the logarithm of the firm-level revenue-based total factor productivity in regression (1), Cost of inputs per unit of sales in regression (2) and Sales per labor cost in regression (3). In each regression, the treatment variable represents power outages dummy variable. Firm-level controls variables are: Firm size, Firm's longevity, Own website, Foreign private participation. Country-level controls variables are: GDP growth (annual %), Inflation (annual %), log(Bank concentration in %), log(FD index), log(GDP per capita), log(Net ODA in % of GNI), log(Regulatory Quality). Each estimate includes Year FE, Country FE, Region FE, Income group FE and a Constant. Standard errors in parentheses are clustered at country level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

5.4 Heterogeneity check

We also tested the evolution of our results following the income group of the countries in which the firms operate and following the geographical regions. In Table (11), we have the effect of power constraints on TFPR following the income level of countries. We see that the negative effect found in Lower Income countries far exceeds those found in Middle Income countries. Indeed, the magnitude found in these Lower Income countries is 2.5 times that found in Upper Middle Income countries and 4.5 times that found in Lower Middle Income countries. For the Lower Income countries, this negative effect could be explained by the low level of resilience for firms in these fragile environments. For the Upper Middle Income countries, part of the explanation could lie in the fact that firms in these countries are relatively more energy-intensive, and therefore more exposed to energy constraints. The absence of a significant effect in the Middle Income countries would reflect the fact that firms in these countries are relatively more resilient than those in the Lower Income countries, and energy intensity is lower than in the Upper Middle Income countries.

Table 11: Heterogeneity check – The effect of power outages on the firm's revenue-based TFP by countries income group

	(1) Low Income	(2) Lower Middle Income	(3) Upper Middle Income
Power Outages	-0.214**	-0.047	-0.085*
	(0.082)	(0.031)	(0.044)
Observations	6848	14215	10340

Notes: Table shows the average treatment effects on the treated obtained by weighted least squares regressions (Entropy Balancing). The dependent variable is the logarithm of the firm-level revenue-based total factor productivity for all regressions (1-3). In each regression, the treatment variable represents power outages dummy variable. Firm-level controls variables are: Firm size, Firm's longevity, Own website, Foreign private participation. Country-level controls variables are: GDP growth (annual %), Inflation (annual %), log(Bank concentration in %), log(FD index), log(GDP per capita), log(Net ODA in % of GNI), log(Regulatory Quality). Each estimate includes Year FE, Country FE, Region FE and a Constant. Standard errors in parentheses are clustered at country level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

In the Table (12), we then provide further evidence that the overall negative effect is particularly driven by Sub-Saharan African (column 1) and MENA countries (column 5). This highlights to some extent the low resilience of firms in these regions (lack of alternative solutions such as back-up generators, low level of investment in R&D). Although the effect is negative in all regions, it remains statistically non-significant in the other regions. Firms in South Asia (SAR) remain the most resilient, followed by those in Europe and Central Asia (ECA).

Table 12: Heterogeneity check – The effect of power outages on the firm's revenue-based TFP by geographical regions

	(1) AFR	(2) EAP	(3) ECA	(4) LAC	(5) MNA	(6) SAR
Power Outages	-0.223***	-0.052	-0.028	-0.082	-0.115***	-0.026
	(0.052)	(0.092)	(0.059)	(0.050)	(0.026)	(0.066)
Observations	7714	3586	3132	9120	3168	4683

Notes: Table shows the average treatment effects on the treated obtained by weighted least squares regressions (Entropy Balancing). The dependent variable is the logarithm of the firm-level revenue-based total factor productivity for all regressions (1-6). In each regression, the treatment variable represents power outages dummy variable. Firm-level controls variables are: Firm size, Firm's longevity, Own website, Foreign private participation. Country-level controls variables are: GDP growth (annual %), Inflation (annual %), log(Bank concentration in %), log(FD index), log(GDP per capita), log(Net ODA in % of GNI), log(Regulatory Quality). Each estimate includes Year FE, Country FE, Income group FE and a Constant. Sub-Saharan Africa (AFR), East Asia and Pacific (EAP), Europe and Central Asia (ECA), Latin America and Caribbean (LAC), Middle East and North Africa (MNA), South Asia (SAR). Standard errors in parentheses are clustered at country level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

5.5 Transmission channels

Our intuition is that power constraints directly affect the operations of firms by influencing their operating regime (capacity utilization) and inducing losses related to power outages (losses in % of sales). Column (1) in Table (13) indicates that power constraints significantly reduce the capacity utilization of the firms affected. This is linked to the fact that, in the event of a outage or a rise in the cost of kwh, firms can no longer operate at full capacity, so they first seek to readjust and reorganize their operating regime. Indeed, one of the consequences of the increase in power costs is a decrease in the size of the firm and productivity (Allcott et al., 2016), and therefore a lower profitability for the affected firm. Similarly, power outages, for example, cause sizeable damage to firms. This leads to considerable losses (increased losses) especially for firms that are not very resilient and do not have alternative measures such as back-up generators (column 2).

5.6 Mitigating factors

Many developing countries are not able to provide their industrial sectors with reliable power, so many firms have to deal with an insufficient and unreliable power supply (Alby et al., 2013). The response of firms to unreliable power supply can vary. In its simplest form, it means additional costs if, for example, the firm has to buy and run a back-up generator, which also results in a higher unit cost of power (Elliott et al., 2021). It has to be said that affected firms often opt for self-generation of power, even though this is widely considered to be a second-best solution (Abdisa, 2018). Indeed, in Africa, for example, self-generated power is on average 313% more expensive than power from the grid (Alby et al., 2013). Are back-up

Table 13: Main channels – The effect of power outages on the firm's Capacity Utilization (%) and Losses due to Outages (% of annual Sales)

	(1) Capacity Utilization (%)	(2) Losses (% Sales)
Power Outages	-1.390**	6.680***
	(0.692)	(0.700)
Observations	30711	14397

Notes: Table shows the average treatment effects on the treated obtained by weighted least squares regressions (Entropy Balancing). The dependent variable is the logarithm of the firm-level revenue-based total factor productivity for all regressions (1-2). In each regression, the treatment variable represents power outages dummy variable. Firm-level controls variables are: Firm size, Firm's longevity, Own website, Foreign private participation. Country-level controls variables are: GDP growth (annual %), Inflation (annual %), log(Bank concentration in %), log(FD index), log(GDP per capita), log(Net ODA in % of GNI), log(Regulatory Quality). Each estimate includes Year FE, Country FE, Region FE, Income group FE and a Constant. Standard errors in parentheses are clustered at country level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

generators really a solution to the constraints in the power sector in developing countries? In column (3) and (4) of the Table (14), we can see that having a back-up generator reduces the negative effect of power constraints by half, even if it does not fully correct the shock (Abdisa, 2020).

Given the prominent role of research and development (R&D) in the operation of firms in general, we also tested a potential mitigating role for the R&D investments of the firms in our analysis. Through R&D, firms can mitigate the effect of unreliable energy supply by switching to less energy-intensive technologies (Alam, 2013), or can replace power with other types of fuels (Allcott et al., 2016) or materials (Fisher-Vanden et al., 2015). R&D can also instruct firms on the production of energy-intensive intermediates to be externalized instead of producing them internally. R&D also allows firms to effectively modify their production strategy. This ability to re-optimize decisions can therefore limit the negative effects of poor quality of power service for the affected firms (Alam, 2013). This is why we were also keen to test the mitigating role of R&D in column (1) and (2). The results suggest that investments in R&D allow firms to mitigate the negative effects of the constraints encountered in the power sector.

Table 14: Mitigating factors – The effect of power outages on the firm's revenue-based TFP

	(1) No R&D	(2) R&D	(3) No Generator	(4) Generator
Power Outages	-0.151***	-0.093	-0.179***	-0.098**
	(0.034)	(0.093)	(0.035)	(0.042)
Observations	16152	5683	20229	10210

Notes: Table shows the average treatment effects on the treated obtained by weighted least squares regressions (Entropy Balancing). The dependent variable is the logarithm of the firm-level revenue-based total factor productivity for all regressions (1-4). In each regression, the treatment variable represents power outages dummy variable. Firm-level controls variables are: Firm size, Firm's longevity, Own website, Foreign private participation. Country-level controls variables are: GDP growth (annual %), Inflation (annual %), log(Bank concentration in %), log(FD index), log(GDP per capita), log(Net ODA in % of GNI), log(Regulatory Quality). Each estimate includes Year FE, Country FE, Region FE, Income group FE and a Constant. Standard errors in parentheses are clustered at country level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

5.7 Placebo tests

Finally, we perform some placebo tests to ensure that the effect captured is essentially that of the constraints observed in the power sector. To do this, in Table (15), we have dummy variables (1/2 1/2), (1/3 2/3), (2/3 1/3), (1/4 3/4) and (3/4 1/4). When replacing each of these random dummies in our baseline model, we find no statistically significant effect on firm-level revenue-based total factor productivity.

Table 15: Placebo tests – The non-significant effects of random treatment variables on the firm's revenue-based TFP

	(1)	(2)	(3)	(4)	(5)
Random treatment (1/2 1/2)	0.012				
	(0.021)				
Random treatment (1/3 2/3)		-0.002			
		(0.021)			
Random treatment (2/3 1/3)			-0.025		
			(0.022)		
Random treatment (1/4 3/4)				-0.006	
				(0.017)	
Random treatment (3/4 1/4)					0.030
					(0.019)
Observations	31406	31404	31404	31405	31404

Notes: Table shows the average treatment effects on the treated obtained by weighted least squares regressions (Entropy Balancing). The dependent variables is the logarithm of the firm-level revenue-based total factor productivity for all regressions (1-5). In each regression, the treatment variable represents a random treatment variable. Firm-level controls variables are: Firm size, Firm's longevity, Own website, Foreign private participation. Country-level controls variables are: GDP growth (annual %), Inflation (annual %), log(Bank concentration in %), log(FD index), log(GDP per capita), log(Net ODA in % of GNI), log(Regulatory Quality). Each estimate includes Year FE, Country FE, Region FE, Income group FE and a Constant. Standard errors in parentheses are clustered at country level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

6 Conclusion

The objective of this paper was to analyze the role of power sector constraints on the performance level of firms in developing countries. Theoretically, we have shown that it is relatively complex to conclude the expected overall effect. Indeed, the constraints on the power sector lead to two types of effects in opposite directions on the productivity of firms, namely a direct negative effect and an indirect mitigating effect (output prices adjustment producers). Empirically, our approach based on Entropy Balancing to control endogeneity shows that the overall effect of power outages on revenue-based total factor productivity (TFPR) is negative and statistically significant. Indeed, we observed a 9% lower unconditional average productivity for exposed firms compared to non-exposed firms. Moreover, we establish a robust link between the severity of self-reported power constraints or obstacles by firms (minor, moderate, major, severe, and biggest) and the magnitude of productivity loss for firms. In other words, the greater the level of power constraints self-reported by a firm, the greater the effect of these constraints on its productivity, and vice versa. Our results are robust to changes in the level of clustering, the estimation model, and the measure of our productivity variable.

We also show that the most affected firms operate mainly in Sub-Saharan Africa and in the MENA region. Our results suggest that power constraints affect the TFPR by reducing firms' capacity utilization (they no longer operate at full capacity) and by increasing direct losses due to numerous power outages. Finally, we have identified the acquisition of back-up generators and R&D investments as important factors in mitigating power constraints for firms in developing countries.

In terms of recommendations, we would like first to recall that manufacturing firms are the main drivers of economic growth in developing countries. To fully play their part in the path to emergence, these firms need to benefit from a modern, reliable and affordable power service. However, this requires the establishment of a financially viable power sector. To achieve this, on the supply side, the authorities must set up independent regulatory agencies in order to put in place appropriate measures, notably tariff (automatic tariff adjustment mechanisms, cost reflectivity, etc.) and non-tariff measures (development of a master plan for instance) to reassure investors. Combined with the opening-up of the power generation to private actors (through IPPs, PPPs, etc.), this will make it possible to move capital into the sector and thus reduce the investment gap. In parallel with this effort to improve the power infrastructure, strengthen the quality of the country's institutions as a whole in order to attract foreign investors in various sectors and boost economic growth (Acemoglu et al., 2002; Rodrik, 2006) in order to drive the demand for power for the viability of the entire power sector. A viable power sector attracts more capital and provides quality power service to firms, which will in turn be more productive and competitive. This would create a virtuous circle for the whole economy.

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A Appendix

Table 16: Main variables description

Variables	Description	Source
TFPR	TFPR (VAKL model)	World Bank Group, Enterprise Analysis Unit. 2017. "firm-level Productivity Estimates".
Cost	Cost of inputs per unit of sales	–
Sales	Sales per labor cost	–
Capacity	Capacity Utilization (%)	The World Bank Enterprise Surveys (WBES)
R&D	Investmet in R&D	–
Generator	Generator acquisition by the firm	–
Losses	Losses due to Outages (% of annual Sales)	–
Outages	Firm facing Power Outages	–
Obstacles	How Much Of An Obstacle: Electricity To Operations Of This Establishment?	–
Biggest	Power as biggest obstacle	–
Size	Firm size	–
Age	Firm's longevity	–
Private	Foreign private participation	–
Website	Own website	–
Regulation	Regulatory Quality	Worldwide Governance Indicators - World Bank DataBank
Bank	Bank concentration in %: Assets of three largest commercial banks as a share of total commercial banking assets. Total assets include total earning assets, cash and due from banks, foreclosed real estate, fixed assets, goodwill, other intangibles, current tax assets, deferred tax assets, discontinued operations and other assets.	Bankscope and Orbis Bank Focus, Bureau van Dijk (BvD)
ODA	Net official development assistance (ODA) received in % of GNI:	World Development Indicators — DataBank
Inflation	Inflation, consumer prices (annual %)	–
Growth	GDP growth (annual %)	–
Capita	GDP per capita in USD	–
FINDEX	Financial development index	Global Financial Development Database - World Bank
Exports	Direct Exports (% of Sales)	The World Bank Enterprise Surveys (WBES)
Locality	Size Of Locality	–
Government	% Owned By Government/State	–
Other	% Owned By Other	–
Female	Is The Top Manager Female?	–
Certification	Does Establishment Have An Internationally-Recognized Quality Certification?	–
Informal	Percent Of Total Annual Sales Paid In Informal Payments	–
Investment	Did This Establishment Purchase Any Fixed Assets In Last Fiscal Yr?	–
Account	Does This Establishment Have A Checking AndSaving Account?	–
Credit	Establishment Has A Line Of Credit Or Loan From A Financial Institution?	–

Table 17: Robustness tests – The effect of power outages on the firm's revenue-based TFP by including additional control variables to the baseline specification

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Power Outages	-0.102***	-0.090***	-0.086**	-0.091***	-0.091***	-0.078**	-0.091***	-0.087***	-0.095***	-0.087***	-0.090***
	(0.032)	(0.029)	(0.035)	(0.029)	(0.029)	(0.035)	(0.029)	(0.031)	(0.029)	(0.028)	(0.029)
Direct Exports (% of Sales)		0.001*									
		(0.001)									
Size Of Locality			-0.068***								
			(0.023)								
% Owned By Government/State				-0.000							
				(0.003)							
% Owned By Other					0.002**						
					(0.001)						
Female Top Manager						-0.017					
						(0.024)					
Recognized Quality Certification							0.007				
							(0.008)				
Informal Payments (% Of Sales)								0.003			
								(0.002)			
Purchase of Fixed Assets									-0.048***		
									(0.012)		
Checking/Saving Account										-0.011	
										(0.013)	
Line Of Credit Or Loan											0.014
											(0.008)
Observations	31403	31402	25217	31403	31403	22999	31397	25342	31402	30448	31401

Notes: Table shows the average treatment effects on the treated obtained by weighted least squares regressions (Entropy Balancing). The dependent variable is the logarithm of the firm-level revenue-based total factor productivity for all regressions (1-11). In each regression, the treatment variable represents power outages dummy variable. Firm-level controls variables are: Firm size, Firm's longevity, Own website, Foreign private participation. Country-level controls variables are: GDP growth (annual %), Inflation (annual %), log(Bank concentration in %), log(FD index), log(GDP per capita), log(Net ODA in % of GNI), log(Regulatory Quality). Each row represents an additional control variable. Each estimate includes Year FE, Country FE, Region FE, Income group FE and a Constant. Standard errors in parentheses are clustered at country level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 18: Summary statistics on revenue-based TFP by outages and over regions

	Mean	Std. dev.	Min	Max	N
No Outages					
AFR	2.76	1.49	-1.47	8.58	1504.00
EAP	2.47	1.46	-1.89	8.11	1535.00
ECA	2.12	1.58	-2.13	8.51	2015.00
LAC	2.41	1.41	-2.44	7.41	4271.00
MNA	2.59	1.51	-2.13	8.45	1553.00
SAR	2.54	1.58	-1.79	7.53	1439.00
Outages					
AFR	2.63	1.44	-1.85	8.04	6210.00
EAP	2.32	1.46	-1.76	8.83	2051.00
ECA	2.22	1.64	-2.52	8.16	1117.00
LAC	2.34	1.46	-3.23	7.54	4849.00
MNA	2.53	1.53	-1.92	7.24	1615.00
SAR	2.50	1.56	-1.86	8.29	3244.00

Table 19: Summary statistics on capacity utilization by outages and over regions

	Mean	Std. dev.	Min	Max	Obs.
No outages					
AFR	73.74	22.80	0.00	100.00	1469.00
EAP	82.31	21.05	0.00	100.00	1498.00
ECA	71.57	24.31	0.00	100.00	1958.00
LAC	72.20	20.70	0.00	100.00	4192.00
MNA	67.99	23.11	1.00	100.00	1487.00
SAR	82.59	16.79	10.00	100.00	1435.00
Outages					
AFR	71.08	20.56	1.00	100.00	6075.00
EAP	79.34	21.17	1.00	100.00	2017.00
ECA	68.95	24.12	1.00	100.00	1088.00
LAC	71.39	20.47	0.00	100.00	4709.00
MNA	71.91	21.38	1.00	100.00	1556.00
SAR	76.79	16.21	2.00	100.00	3227.00

Table 20: Summary statistics on the number of observations by region and over years of survey

	Region						
	AFR	EAP	ECA	LAC	MNA	SAR	Total
Year of survey							
2006	1,416			3,254			4,670
2007	3,434		204				3,638
2008			303				303
2009	257	1,523	601	686		109	3,176
2010	117			3,945			4,062
2011	27					230	257
2012		28					28
2013	936	57	536		1,910	1,423	4,862
2014	364	179				2,863	3,406
2015	232	630				58	920
2016	227	999		282	761		2,269
2017	72			953			1,025
2018	519	66	237				822
2019	113	104	1,251		497		1,965
Total	7,714	3,586	3,132	9,120	3,168	4,683	31,403

Table 21: Summary statistics on the number of observations by region and by income group

	Region						
	AFR	EAP	ECA	LAC	MNA	SAR	Total
WB income group							
Low Income	5,381		111			1,356	6,848
Lower Middle Income	1,433	3,098	1,184	2,774	2,399	3,327	14,215
Upper Middle Income	900	488	1,837	6,346	769		10,340
Total	7,714	3,586	3,132	9,120	3,168	4,683	31,403

Table 22: Summary statistics on the number of observations by industry and by region

	Region						
	AFR	EAP	ECA	LAC	MNA	SAR	Total
Industry stratification							
Basic Metals & Metal Products					83	300	383
Basic Metals/Fabricated Metals/Machinery & Equip.	83			398			481
Chemicals & Chemical Products	8	132		588	184	326	1,238
Chemicals, Non-Metallic Mineral, Plastics & Rubber				38			38
Chemicals, Plastics & Rubber	97			367			464
Electronics		63		99			162
Electronics & Communications Equip.		62				209	271
Fabricated Metal Products	68	154	181	183	65	240	891
Food	1,768	413	442	1,726	662	515	5,526
Furniture	116			227	92	81	516
Garments	906	438	227	696	340	266	2,873
Leather Products				75	119	100	294
Machinery & Equipment			165	302		279	746
Machinery & Equipment, Electronics & Vehicles					49		49
Manufacturing	1,524	1,067	1,539	1,111	68	328	5,637
Manufacturing Panel	62						62
Metals, Machinery, Computer & Electronics	57						57
Minerals, Metals, Machinery & Equipment				55			55
Mining Related Manufacturing	15						15
Motor Vehicles				61		188	249
Motor Vehicles & Transport Equip.						29	29
Non-Metallic Mineral Products	68	302	163	229	260	220	1,242
Other Manufacturing	2,367	541	415	995	673	1,094	6,085
Petroleum products, Plastics & Rubber					89		89
Printing & Publishing	50				33		83
Rest of Universe	358			901			1,259
Rubber & Plastics Products		261		128	86	255	730
Textiles	24	153		222	152	253	804
Textiles & Garments	143			719	83		945
Wood Products					57		57
Wood products, Furniture, Paper & Publishing					73		73
Total	7,714	3,586	3,132	9,120	3,168	4,683	31,403

Table 23: Summary statistics on the number of observations by industry and over years of survey

	Year of survey														
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total
Industry stratification															
Basic Metals & Metal Products									300		83				383
Basic Metals/Fabricated Metals/Machinery & Equip.					398			83							481
Chemicals & Chemical Products	396	8		173	118			219	213	33	78				1,238
Chemicals, Non-Metallic Mineral, Plastics & Rubber	38														38
Chemicals, Plastics & Rubber					367			47					50		464
Electronics	99			36						27					162
Electronics & Communications Equip.									209		62				271
Fabricated Metal Products	42	103		65	141			65	264	89				122	891
Food	1,173	910	33	338	607	83		765	320	161	309	200	234	393	5,526
Furniture		70		84	110			194	25		33				516
Garments	656	724	39	322	106	72		474	17	120	120		52	171	2,873
Leather Products				75				162			57				294
Machinery & Equipment	131		47	83	88			22	279					96	746
Machinery & Equipment, Electronics & Vehicles											49				49
Manufacturing		690	163	914	886	27	28	838	241		810	342	119	579	5,637
Manufacturing Panel									62						62
Metals, Machinery, Computer & Electronics													57		57
Minerals, Metals, Machinery & Equipment					55										55
Mining Related Manufacturing								15							15
Motor Vehicles				61					188						249
Motor Vehicles & Transport Equip.								29							29
Non-Metallic Mineral Products	229			223				193	246	113	105			133	1,242
Other Manufacturing	856	736	21	464	615	75		1,309	546	309	138	273	272	471	6,085
Petroleum products, Plastics & Rubber											89				89
Printing & Publishing		39						33	11						83
Rest of Universe	901	358													1,259
Rubber & Plastics Products				112	128			86	255	35	114				730
Textiles	149			226				199	230						804
Textiles & Garments					443			72		33	149	210	38		945
Wood Products								57							57
Wood products, Furniture, Paper & Publishing											73				73
Total	4,670	3,638	303	3,176	4,062	257	28	4,862	3,406	920	2,269	1,025	822	1,965	31,403

Table 24: Sub-Saharan Africa (AFR)

	WB income group			
	Low Income	Lower Middle Income	Upper Middle Income	Total
Official Country Name				
Angola		206		206
Benin	53			53
Botswana			158	158
Burkina Faso	26			26
Burundi	134			134
Cameroon		120		120
Congo, Dem. Rep.	298			298
Eswatini		64		64
Ethiopia	259			259
Gambia, The	83			83
Ghana	278	186		464
Guinea	5			5
Kenya	600	261		861
Lesotho		39		39
Liberia	66			66
Madagascar	230			230
Mali	350			350
Mauritania	77	13		90
Mauritius			57	57
Mozambique	532			532
Namibia		94	13	107
Niger	6			6
Nigeria	930	216		1,146
Rwanda	171			171
Senegal	250	86		336
South Africa			672	672
Tanzania	362			362
Togo	19			19
Uganda	353			353
Zambia	299	148		447
Total	5,381	1,433	900	7,714

Table 25: Sub-Saharan Africa (AFR)

	Year of survey												
	2006	2007	2009	2010	2011	2013	2014	2015	2016	2017	2018	2019	Total
Official Country Name													
Angola	199			7									206
Benin									53				53
Botswana	110			48									158
Burkina Faso			26										26
Burundi	98						36						134
Cameroon			55						65				120
Congo, Dem. Rep.	143			49		106							298
Eswatini	64												64
Ethiopia					27			232					259
Gambia, The	30										53		83
Ghana		278				186							464
Guinea									5				5
Kenya		387				213					261		861
Lesotho									39				39
Liberia										66			66
Madagascar			119			111							230
Mali		291		13					46				350
Mauritania	77						13						90
Mauritius			57										57
Mozambique		327									205		532
Namibia	94						13						107
Niger										6			6
Nigeria		930					216						1,146
Rwanda	58											113	171
Senegal		250					86						336
South Africa		672											672
Tanzania	254					108							362
Togo									19				19
Uganda	289					64							353
Zambia		299				148							447
Total	1,416	3,434	257	117	27	936	364	232	227	72	519	113	7,714

Table 26: East Asia and Pacific (EAP)

	WB income group		
	Lower Middle Income	Upper Middle Income	Total
Official Country Name			
Cambodia	109		109
Indonesia	529		529
Lao PDR	198		198
Mongolia	283		283
Myanmar	477		477
Philippines	579		579
Thailand		488	488
Vietnam	923		923
Total	3,098	488	3,586

Table 27: East Asia and Pacific (EAP)

	Year of survey								
	2009	2012	2013	2014	2015	2016	2018	2019	Total
Official Country Name									
Cambodia						109			109
Indonesia	529								529
Lao PDR		28				104	66		198
Mongolia	122		57					104	283
Myanmar				179		298			477
Philippines	324				255				579
Thailand						488			488
Vietnam	548				375				923
Total	1,523	28	57	179	630	999	66	104	3,586

Table 28: Europe and Central Asia (ECA)

	WB income group			
	Low Income	Lower Middle Income	Upper Middle Income	Total
Official Country Name				
Albania		25	78	103
Armenia		81		81
Azerbaijan			92	92
Belarus			324	324
Bosnia and Herzegovina			168	168
Croatia			179	179
Georgia		101	94	195
Kazakhstan			555	555
Kyrgyz Republic	54	107		161
Moldova		159		159
North Macedonia			133	133
Serbia			214	214
Tajikistan	57			57
Ukraine		711		711
Total	111	1,184	1,837	3,132

Table 29: Europe and Central Asia (ECA)

	Year of survey						
	2007	2008	2009	2013	2018	2019	Total
Official Country Name							
Albania	25			14		64	103
Armenia			58	23			81
Azerbaijan			70	8		14	92
Belarus		40		47	237		324
Bosnia and Herzegovina			64	60		44	168
Croatia	179						179
Georgia		66		35		94	195
Kazakhstan			102	35		418	555
Kyrgyz Republic			54	25		82	161
Moldova			90	13		56	159
North Macedonia			60	73			133
Serbia			103	55		56	214
Tajikistan		57					57
Ukraine		140		148		423	711
Total	204	303	601	536	237	1,251	3,132

Table 30: Latin America and Caribbean (LAC)

	WB income group		
	Lower Middle Income	Upper Middle Income	Total
Official Country Name			
Bolivia	303		303
Brazil		686	686
Chile		1,024	1,024
Colombia		946	946
Costa Rica		195	195
Dominican Republic		96	96
Ecuador	250	187	437
El Salvador	597		597
Guatemala	484	79	563
Guyana	57		57
Honduras	321		321
Jamaica		80	80
Mexico		1,760	1,760
Nicaragua	321		321
Panama		21	21
Paraguay	201	39	240
Peru	240	792	1,032
St. Lucia		47	47
Suriname		73	73
Uruguay		321	321
Total	2,774	6,346	9,120

Table 31: Latin America and Caribbean (LAC)

	Year of survey					
	2006	2009	2010	2016	2017	Total
Official Country Name						
Bolivia	215		35		53	303
Brazil		686				686
Chile	435		589			1,024
Colombia			540		406	946
Costa Rica			195			195
Dominican Republic			76	20		96
Ecuador	250		88		99	437
El Salvador	310		77	210		597
Guatemala	273		211		79	563
Guyana			57			57
Honduras	196		73	52		321
Jamaica			80			80
Mexico	798		962			1,760
Nicaragua	249		72			321
Panama			21			21
Paraguay	131		70		39	240
Peru	240		515		277	1,032
St. Lucia			47			47
Suriname			73			73
Uruguay	157		164			321
Total	3,254	686	3,945	282	953	9,120

Table 32: Middle East and North Africa (MNA)

	WB income group		
	Lower Middle Income	Upper Middle Income	Total
Official Country Name			
Djibouti	2		2
Egypt, Arab Rep.	2,057		2,057
Jordan		210	210
Lebanon		330	330
Morocco	340		340
Tunisia		229	229
Total	2,399	769	3,168

Table 33: Middle East and North Africa (MNA)

	Year of survey			
	2013	2016	2019	Total
Official Country Name				
Djibouti	2			2
Egypt, Arab Rep.	1,296	761		2,057
Jordan	183		27	210
Lebanon	106		224	330
Morocco	94		246	340
Tunisia	229			229
Total	1,910	761	497	3,168

Table 34: South Asia (SAR)

	WB income group		
	Low Income	Lower Middle Income	Total
Official Country Name			
Bangladesh	1,028		1,028
Bhutan		58	58
India		2,863	2,863
Nepal	328		328
Pakistan		176	176
Sri Lanka		230	230
Total	1,356	3,327	4,683

Table 35: South Asia (SAR)

	Year of survey					
	2009	2011	2013	2014	2015	Total
Official Country Name						
Bangladesh			1,028			1,028
Bhutan					58	58
India				2,863		2,863
Nepal	109		219			328
Pakistan			176			176
Sri Lanka		230				230
Total	109	230	1,423	2,863	58	4,683