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Electricity Supply Reliability and Firm Growth in Liberia: Evidence from the 2025 World Bank Enterprise Survey

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Abstract

Reliable electricity is a productive input whose interruption can reduce operating hours, damage equipment, interrupt digital services and force firms to purchase costly backup power. This article examines the relationship between electricity supply reliability and firm growth in Liberia using firm-level data from the 2025 World Bank Enterprise Survey. The dataset contains 158 formal manufacturing and service establishments. Survey-weighted descriptive statistics show that 64.5% of firms experienced outages during the most recent fiscal year, while 90.5% owned or shared a generator. Among firms reporting outage frequency, the typical establishment experienced a median of 10 outages per month, and the median interruption lasted approximately four hours and thirty minutes. Annualised sales and employment growth are constructed from current and three-year retrospective values. Weighted least-squares models with heteroskedasticity-robust standard errors control for firm size, sector, location, age, managerial experience, access to loans and innovation. Outage exposure is negatively associated with sales growth, but the coefficient is not statistically significant at conventional levels. It is positively but insignificantly associated with employment growth. Large firms and firms outside Montserrado record significantly slower sales growth, while older firms record significantly slower employment growth. The results suggest that unreliable electricity remains a widespread operating constraint, but simple outage exposure alone does not fully explain heterogeneous firm growth. Policy should therefore combine improvements in grid reliability with affordable productive-use electricity, cleaner backup options and firm-level measures that reduce vulnerability to interruptions.

Keywords: *electricity outages; firm growth; enterprise performance; generators; Liberia; World Bank Enterprise Survey*
JEL classification: *D22, L25, L94, O12, O55*

1 Introduction

Electricity is a central input into modern production. It powers machinery, lighting, refrigeration, communications, payment systems and the digital infrastructure through which firms coordinate suppliers and customers. When electricity is unreliable, establishments may lose production time, incur restart costs, discard damaged inputs, miss delivery schedules and divert scarce capital towards generators and fuel. Evidence from India and China shows that shortages reduce output and productivity, alter input choices and weaken the effective return to capital, although firms partly adapt through self-generation and other production adjustments (Fisher-Vanden et al., 2015; Allcott et al., 2016; Abeberese, 2017). These burdens can be particularly severe in low-income economies, where grid redundancy is limited and smaller firms face financing constraints.

The economic importance of power reliability extends beyond whether a firm is formally connected to the grid. Connection without adequate duration, voltage quality and predictability may leave firms unable to use electricity productively. Studies of low- and middle-income countries therefore distinguish nominal access from quality and reliability, while firm-level research emphasises outage frequency, duration, losses and adaptation costs (Scott et al., 2014; Oseni & Pollitt, 2015; World Bank, 2025a). Enterprise analysis should also account for firms' ability to adapt through generators, solar systems,

storage or changes in production schedules. The World Bank Enterprise Surveys provide comparable measures of these dimensions and link them to sales, employment, investment and business constraints (World Bank, 2025a).

Liberia provides an important setting for this inquiry. The country continues to rebuild productive infrastructure while seeking private-sector-led growth, and reliable electricity is essential to expanding productive activity beyond basic household connections. For enterprises, unreliable supply may raise unit costs and reduce competitiveness even when formal access expands, a distinction also stressed in international electricity assessments (IEA, 2024; World Bank, 2025a). Evidence from the 2025 Liberia Enterprise Survey confirms the scale of the challenge: almost two-thirds of firms experienced outages, about nine in ten owned or shared a generator, and electricity ranked among the most severe obstacles reported by firms (World Bank, 2025b). These patterns make it necessary to assess whether exposure to unreliable power is systematically related to firm growth.

This study examines the relationship between electricity supply reliability and firm growth in Liberia. It contributes in three ways. First, it provides recent firm-level evidence from the 2025 survey, thereby extending a literature dominated by multi-country or earlier survey evidence (Cole et al., 2018; Apeti & Ly, 2023). Second, it measures performance with annualised sales and employment growth rather than relying exclusively on managers' subjective obstacle ratings. Third, it considers generator ownership as a coping mechanism while controlling for observable firm characteristics, consistent with research showing that self-generation can reduce outage losses but may also impose substantial private costs (Steinbuks & Foster, 2010; Oseni & Pollitt, 2015). The analysis is associational because the survey is cross-sectional and retrospective outcomes may be subject to recall error.

The remainder of the article reviews the relevant theory and evidence, presents the data and empirical strategy, reports the results, discusses their implications and concludes with policy recommendations.

2 Literature Review

2.1 Electricity reliability and firm performance

Production theory treats electricity as an intermediate input that complements labour and capital. An outage can reduce output directly by idling productive assets and indirectly by lowering the effective return to machinery, worker time and inventories. Where interruptions are frequent or unpredictable, firms may avoid electricity-intensive technologies, maintain excess inventories or operate below efficient scale. Fisher-Vanden et al. (2015) show that firms can respond to shortages by changing input use, while Allcott et al. (2016) demonstrate that shortages impose both direct output losses and broader adjustment costs. The burden of unreliable supply can therefore persist beyond the hours in which electricity is unavailable.

Empirical studies generally identify substantial performance costs from unreliable power, although estimates vary with data, identification strategy and firms' adaptive capacity. Cole et al. (2018), using firm-level evidence across Sub-Saharan Africa, find that outages reduce sales while addressing endogeneity arising because productive firms may simultaneously demand more electricity and report more interruptions. Mensah (2018) reports adverse effects on industrial performance in the region, and Cissokho (2020) finds productivity losses among manufacturing firms. At a broader developing-country level, Apeti and Ly (2023) report that power constraints reduce revenue-based total factor productivity. Related evidence from India and China similarly links electricity shortages or higher electricity costs to weaker firm outcomes and altered production decisions (Fisher-Vanden et al., 2015; Allcott et al., 2016; Abeberese, 2017).

The literature also warns against treating backup generation as a costless solution. A generator may protect output during an outage, but firms incur acquisition, maintenance and fuel costs. Steinbuks and

Foster (2010) show that generator adoption among African firms reflects both outage exposure and firm characteristics. Oseni and Pollitt (2015) find substantial differences in outage losses between self-generating and non-self-generating firms, confirming that adaptation changes, rather than eliminates, the economic burden. Smaller establishments may be unable to finance adequately sized equipment, while diesel generation exposes firms to fuel-price volatility and pollution. Ramachandran et al. (2018) likewise emphasise heterogeneous responses across African firms.

2.2 Firm heterogeneity and coping capacity

Firm size, age, sector and location influence both electricity exposure and the capacity to respond. Large firms may afford backup systems and energy-management practices, yet their complex production processes can make interruptions costly. Small firms may consume less electricity in absolute terms but face binding liquidity constraints and higher unit costs of self-generation. Manufacturing establishments are generally more electricity-intensive than many service firms, while digitally enabled services can be highly sensitive to short interruptions. Empirical work confirms that outage losses and generator adoption vary systematically with firm size, sector and operating characteristics (Steinbuks & Foster, 2010; Oseni & Pollitt, 2015; Ramachandran et al., 2018).

Finance and innovation may further shape resilience. Access to formal credit allows firms to purchase generators, efficient machinery or storage systems, whereas financial constraints may force them to absorb lost operating hours. Innovation can permit process redesign, alternative work schedules and digital monitoring. However, finance and innovation also correlate with unobserved managerial quality and market opportunities, which complicates causal interpretation. The empirical model therefore includes these characteristics as controls rather than treating their coefficients as causal effects, following the broader firm-performance literature's concern with observable and unobservable heterogeneity (Cole et al., 2018; Apeti & Ly, 2023).

2.3 Conceptual framework and hypotheses

The conceptual argument is that unreliable electricity affects growth through lost operating time, damaged inputs, higher energy costs and postponed investment. Firms can moderate these channels through backup generation, input substitution and organisational adaptation (Fisher-Vanden et al., 2015; Allcott et al., 2016). Let firm growth depend on outage exposure, coping mechanisms and observable firm characteristics. If interruptions constrain production, outage exposure should carry a negative coefficient in a sales-growth equation. The expected relationship with employment is less certain: outages may suppress hiring, but firms may substitute labour for electricity-intensive capital or retain additional workers to compensate for disrupted processes (Abeberese, 2017).

The study tests the following hypotheses:

1. **H1:** Firms exposed to electricity outages record lower sales growth than otherwise comparable firms.
2. **H2:** Firms exposed to electricity outages record lower employment growth than otherwise comparable firms.
3. **H3:** Generator ownership moderates the relationship between outage exposure and firm growth.
4. **H4:** The electricity–growth relationship varies with firm size, sector and location.

3 Methodology

3.1 Data and study population

The study uses the 2025 Liberia World Bank Enterprise Survey dataset. Enterprise Surveys collect information from business owners and senior managers through standardised instruments covering

infrastructure, finance, competition, regulation, innovation, labour and performance. Their stratified sampling framework is designed to produce comparable estimates for the formal private sector while preserving establishment confidentiality (World Bank, 2025a). The file contains 158 establishments, of which 80 operate in manufacturing and 78 in services. It includes 101 small, 41 medium and 16 large establishments; 82 firms are located in Montserrado and 76 elsewhere in Liberia (World Bank, 2025b).

The analysis applies the median-eligibility survey weight supplied in the dataset (wmedian). Negative survey codes such as “do not know”, “refusal” and “not applicable” are treated as missing rather than as numerical observations. Regression samples vary because current and retrospective outcome values must both be positive and because some control variables are incomplete.

3.2 Measurement of variables

Table 1. Operational definition of variables

Variable	Definition and construction	Expected sign
Sales growth	Annualised log difference between current annual sales (d2) and sales three years earlier (n3): $100[\ln(Sales_t) - \ln(Sales_{t-3})]/3$.	Dependent
Employment growth	Annualised log difference between current permanent employment (l1) and employment three years earlier (l2).	Dependent
Outage exposure	One if the firm experienced an electrical outage in the latest fiscal year (c6); zero otherwise.	Negative
Generator ownership	One if the establishment owned or shared a generator (c10); zero otherwise.	Ambiguous
Firm size	Medium and large-firm indicators from the survey size classification (a6a); small is the reference.	Ambiguous
Sector	One for services and zero for manufacturing (a4a).	Ambiguous
Location	One for establishments outside Montserrado and zero for Montserrado (a2).	Ambiguous
Firm age	2024 minus the year in which the establishment began operations (b5).	Ambiguous
Managerial experience	Top manager’s years of experience in the sector (b7).	Positive
Access to loan	One if the establishment had a loan from a financial institution (k82a).	Positive
Product innovation	One if a new or significantly improved product or service was introduced during the previous three years (h1).	Positive

Because sales are reported in nominal local currency, their growth measure combines real expansion and price changes. The dependent variables are winsorised at the first and ninety-ninth percentiles to limit the influence of extreme retrospective values, a precaution that is important in firm surveys with highly skewed sales distributions. Employment growth provides a non-monetary robustness outcome. A future revision may deflate sales using an appropriate sectoral or national price index if consistent annual deflators are available. This limitation is explicitly recognised because nominal growth can overstate real expansion during periods of inflation (World Bank, 2025b).

3.3 Model specification and estimation

The baseline model is specified as:

$$G_i = \beta_0 + \beta_1 Outage_i + \beta_2 Generator_i + \gamma X_i + \varepsilon_i$$

where G_i is annualised sales growth or employment growth, $Outage_i$ indicates outage exposure, $Generator_i$ identifies generator ownership, and X_i contains firm size, sector, location, age, managerial experience, access to a formal loan and product innovation. The models are estimated by weighted least squares using wmedian, with heteroskedasticity-robust standard errors. The sales-growth model uses 140 complete observations and the employment-growth model uses 141.

The outage coefficient measures a conditional association, not a definitive causal effect. Reverse causality and omitted variables remain possible: faster-growing firms may demand more electricity and report more interruptions, while infrastructure quality may correlate with local demand, transport or institutional conditions. This endogeneity problem is well established in the firm-level electricity literature, which has used instruments, panel methods and detailed shortage measures to strengthen identification (Fisher-Vanden et al., 2015; Allcott et al., 2016; Cole et al., 2018). A stronger causal design for Liberia would require panel data, plausibly exogenous outage measures or feeder-level operational records.

4 Results

4.1 Descriptive evidence

Table 2. Selected characteristics of firms and electricity reliability

Indicator	Observations	Unweighted value	Survey-weighted value
Firms experiencing outages	158	66.5%	64.5%
Firms owning or sharing a generator	158	86.7%	90.5%
Firms using on-site solar panels	158	3.8%	3.0%
Electricity rated major or very severe obstacle	158	70.3%	—
Median outages in a typical month	104	10.0	—
Mean outages in a typical month	104	9.3	—
Median duration per outage	104	4 hours 30 minutes	—
Median share of electricity from own/shared generator	137	55.0%	—

Source: Authors' calculations from the 2025 Liberia World Bank Enterprise Survey. "—" indicates that the corresponding weighted statistic was not used in this table.

Table 2 shows that electricity unreliability is widespread. Nearly two-thirds of firms experienced outages, and the typical affected firm reported about ten interruptions in a month. The median interruption lasted four and a half hours. Generator ownership is exceptionally common, with a survey-weighted prevalence of 90.5%, and the median generator-dependent firm obtained 55% of its electricity from that source. By contrast, on-site solar adoption was only 3.0% on a weighted basis. The pattern is consistent with evidence that African firms frequently use self-generation as a private response to unreliable public supply (Steinbuks & Foster, 2010; Oseni & Pollitt, 2015).

The obstacle ratings reinforce this conclusion. About 70.3% of establishments classified electricity as a major or very severe obstacle, placing it alongside access to finance and corruption among firms' most serious constraints. Such perception-based measures are useful indicators of the business environment, but they do not reveal the counterfactual growth that would have occurred without outages (World Bank, 2025a). The regression analysis therefore compares growth outcomes after accounting for observable differences among firms.

4.2 Regression results

Table 3. Electricity reliability and annualised firm growth

Explanatory variable	Sales coefficient	Robust SE	p-value	Employment coefficient	Robust SE	p-value
Outage exposure	−4.3574	3.2053	0.1764	2.9441	2.2307	0.1892
Generator ownership	2.1191	3.7255	0.5705	−3.3572*	1.9787	0.0921
Medium firm	−1.6267	2.6590	0.5418	−1.5248	1.4133	0.2826
Large firm	−9.0588**	4.4282	0.0428	−0.7582	2.1320	0.7227
Services sector	−0.7278	2.4409	0.7660	−0.2465	1.7110	0.8857
Outside Montserrado	−6.1772**	2.4137	0.0116	1.5481	1.2679	0.2243
Firm age	0.0470	0.0933	0.6154	−0.1454**	0.0625	0.0216
Managerial experience	−0.1646	0.2439	0.5009	0.1567	0.1668	0.3495
Access to loan	0.4739	2.2734	0.8352	1.9285	1.5312	0.2101
Product innovation	1.9454	3.3517	0.5626	−1.2295	1.8893	0.5163
Constant	16.8954***	5.6669	0.0034	4.8567*	2.9193	0.0986
Observations	140			141		
R-squared	0.1294			0.2052		

Notes: Weighted least-squares estimates using wmedian. Dependent variables are annualised log growth rates winsorised at the first and ninety-ninth percentiles. Robust standard errors are reported. Small firms, manufacturing establishments and Montserrado are the reference categories. ** p < 0.01, ** p < 0.05, * p < 0.10.*

Outage exposure is associated with a 4.36 percentage-point reduction in annualised sales growth after controlling for observed firm characteristics. The sign is consistent with the first hypothesis, but the estimate is not statistically significant (p = 0.1764). This means the sample does not provide sufficiently precise evidence to reject a zero conditional association at conventional significance levels. Generator ownership carries a positive but insignificant sales-growth coefficient, which is compatible with some mitigation but does not establish that generators improve growth.

The employment model produces a different pattern. Outage exposure is positively associated with employment growth, but again the coefficient is statistically insignificant (p = 0.1892). Generator ownership is negatively related to employment growth at the 10% level. One possible interpretation is that firms investing in backup power are more capital- or energy-intensive, or that generator costs

constrain other expenditure. Another is selection: firms facing the most severe reliability problems are the firms most likely to acquire generators. The coefficient should therefore not be read as evidence that generators cause job losses.

Among the controls, large firms record sales growth about 9.06 percentage points below small firms, while establishments outside Montserrado record sales growth about 6.18 percentage points lower than establishments in Montserrado. Both coefficients are significant at the 5% level. Firm age is negatively associated with employment growth, suggesting that younger establishments expanded employment faster during the reference period. Sector, managerial experience, loan access and product innovation are not statistically significant in these parsimonious models.

4.3 Robustness and interpretation

The absence of a statistically significant outage coefficient should not be interpreted as evidence that electricity reliability is economically unimportant. First, outage exposure is measured as a binary indicator and does not capture differences in frequency, duration, timing or voltage quality. Second, nearly all firms own generators, leaving limited variation in the principal coping variable. Third, firms may adjust production schedules, substitute labour for machinery or pass part of the cost to customers. Prior studies show that such adaptation can obscure the gross cost of shortages in observed output while shifting costs into fuel, capital and altered input choices (Fisher-Vanden et al., 2015; Allcott et al., 2016; Oseni & Pollitt, 2015). Fourth, a sample of 158 firms limits precision once several controls are introduced.

Additional specifications should replace the binary outage measure with monthly outage hours, interact outage exposure with generator ownership, estimate separate models for manufacturing and services, and compare small firms with medium and large firms. Quantile regression may reveal effects concentrated among slow-growing firms. Where sample size permits, a two-part approach can distinguish the probability of experiencing an outage from outage intensity among affected firms. These extensions should be treated as robustness checks because intensity questions are conditional and reduce the usable sample.

5 Discussion

The descriptive results are consistent with the wider Sub-Saharan African literature: unreliable electricity is pervasive, and firms respond through extensive self-generation (Steinbuks & Foster, 2010; Oseni & Pollitt, 2015). The negative coefficient for sales growth also accords with the theoretical prediction and with Cole et al. (2018), Mensah (2018), Cissokho (2020), and Apeti and Ly (2023). However, the Liberia estimate is imprecise. This divergence between a severe reported constraint and statistically weak growth coefficients highlights the difference between incidence and marginal impact. A constraint can be common and costly even when cross-sectional variation does not cleanly predict growth because firms have already adapted or because the most vulnerable establishments have exited the market.

The high prevalence of generators suggests that measured sales growth reflects performance after costly adaptation. A firm that maintains output by operating a generator may appear resilient in sales data while experiencing lower profit, investment or competitiveness. Studies of African enterprises show that self-generation reduces some outage losses but entails high private electricity costs and does not fully substitute for reliable grid supply (Steinbuks & Foster, 2010; Oseni & Pollitt, 2015). Because the Enterprise Survey does not provide a complete profit-and-loss account for every firm, a growth regression may understate welfare costs arising from higher unit energy expenditure.

The location result deserves attention. Firms outside Montserrado experienced significantly slower conditional sales growth, which may reflect differences in market size, logistics, finance,

telecommunications and electricity infrastructure. The international evidence shows that the productivity effect of electricity constraints is mediated by complementary infrastructure and firms' ability to reorganise production (Scott et al., 2014; Allcott et al., 2016). Electricity policy should therefore be coordinated with broader regional enterprise development; additional generation will not yield its full effect if transmission, distribution, roads and working capital remain binding constraints.

The employment findings also caution against assuming that all production disruptions translate directly into fewer workers. Firms can respond by extending shifts, using more labour-intensive processes or retaining workers during temporary interruptions. Conversely, generator costs may crowd out hiring or encourage capital substitution. Evidence from India and China demonstrates that firms alter input combinations when electricity becomes scarce or costly (Fisher-Vanden et al., 2015; Abeberese, 2017). More detailed panel information on hours worked, wages, capital utilisation and energy spending would help separate these mechanisms in Liberia.

6 Conclusion and Policy Implications

This article examined electricity supply reliability and firm growth in Liberia using 158 establishments from the 2025 World Bank Enterprise Survey. The descriptive evidence is unequivocal: outages are widespread, interruptions are lengthy, generator dependence is exceptionally high and electricity is widely considered a serious obstacle. Regression estimates show a negative but statistically insignificant relationship between outage exposure and annualised sales growth. The corresponding employment relationship is positive but insignificant. Large firms and establishments outside Montserrado record slower sales growth, while older firms record slower employment growth.

The main conclusion is not that outages are harmless. Rather, the available cross-sectional evidence cannot isolate a precise causal growth effect from a simple outage indicator. The combination of widespread exposure and widespread self-generation means observed firm performance already incorporates adaptation. Policies should therefore focus on both reliability and the cost of resilience.

First, power-sector investment should prioritise dependable service to productive clusters, with transparent reliability targets covering interruption frequency and duration. Second, distribution maintenance, metering and commercial management should accompany new generation so that additional capacity translates into usable power. Third, financing mechanisms should help small and medium enterprises adopt efficient, cleaner backup systems, including appropriately designed solar-plus-storage solutions where technically and financially viable. These priorities are consistent with the broader evidence that access alone is insufficient when reliability remains poor and that private self-generation cannot efficiently replace a dependable grid (Scott et al., 2014; IEA, 2024; Oseni & Pollitt, 2015). Fourth, agencies should collect regular data on outage hours, energy expenditure, generator fuel costs and lost production.

Future studies should exploit panel survey waves or operational electricity data to strengthen causal identification. Linking establishment records to feeder-level outage logs would reduce recall error and permit analysis of interruption timing and severity. Even without such extensions, the present evidence shows that reliable and affordable electricity remains fundamental to Liberia's private-sector development.

Declarations

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Data availability: The study uses firm-level World Bank Enterprise Survey data. Access is governed by the World Bank Enterprise Surveys Data Access Protocol.

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