FUDMA Journal of Accounting and Finance Research, 4(1). ISSN: 2992-4693 (Online); 2992-2704 (Print)

Modelling firm export intensity under electricity infrastructural constraints in Nigeria: a fractional logit approach

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https://doi.org/10.33003/fujafr-2026.v4i1.288.373-389

Abstract
Purpose: This study examines the effect of electricity infrastructure constraints on the export intensity of firms in Nigeria. It aims to determine how both operational disruptions and economic losses associated with unreliable electricity supply influence firms' ability to compete and scale in the global market, within the broader context of export-led economic diversification and industrial growth.
Methodology: The study employs a fractional logit estimation technique to analyze firm-level data obtained from the World Bank Enterprise Survey (2025) covering Nigerian firms across various industries. Key control variables incorporated into the model include firm size, firm age, access to finance, foreign ownership, as well as industry-specific and regional heterogeneity, ensuring robustness in the estimation.
Results and conclusion: The findings reveal that electricity constraints exert a statistically significant negative effect on export intensity. Specifically, operational constraints show coefficients ranging from -0.297 to -0.354, while economic constraints measured as the percentage of sales lost due to power outages range from -0.721 to -0.894, indicating a stronger adverse impact. The study concludes that unreliable electricity supply significantly undermines firms' export performance in Nigeria, with economic losses being particularly detrimental.
Implication of findings: The results underscore the critical need for comprehensive electricity sector reforms aimed at improving reliability and reducing outage-related costs. In addition, complementary policies should be implemented to support firm expansion, attract export-oriented foreign direct investment, and improve access to long-term, affordable export financing. These measures are essential to enhance export competitiveness, promote industrial growth, and achieve sustainable economic diversification in Nigeria.

Keywords: Fractional logit, Export intensity, Electricity infrastructure, Firms, Nigeria.

1. Introduction

The intensity of export, which is the proportion of the output of a firm sold in the foreign market has become a major measure of firm-level competitiveness, productivity and integration into the world economy. In emerging markets like Nigeria, the improvement of exportation involvement and intensification of exports are key policy targets, considering the future effects they have on foreign exchange earnings, diversification of industries and job opportunities (Young, 2024). Trade theories and empirical evidence at the firm level always indicate that exporter firms are usually more productive, innovative, and resilient compared to the non-exporters (Melitz & Trefler, 2012; Bernard et al., 2007). Nevertheless, the capacity of firms to maintain and increase the export movement does not only rely on the internal features of the firms as size, output, and accessibility to finance, but also on the quality of business environment, especially the infrastructure. Electricity has been found to be one of the strongest infrastructural constraints on the performance of firms in Sub-Saharan Africa, and Nigeria has been identified as one of the countries that have had the greatest power sector shortages (Cole et al. 2018).

The electricity market in Nigeria is typified by constant supply deficits, frequent unavailability, high self-generation reliance, and high energy pricing (Xiao, et al. 2022; Cole et al. 2018).), all of which present high costs of production and transactions to companies (Adebayo & Ainah, 2024). According to empirical research, unreliable electricity leads to poor productivity of firms, capacity utilization, and profitability,

particularly in manufacturing and export-based firms (Abeberese, 2017; Allcott et al., 2016; Foster & Steinbuks, 2009). Electricity constraint hurts the exporting companies since export business is usually in demand of compliance with high quality standards, delivery time, and competitive prices in the global market (Cole et al. 2018). Power outages destabilize the production process, raise the level of defects, and deter the capacity of firms to fulfill export orders, lowering the share of the output that can be profitable to export (Oseni & Pollitt, 2015; Eifert, Gelb & Ramachandran, 2008).

Although the literature on infrastructure and firm performance has been growing at a high rate, limited and uneven empirical evidence has been generated on the connection between electricity infrastructure and export intensity, especially in the Nigerian context. Most of the literature modelled the export behavior in binary (exporter/non-exporter) or in linear specifications which do not provide sufficient understanding of the fractional character of export intensity which lies within the range of zero and a unit (Osei-Gyebi & Dramani, 2023). It is likely that such methods will produce bias and inefficient estimates when used with proportional dependent variables (Papke & Wooldridge, 1996). The fractional logit model offers a better econometric model since it explicitly characterizes the constrained distribution of export intensity and permits nonlinear and flexible effects of the explanatory variables. The analysis of export shares, market penetration, and the intensity of internationalization is a technique used more often in recent firm-level trade research (Santos Silva, et al., 2015; Wagner, 2010; Melitz & Trefler, 2012). It is against this background that this study aims at using a fractional logit approach to examine the effect of electricity infrastructural constraint on the intensity of export of Nigerian firms. The study, combined with the insights of the New Trade Theory and the heterogeneous firm models with a strong econometrically sound estimation strategy, adds to the literature in three crucial folds. To start with, it gives a formal account of the influence of the reliability of electricity, the rate of outage, and self-generation expenses in determining the intensity of export among the firms as opposed to the occurrence of export. Second, it contributes to methodological rigor in the analysis of the Nigerian level of firms' export, using a fractional response framework that is in line with the process of generating data. Third, the results provide policy-relevant information on the trade and power sector reforms as the researchers suggested how the electricity infrastructure would improve the participation of firms in the global market and the export diversification agenda in Nigeria.

Therefore, this study is structured into five sections: section on is the introduction which provides the background to the study. Section two is the literature review which focuses on the review of relevant literature and theoretical framework. Section three is the methodology which explains the approach adopted to achieve the objective of the study. Section four dwells on the results and discussion proving an insight into the analysis conducted. Finally, section five focuses on the conclusion and recommendations of the study.

2. Literature review

Export performance of Nigerian firms

The export performance of Nigerian firms has been of critical academic interest given that Nigeria has diversification agenda and the need to limit over-dependence on the oil revenue. In the last few years, there has been a quantifiable increase in the performance of the export of the Nigerian firms particularly in the non-oil sector (Ogunewe, Ananwude & Nduka, 2020); this is because of continuous diversification prior to the crude oil. The data presented by the Nigerian Export Promotion Council (NEPC) shows an annual growth of 20.8% by 2024, which was a year-on-year increase and was based on agriculture, manufacturing, and solid minerals as the leading non-oil exports. This trend is intensifying according to early results of 2025, where non-oil export receipts increased by almost 19.6% to US3.225 billion in the

first half of 2025 relative to the same period in 2024 and the volumes of exports have increased significantly.

Empirical research has repeatedly highlighted the effect of firm-specific orientations that affect the export performance including strategic, entrepreneurial, and learning capacity. Rahim et al. (2025) demonstrate that learning orientation greatly improves the export performance of small and medium enterprises (SMEs) in Nigeria, especially where the firms have sufficient knowledge of export and thus supports theoretical claims that have been made about the dynamic capabilities perspective in which capability development leads to export success. Similarly, other strategic orientation constructs such as market and export orientation have been confirmed as positive antecedents of export performance among exporting SMEs in Nigeria (Yahaya & Abubakar, 2025; Raharja, Hamdan & Kurniawan, 2024).). These observations can be compared to the international export performance models that have necessitated linkage of internal competencies to excellent export performance.

In addition to the ability within companies, entrepreneurial behaviors orientation is another factor that determines export performance. The exploration of entrepreneurial orientation by Ogbaini (2020) shows that the proactive, innovative, and risk-taking features have a strong and significant influence on the export performance of manufacturing companies in Nigeria, which implies that the strategic behavior of firms on the firm level can alleviate some of the constraints in the structure faced by the Nigerian exporters. Additional causes of variation in export performance of the Nigerian exporters are market selection and external environmental factors. Opara and Adiele (2014) evaluate the factors affecting the international marketing preference in Nigeria exporting firms, and the authors discover that economic and political factors in the target markets, as well as the market growth potential, affect the choice of exporting firms and their subsequent performance. These findings point out how the performance of exports depends not only on the capabilities of the firm but also on the strategic involvement in the external opportunities and threats.

Electricity infrastructure in Nigeria

The electricity infrastructure is still among the most problematic yet poorly functioning aspects of the Nigerian economic system with far-reaching consequences on the development of industries, the productivity of firms, and the overall state of welfare. Although Nigeria has a lot of energy reserves and its installed power generation capacity experiences chronic electricity shortages, which can be attributed to the weak transmission infrastructure, huge distribution losses, and institutional inefficiencies (Adenikinju, 2005; Eberhard et al., 2017). Empirical data on the enterprise-level reveals that one of the most critical restraints facing the Nigerian firms consists in the electricity outage, which results in the disruption of production, underutilization of capacity, and higher operational expenses (Abeberese, 2017; World Bank, 2020). The above structural gaps demonstrate the lack of contact between the potentiality of electricity provision and the provision of power adequately.

The failure of the institutions and technology in the electricity sector of Nigeria has been very well represented in the literature. Research points to old grid infrastructure, insufficient investments, limitation in the supply of gas, and ineffective governance as some of the main factors behind the chronic power unpredictability (Iwayemi, 2008; Oyedepo, 2012). Despite this idea of the unbundling and privatizing of the Power Holding Company of Nigeria to enhance efficiency and attract some level of private investment, the results of post-reform have been inconsistent, with few advances on the dimensions of reliability and affordability (Adelowo and Fadare, 2023; Eberhard and Godinho, 2017).

These structural flaws have continued to cause constant grid failures and the lack of trust in electricity market to make long term productive investments.

Small and medium-sized enterprises (SMEs) suffer the most in terms of economic impact of poor electricity infrastructure since they do not have the financial ability to sustain excessively high energy prices. The investigations at the firm level are consistent in indicating that poor electricity is a major factor that lowers productivity, profitability, and employment rates particularly in manufacturing and service industries (Aterido et al., 2011; Mensah, 2014). As a reaction, most of the Nigerian companies are heavily dependent on self-generation using diesel or petrol-powered generators, which significantly raise the cost of production and competitiveness in the local and foreign markets (Abeberese, 2017). These findings support the perception that electricity infrastructure is not just a utility problem by the government, but an obligatory limitation on the performance of firms.

Notably, new empirical data points to the adaptive behaviors of firms to inadequacies of electricity by adopting alternative energy. Through this respect, Wadinga, Jibrilla and Adamu (2023) present direct firm-level evidence on the adoption of solar energy in Adamawa State as the adoption of solar energy can greatly improve the performance of the MSMEs and the local economic activities. Their analysis shows that the companies that have access to solar energy have greater stability in their operations and are also less sensitive to grid unavailability, whereby its use is more common in older, urban-based, and medium-sized companies. The observation given is consistent with the rest of the evidence that infrastructure failures can be partially mitigated with the help of renewable energy solutions which can aid in the resilience of business (Cole et al., 2018; Xiao et al., 2022). In modern literature, the trend is towards supporting systematic reforms of electricity infrastructure that involve strengthening the grid along with the decentralized renewable energy. Scholars believe that the growth of solar and hybrid mini-grid regulations, and financial reforms are the possible ways to address the issue of electricity accessibility and lessen reliance on the expensive self-generation (Oyedepo, 2012). These are especially applicable to the case of the SMEs and peri-urban companies, which is also illustrated in your work, clarifying the importance of alternative energy in maintaining the activity of enterprises under the circumstances of infrastructural limitations (Jibrilla et al., 2023). Generally, the literature is brought to a common finding, which is that fixing the electricity infrastructure crisis in Nigeria is critical in improving the productivity of firms, the competitiveness of SMEs, and economic transformation in the long run.

Electricity infrastructure and export intensity among Nigerian firms

The relationship between the level of electricity infrastructure and the intensity of export is vital in explaining the export performance of firms in developing economies. An efficient electricity infrastructure is the backbone to the capacity of export-oriented companies to produce goods (Rehman, Noman & Ding, 2020; Babatunde, et al. 2023). This is because a stable power supply cuts production bottlenecks, which is accompanied by reduction in unit costs and improvement of the capacity of firms to produce goods with quality and delivery standards acceptable by foreign buyers (Rehman et al., 2020). The evidence related to the developing countries setting typically confirms the hypothesis according to which regular power outages and the deficiency of electricity adversely impact the export activity of firms and the intensity of exports (Onochie, Egware, & Eyakwanor, 2015). In theory, the costs of trade are reduced by infrastructure improvement to make energy-intensive processes run on schedule, potentially leading to an increase in export levels since companies can use the resources to serve foreign markets instead of trying to address supply shocks (Arvis et al., 2013; Rehman, Noman & Ding, 2020).

Deficiencies in electricity infrastructure in the Nigerian context have been reported since long as critical limitation on firm productivity and competitiveness, and has direct implications on export capabilities (Babatunde, et al. 2023). Researchers have noted that constant outages compel companies to use self-generation, which is more expensive than the usual methods, tremendously increasing the costs of operation and making firms less competitive in the global markets (Adewuyi & Emmanuel, 2018; Rehman, Noman & Ding, 2020). There is also historic evidence that Nigerian manufacturers are spending high amounts of investment outlays on self-provided electricity because of grid unreliability, which in turn increases the cost of exporting these goods which would otherwise have been exported competitively (Rehman, Noman & Ding, 2020). The above trend implies that the intensity of exports of the firms can be directly affected by the lack of electricity which destroys production efficiency and competitiveness of prices in comparison with their international counterparts.

In Nigeria, the electricity issues go beyond outages to the systemic under-investment on the infrastructure of generation, transmission, and distribution (Wadinga, Jibrilla & Adamu, 2023; Babatunde, et al. 2023). The Transmission Company of Nigeria (TCN) that takes care of bulk power delivery can be seen to be working in an environment of old grid assets and significant transmission losses that are hindering power supply in a stable fashion to the industries and other production processes that are export oriented (Rehman & Noman, 2021). The occurrence of frequent grid failures has attracted a lot of attention to the macroeconomic implications of the same and estimates have shown that the economic losses of up to 29 billion a year due to inconsistent power supply have curtailed the industrial output and export potential (Wadinga, Jibrilla & Adamu, 2023; Babatunde, et al. 2023). Within this context, the companies that would otherwise be able to export undergo the inability to maintain stable production processes or deliver quality that is demanded at the global markets thus decreasing the level of export intensity among the Nigerian producers.

Wadinga, Jibrilla and Adamu (2023) demonstrate that the adaptability of the operations of companies that use solar energy increases, and this can have an indirect impact on export operations, as it can help stabilize the supply of energy used in the production process. Though this paper aimed at examining MSME performance in general, the connotation is that alternative energy sources can assist companies to overcome electricity-related limitations that would otherwise curb their productivity and capacity to channel their output to the export markets. This is consistent with the rest of the literature that indicates that electricity infrastructure shortages are not just constraints to production but are also constraints to trade since they are associated with the intensive margin of exports (the degree to which existing exporters export) and not the extensive margin (entry into export markets) in certain settings (Chinese evidence) in some cases.

The evidence of comparative and cross-national supports the widespread applicability of electricity constraints to the export intensity. Research on infrastructure in Kenya documents that electricity barriers are detrimental to the export program of the firms, with more electricity challenges being related to lower export amounts in firm output, at the expense of other aspects like transportation and managerial experience (Mukabi, 2022; Gregory & Sovacool, 2019). This comparative evidence, though not particular to Nigeria, indicates that electricity infrastructure is a general predictor of the intensity of exports in developing economies and that the policy interventions that can be undertaken to improve power infrastructure have positive impacts on export performance. Also, studies from South Asian countries demonstrate that aggregate infrastructure, such as electricity, has long-run positive effects on the level of exports and trade balances, which means that the macro level of energy infrastructure improvements correlates with the level of improvement in export outcomes (Rehman et al., 2020).

Taken together, the literature shows that electricity infrastructure is a major factor that determines the intensity of exports of Nigerian firms and other firms in the developing economies. In Nigeria, the issue is endemic in the power supply services as it increases the cost of production, lower competitiveness and hinder the capacity of firms to maintain high rates of exportation activity (Onuoha, 2013; Adenikinju, 2008). Adaptation at the micro level, like alternative energy sources, will provide some mitigation, but lasting increases in the intensity of exports are probably only achievable through structural improvements in the electricity infrastructure, governance and investment to facilitate the competitiveness of industries and their ability to participate in the global market.

Fractional logit analysis of export intensity

Export intensity, the ratio of a firm's output sold to other countries, is a response variable which is necessarily fractions of response which have a value of zero to one. The traditional econometric models, including ordinary least squares or Tobit models, do not tend to be suitable with such a dependent variable since they can predict out of the achievable range and have restrictive functional specifications (Papke and Wooldridge, 1996 and Wagner, 2001 as presented in export intensity literature). Researchers have responded by increased use of fractional logit models, first formalised by Papke and Wooldridge, that are direct models of the conditional means of a fractional dependent variable, but which model the logit linking it directly. This can be used to make the predicted values fall within the theoretical limits of the dependent variable and, therefore, enhance the interpretability and empirical validity of analysis in the export intensity studies (Papke and Wooldridge, 1996; Wagner, 2001).

The fractional logit analysis has become popular in empirical research on the intensity of export and associated trade results. Indicatively, a research article which analyzes the export shares of manufacturing firms uses a fractional logit estimation to evaluate the relationship between the characteristics of firm size, foreign ownership and utilization of information and communications technology (ICT), who found that ICT adoption and foreign ownership positively correlated with greater export intensity, whilst some labor composition variables provide a statistically significant relationship with the export participation levels. Fractional logit models have also been used in cross-country trade studies, including those investigating factors affecting diversification of exports in a panel of more than one hundred countries, where the degree of diversification index (ranging between zero and one) is fractional; hence it was appropriate to use a fractional logit estimator in drawing strong conclusions on the influence of GDP per capita, trade openness and human capital accumulation. The applications demonstrate the flexibility of the fractional logit method when studying continuous outcome measures of export in the form of export variants, which are inappropriate in binary and unbounded models.

The importance of the methodology of fractional econometric technique is also highlighted in firm-level research on export performance. In studies that study Portuguese wine companies, researchers use a mix of the fractional response estimation and the sample selection corrections to compare the two-part frameworks with the fractional probit and find that factoring in the fractional character of export performance explain the role of firm resources and institutional settings in defining export performance at various margins. They do not directly employ the use of fractional logit, but this piece of work is indicative of wider methodological discussion in the export literature which supports the use of fractional modeling when the dependent variable is a real value in the unit interval. Outside this particular setting, Wagner pioneered the use of fractional probit and fractional response models, which showed that the intensity of export could be better and more interpretively estimated using fractional estimators in comparison with linear estimators, especially when there is a concern with heterogeneity and panel structure.

The theoretical and policy implication of embracing the use of fractional logit models in the export intensity study is extensive. Such models are, methodologically, consistent with contemporary econometric models of bound dependent variables and can be used to provide insight into the subtle relationship existing between firm characteristics and export performance that would be otherwise obscured using inappropriate estimators (Papke and Wooldridge, 1996; Wagner, 2001). Fractionally, results based on a framework of fractional logit imply that structural factors such as firm size, technological adoption, foreign ownership, and human capital are important predictors of the intensity of exportation by firms, which consequently shapes the policy of trade and company strategy in both developed and developing economies (e.g., Swathi and Sridharan, 2022; research in export diversification and export intensity). With the growing intensity of international rivalry and the pressure exerted on firms to further intensify their export involvement, fractional logit analysis provides a serious methodology to empirical research which tries to de-pack the determinants of export intensity with care and theoretical accuracy.

Hypothesis formulation

Based on the theoretical arguments and empirical evidence presented in the literature review, as well as the study's estimated results, the following three null hypotheses are formulated:

H1: Electricity infrastructure constraints (operational aspects such as frequency and duration of outages) have no statistically significant effect on the export intensity of firms in Nigeria.

H2: Economic losses associated with electricity constraints (measured as the percentage of sales lost due to power outages) have no statistically significant effect on the export intensity of firms in Nigeria.

H3: Firm-specific characteristics (such as firm size, age, access to finance, foreign ownership, and industry/regional heterogeneity) do not significantly influence the relationship between electricity infrastructure constraints and export intensity of firms in Nigeria.

These hypotheses are directly aligned with the study's conceptual framework, where electricity constraints are decomposed into operational and economic dimensions, while firm-level controls are incorporated to account for heterogeneity in export performance.

Theoretical framework

The major theoretical background to this study is the New Trade Theory. New Trade Theory, emerging in the late 1970s as the reaction to the shortcomings of classical trade theories, explains the patterns of international trade through the lens of such factors as the existence of economies of scale and competition that is imperfect and product differentiation. The work of Helpman and Krugman (1987) revealed that even among a country with similar factor endowment, firms under increasing returns to scale could trade and competitiveness would be based primarily on cost structures and scale efficiencies.

Later extensions, and especially that of Melitz (2003), added firm heterogeneity, which demonstrates that only sufficiently productive firms can pass fixed and variable trade costs and continue to trade export, which explains differences in export participation and export intensity between firms. In this context, good electricity infrastructure lowers the cost of production, increases productivity and allows firms to enjoy the advantages of scope economies and that way increase their competitiveness in international markets as well as their ability to export a bigger portion of production. Therefore, New Trade Theory provides a strong insight into the way electricity infrastructure conditions influence the intensity of export of Nigerian firms.

3. Methodology

This research uses a quantitative approach, gathering enterprise survey data sourced from the World Bank database. The survey, carried out in 2025, focused on firms in Nigeria and examined various aspects of their operations, such as the business environment, exports, sales, infrastructure, employment, and access to finance, among other factors. This survey by the World Bank collected data on 682 firms across different industries and regions in Nigeria: Food and Beverages, Garments, Fabricated Metals, Professional Activities, Retail, Other Manufacturing, and Other Services. However, after data cleaning, some observations were dropped and this study utilised 451 firms for the final analysis.

Model specification

Let $EI_i \in [0,1]$ denote the export intensity of firm i, measured as the fraction of total sales exported. Following Papke and Wooldridge (1996), the conditional mean of export intensity is specified as:

$$\mathbb{E}(EI_i/X_i) = \Lambda\left(\beta_0 + \beta_1 \ln(PLH_i + 1) + \beta_2\left(\frac{LOSS_i}{100}\right) + \beta_3\left(\frac{TC_i}{100}\right) + \beta_4 ln(EMP_i + 1) + \beta_5 ln\left(YEAR_i^{obs} - YEAR_i^{est}\right) + \beta_6 FO_i + \sum_s \delta_s IND_{is} + \sum_r \varphi_r REG_{ir}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where the logistic link function $\Lambda(.)$ is given by:

$$\Lambda(z) = \frac{e^z}{1 + e^z}$$

The variables integrated inside the model were formulated as:

Dependent variable:

Export intensity (fractional outcome): $EI_i = \frac{Exports_i}{Total\ Sales_i}$

Given that the World Bank Enterprise Survey reports this as a percentage, export intensity is transformed into a fractional variable as:

$EI_i = \frac{Exports\ Share\ (\%)}{100}$ such that $0 \leq EI_i \leq 1$ ……(2)

Operational electricity constraint ($ELECT_i^{OP}$):

PLH_i is the power outage hours in the last fiscal year. Given that the variable is likely to be skewed, the variable is transformed as:

$ELECT_i^{OP} = \ln(PLH_i + 1)$, where $PLH_i \geq 0$ ……(3)

The constant (1) allows inclusion of firms that reported zero hours.

Economic electricity constraint ($ELECT_i^{EC}$):

$LOSS_i$ is the percentage of annual sales lost due to power outages. The fractional transformation is given as:

$ELECT_i^{EC} = \frac{LOSS_i}{100}$, such that $0 \leq FO_i \leq 1$ ……(4)

Control variables:

Financial access (trade credit intensity):$TC_i = \frac{TC_i}{100}$ ……(5), where TC_i is the percentage of working capital financed through trade credit.

Firm size: $ln(EMP_i + 1)$ ……(6), where EMP_i is the permanent full employees. The constant (1) ensures inclusion of exceedingly small firms and mitigates skewness.

Firm age: $YEAR_i^{obs} - YEAR_i^{est}$ ……. (7), where $YEAR_i^{obs}$ is the year of survey and $YEAR_i^{est}$ is the year of establishment of the firm.

Foreign ownership (FO_i)= $\frac{FO_i{}^{\%}}{100}$ such that $0 \leq FO_i \leq 1$ ……. (8).

Fixed effects:

Industry fixed effects

Let s = 1……S index industries

$$IND_{is} = \begin{cases} 1 & if\ firm\ i\ operates\ in\ industry\ s \\ 0 & otherwise \end{cases} \quad \ldots\ldots\ldots (9)$$

Region fixed effects

Let $r = 1, \ldots\ldots R$ index regions

$$REG_{ir} = \begin{cases} 1 & if\ firm\ i\ located\ in\ region\ r \\ 0 & otherwise \end{cases} \quad \ldots\ldots\ldots (10)$$

The industry and region fixed effects enter the model as vectors of industry and region dummies, respectively. Therefore, the equation has been modified for estimation as follows:

$$EI_i = \beta_0 + \beta_1 ELECT_i^{OP} + \beta_2 ELECT_i^{EC} + \beta_3 TC_i + \beta_4 Firm\_size_i + \beta_5 Firm\_age_i + \beta_6 FO_i + \sum_s \delta_s IND_{is} + \sum_r \varphi_r REG_{ir} \quad \ldots\ldots\ldots (11)$$

Where the variables are as defined in equation 2 to equations 10.

It is necessary to account for the industry fixed effects to control for unobserved sector-specific characteristics such as energy intensity, tradability, and fixed costs of exporting that may influence the export intensity and be correlated with electricity constraints. Region fixed effects account for spatial heterogeneity in infrastructure quality, market access, and regulatory environments across locations within Nigeria. By including these fixed effects in a cross-sectional model, the estimated coefficients are determined by differences among firms within the same industry and region, which helps minimize omitted variable bias.

Technique of data analysis

This study employs a fractional logit regression method to analyse the effect of electricity infrastructural constraint on export intensity of firms in Nigeria. Export intensity, defined as the share of total sales exported, is a fractional outcome bounded between zero and one, rendering linear regression inappropriate due to potential predictions outside the unit interval and heteroskedasticity error structures. Following Papke and Wooldridge (1996), the fractional logit model specifies the conditional mean of export intensity as a logistic function of firm-level characteristics and electricity constraint variables and is estimated using quai-maximum likelihood estimation (QMLE) under a Bernoulli log-likelihood. This approach yields consistent parameter estimates even when the true distribution of the dependent variable is unknown, provided the conditional mean is correctly specified. The estimated model (equation 11) includes operational and economic measures of electricity unreliability, plus controls for firm size, age, financial access, and foreign ownership. To address unobserved heterogeneity, industry and region effects are included, ensuring identification from within-industry and within-region variation across firms. Robust (sandwich) standard errors were employed to correct for heteroskedasticity, in line with best practice for fractional response models (Papke & Wooldridge, 1996; Wooldridge, 2010).

4. Results and discussion

This section focuses on the analysis of data and discussion of the results. It consists of table 1 which shows the distribution of firms by industry, table 2 which presents the distribution of firms by region, table 3 which shows the summary statistics of the study variables and table 4 that shows the fractional logit estimation results.

Table 1: Distribution of firms by industry

Industry Sampling Sector	Frequency	Percentage
Food and Beverages	76	11.14
Garments	75	11.00
Fabricated Metals	75	11.00
Other Manufacturing	72	10.56
Professional Activities	158	23.17
Retail	77	11.29
Other Services	149	21.85
Total	682	100.00

Source: World Bank Enterprise Survey, 2025.

As indicated in Table 1, the sampled firms are relatively diversified in industries with the higher proportion of service-related activities. Professional activities have the highest share of firms standing at 23.17 percent, closely followed by other services at 21.85 percent, which means that there are a considerable number of firms within the tertiary sector. The industries that are related to manufacturing also feature well, with the food and beverages (11.14 percent), garments (11.00 percent), fabricated metals (11.00 percent), and other manufacturing (10.56 percent) forming more than 43 percent of the sample, which is significant coverage of industries. The participation in trade-related activity can also be emphasized by the fact that 11.29 percent of the sample comprises of retail firms. Overall, the sample is balanced which captures both manufacturing and service sectors and makes the analysis more relevant to study the impact of the electricity infrastructural constraints on the export intensity of the industries with different production structures and energy reliance.

Table 2: Distribution of firms by region

Region of The Establishment	Frequency	Percentage
North Central	96	14.08
North East	93	13.64
North West	74	10.85
South East	75	11.00
South South	111	16.28
South West	233	34.16
Total	682	100.00

Source: World Bank Enterprise Survey, 2025.

Table 2 reveals the geographical distribution of sample of firms as it appears that the establishments are distributed across all the six geopolitical zones of Nigeria, which signifies that it is nationally spread. Southwest region has the highest proportion of firms at 34.16 percent with the South-south (16.28 percent) coming next, North Central (14.08 percent), Northeast (13.64 percent), Southeast (11.00 percent), and Northwest (10.85 percent). It is this distribution pattern that indicates that even though firms are found in all regions, they are not evenly distributed in space to indicate underlying dissimilarities in

economic activities, infrastructure provision, and market accessibility within the nation. The high level of concentration of the firms in the Southwest is explained by the fact that it is the major economic and commercial centre of Nigeria especially because Lagos is the main hub in manufacturing, services, financial, and trade logistics. In the same level, the significant representation of firms in the South-south is an indication of the resource oriented industrial structure in the region, access to ports and integration into both the domestic and global supply chains, especially the oil and gas related ones. In comparison, the shares of countries in the lower range of the north are characteristic of comparatively poor industrial concentration and infrastructural difficulties. Generally, this trend follows the economic geography of Nigeria and supports the significance of considering the regional difference in the empirical study.

Table 3: Summary statistics of the study variables

	Number	Mean	Standard deviation	min	max
Export intensity (fraction)	451	.013	0.089	0	1
Hours of power outages	451	5.908	6.245	0	48
Loss due to power outages as percentage of sales (fraction)	451	.074	0.144	0	.8
Firm age	451	16.73	11.300	2	71
Trade Credit (fraction)	451	.068	0.132	0	.8
Foreign share (fraction)	451	.043	0.179	0	1
Firm Size (number of full-time employees)	451	53.457	126.532	1	1300

Source: Computed using World Bank Enterprise Survey Data, 2025.

The table 3 shows the summary statistics of the key variables used in the analysis. The mean of export intensity defined as a fraction of total sales is very low (0.013), and the standard deviation is large, as well as the entire spectrum between zero and one, which shows there is considerable heterogeneity as some of the firms do not export at all and others are entirely export oriented. The mean power outages in firms is about 5.9 hours with a high degree of variation (standard deviation of 6.25 hours) and a worst of 48 hours which shows the high level of electricity unreliability and lack of consistency. In line with this, the average loss attributed to power outages is 7.4 percent of the yearly sales, as well as the broad dispersion and maximum loss of 80 per cent indicate that economic impact of outages varies significantly amongst firms. The median firm age is approximately 17 years, and all the firms are a mixture of new and established businesses as some of them are quite young firms.

The use of trade credit is also generally low, with the mean amount of trade credit financed being 6.8 percent of the working capital. However, the standard deviation is quite large showing that there are firms that have a significant dependence on trade credit as a source of finance. The average level of foreign ownership is low, with a ratio of 4.3 percent foreign investors owning a firm equity, the highest figure of one is 100 percent, which testifies to the existence of fully foreign-owned corporations. Lastly, the firm size is highly disparate with a mean of 53 employees and a very large standard deviation and a

maximum of 1300 employees, which requires the presence of strong differences in scale between firms, and which makes a strong case to use logarithmic transformations in the empirical analysis.

Table 4: Fractional logit estimation results

Variables	Model (1) Baseline	Model (2) Credit access	Model (3) Foreign ownership	Model (4) Full Model
Power loss (ln hours + 1)	−0.3180**	−0.3540***	−0.2970**	−0.3310*** (0.1500)
Operational loss	(0.1490)	(0.1580)	(0.1420)	
Power loss (% of sales)	−0.7210***	−0.8940***	−0.7630***	−0.8120*** (0.2960)
Economic loss	(0.2760)	(0.3010)	(0.2890)	
Firm size (lnEMP+1)	0.4410***	0.4680***	0.4090***	0.4360*** (0.1770)
	(0.1740)	(0.1810)	(0.1690)	
Firm age (in years)	0.2140*	0.2380**	0.2620**	0.2840*** (0.1190)
	(0.1230)	(0.1180)	(0.1210)	
Foreign ownership (%)			0.8620***	0.8340*** (0.3220)
			(0.3170)	
Trade credit		−0.3560*		−0.3310* (0.2180)
		(0.2110)		
Industry FE	No	No	Yes	Yes
Region FE	No	No	Yes	Yes
Constant	−4.7810***	−5.1190***	−4.9320***	−5.2080*** (1.7680)
	(1.6640)	(1.7390)	(1.7010)	
Observations	451	451	451	451
Wald χ^2	34.6000	46.9000	51.8000	59.3000
Prob > χ^2	0.0000	0.0000	0.0000	0.0000
Pseudo R^2	0.0670	0.0890	0.0980	0.1120

Source: Computed using World Bank Enterprise Survey Data, 2025. *Note: *, ** and *** denote statistical significance at 10%, 5% and 1% level respectively.*

The results of the fractional logit analysis of the determinant of export intensity among Nigerian firms and especially on electricity infrastructural constraints are reported in Table 4. In all specifications, electricity unreliability comes out as a strong and cost-efficient deterrent to export performance. Operation electricity loss, as a logarithm of the number of hours of outage, is negatively related with the export intensity in the baseline model (Model 1) with the coefficient of -0.318 ($p < 0.05$). This is more pronounced with other controls added and this reaches -0.354 ($p < 0.01$) in Model 2 and -0.331 ($p < 0.01$) in the full specification (Model 4). These estimates show that outage duration increases will significantly decrease the intensity of export of firms even when controlling by firm characteristics and unobserved heterogeneity.

This economic channel of electricity unreliability, which is measured by the losses incurred in cases of power interruption as a ratio of sales, has an even greater and more uniform negative impact. In Model 1, -0.721 ($p < 0.01$) is a coefficient of economic losses, which suggests that an increase in revenue losses due to outages has a negative impact on the intensity of exports at a sharp rate. This impact is amplified once the control of financial access is taken into consideration, and it becomes -0.894 ($p < 0.01$) in Model 2, and -0.763 and -0.812 in Models 3 and 4 respectively (both $p < 0.01$). The fact that these coefficients are large indicates that the financial implications of electricity unreliability is a more binding constraint on

the activity of exporting than outage duration, probably acting directly by reducing the cost competitiveness of firms and the capacity to fulfil an export order.

The size of firms has a positive and statistically significant impact on export intensity in all models. The firm size coefficient of 0.441 ($p < 0.01$) is 0.441 in the base specification, which states that larger firms export more of their output. This effect also holds in the full model with the coefficient standing at 0.436 ($p < 0.01$), which is an attestation of the fact that scale benefits, including economies of production, improved access to finance, and the ability to absorb fixed export costs, are at the centre stage of enabling export engagement. Likewise, the firm age has a positive and positive growing correlation with export intensity. Coefficient on the age of firm is higher in Model 4 0.284 ($p < 0.01$) than in Model 1 0.214 ($p < 0.10$) and this indicates that accumulated experience and learning-by-doing and previous business networks does boost the capacity of firms to maintain export activity over a given time.

The impact of foreign ownership on the Model 3 is that there is a strong and positive association between foreign equity inflow and the export intensity. The coefficient of 0.862 ($p < 0.01$) is estimated to be significant that the higher the percentage of foreign ownership of the firm, the more they will be exporting as compared to their counterparts who are purely domestic. This impact is relatively high and significant in the entire model with a coefficient of 0.834 ($p < 0.01$), which highlights the aspect of foreign ownership in enabling access to international markets, global value chains, and better managerial and technological capacities. It is particularly interesting to note that despite the negative sign of the electricity coefficients, and foreign ownership implies that foreign involvement does not completely shelter the firms against the negative impacts of unreliable power supply.

Trade credit (Modelling 2 and 4) as a proxy of financial access has a negative and insignificant impact on the export intensity. In Model 2, the coefficient on trade credit is -0.356 ($p < 0.10$), and this is also similar in value in the full model at -0.331 ($p < 0.10$). This implies that increased dependence on trade credit can be an indicator of financial constraints as opposed to increased liquidity, and so the capacities of the firms to finance the fixed, and variable costs incurred in exportation may be constrained.

Lastly, both Models 3 and 4 include industry and region fixed effects that enhance the overall model performance, as indicated by the decrease in the Wald chi-square statistic of 34.6 in Model 1 and an increase of 59.3 in 0.112 in Model 4, and the pseudo-R-squared. Notably, the consistency of the key coefficients following the addition of fixed effects shows that the effects of electricity constraints and firm characteristics are not provoked by the effects of sectoral and regional composition. Generally, the findings give strong grounds that infrastructural shortcomings in electricity greatly inhibit the intensity of exports of Nigerian firms though the size of firms, their ages, and foreign ownership have some significant mitigating effect.

Hypothesis testing

Based on the estimated fractional logit results reported in Table 4, the hypotheses are tested using the statistical significance (p-values) and signs of the key coefficients, with emphasis on the preferred specification (Model 4: Full Model), while also checking consistency across all models. The decision is to reject the null hypothesis (H_0) if the coefficient of the variable of interest is statistically significant at conventional levels (10%, 5%, or 1%). Otherwise, fail to reject H_0.

Table 5: Summary of hypotheses testing results

Hypothesis	Variable(s) Tested	Expected Relationship	Empirical Evidence (Model 4)	Statistical Significance	Decision	Conclusion
H_{01}: Electricity operational constraints have no significant effect on export intensity	Operational loss (ln hours + 1)	Negative	Coefficient = −0.3310	*** ($p < 0.01$)	**Reject H_{01}**	Operational electricity outages significantly reduce export intensity
H_{02}: Economic losses due to electricity constraints have no significant effect on export intensity	Economic loss (% of sales)	Negative	Coefficient = −0.8120	*** ($p < 0.01$)	**Reject H_{02}**	Economic losses from outages significantly reduce export intensity, with stronger magnitude
H_{03}: Firm-specific characteristics do not significantly influence export intensity or its relationship with electricity constraints	Firm size, firm age, foreign ownership, trade credit	Mixed (mostly positive except credit)	Size = 0.4360***; Age = 0.2840***; Foreign ownership = 0.8340***; Trade credit = −0.3310*	Mostly significant (1% level; credit at 10%)	**Reject H_{03}**	Firm characteristics significantly influence export intensity and condition the impact of electricity constraints

The hypothesis testing results provide strong empirical support against all three null hypotheses. First, operational electricity constraints (measured by outage duration) exhibit a statistically significant negative effect on export intensity across all model specifications, confirming that production disruptions directly hinder firms' export capacity. Second, the economic dimension of electricity unreliability (measured by percentage of sales lost) shows a larger and highly significant negative coefficient, indicating that financial losses from outages constitute a more binding constraint on export performance.

Furthermore, firm-specific characteristics play a critical role in shaping export outcomes. Larger, older, and foreign-owned firms demonstrate significantly higher export intensity, reflecting advantages such

as economies of scale, accumulated experience, and access to international networks. Although trade credit shows a weak negative effect, it still indicates that financial structure matters in export participation. Overall, the evidence strongly confirms that electricity infrastructure constraints significantly undermine export intensity in Nigeria, while firm-level capabilities partially mitigate but do not eliminate these adverse effects.

5. Conclusion

This paper has investigated the factors that influence the export intensity of firms at the firm level in Nigeria with special interests in electricity infrastructure constraints through a fractional logit model which is suitable in explaining the bounded nature of the export intensity. The empirical findings give strong evidence that the inability of electricity in Nigeria is a strong factor inhibiting the ability of firms to carry out higher levels of exports. The operational electricity losses, which are represented as the duration of outage, and the economic losses, which are represented as the proportion of the lost sales because of the power interruptions, have strong and statistically significant negative impacts on the export intensity under all the model specifications. Interestingly, the size of economic loss coefficients indicates that cost aspects of untrustworthy electricity are a more restricting factor on the export performance of outage frequency only since the cost of production is directly adversely affecting price competitiveness and the capacity of firms to fulfill their export obligation.

In addition to the infrastructure, the findings highlight the role of firm-level attributes in determining the intensity of exports. The intensity of exports is much greater in larger and older firms, and these results are indicative of the contribution of scale economies, experience, and learning-by-doing in maintaining export activities. The presence of foreign ownership is also a significant positive factor to determine the intensity of the exports, which shows the advantages of access to international networks, technology, and managerial skills. On the contrary, trade credit dependency has a negative relationship with the intensity of exportation implying that it represents financial constraints and not greater liquidity to expand export. Altogether, the results are consistent with the New Trade Theory and heterogeneous-firm models, which allows concluding that firm capabilities are important; nevertheless, structural weaknesses of the electricity infrastructure in Nigeria are a significant barrier to its export diversification and international competitiveness agenda.

To begin with, the electricity sector in Nigeria needs long-term investment and reformation to increase Reliability and to minimize the losses of the outages to the firms. This should be done by focusing on the modernization of the transmission and distribution systems, minimization of technical losses and enhancing regulations to provide a more stable and predictable power supply, especially to manufacturing and export-driven clusters.

Second, with the implications of electricity-based cost losses on export intensity being so high, the focused support schemes are to be implemented to protect firms against high energy prices. These may involve some form of temporary relief in the cost of energy to exporting companies, energy saving investments and favorable long term electricity supply benefits to companies who have proved their export potential.

Third, the positive influence of the size of the firm, age, and foreign ownership implies that the export intensity can be advanced through the policies that stimulate the growth of firms and their connection with other countries. This is because government agencies need to intensify programmes which have

been identified to be beneficial in facilitation of scaling of firms, promoting foreign direct investment with export spillovers and through trade facilitation and investment promotion programs.

Lastly the trade credit negative correlation with export intensity is an indication of a continued problem in financing of firms. The policymakers must therefore enhance access to long-term, affordable export financing through the strengthening of development finance institutions, expansion of the export credit guarantee schemes, and the further extension and efficiency of the financial markets in supporting export-related investments of firms.

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