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The Nexus between Access to Electricity and Growth of Non-agricultural GDP in Bangladesh

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ABSTRACT

Bangladesh is transitioning from an agrarian to a diversified non-agricultural economy, highlighting the role of infrastructure in structural change. Electricity is significant for the non-agricultural sector, as it is power intensive. In this paper, we examine the role of electricity in fostering the development of non-agricultural GDP in rural Bangladesh. We use data from the Household Income and Expenditure Survey to conduct the analysis based on panel data sets generated for rural areas of 64 districts of Bangladesh over the period from 2000 to 2022. Using econometric methods such as fixed effects, ordinary least squares and feasible generalized least squares, the paper finds that there is a relationship between access to electricity and non-agricultural GDP. The findings show that electricity is pivotal to transitioning the rural Bangladesh economy from an agrarian-based to a non-agrarian-based economy. Furthermore, there is a positive correlation between access to mobile phones and education, whereas there is a negative correlation between farm size and non-agricultural GDP. These results highlight expanding reliable electricity, especially in rural and remote areas, is a key driver of non-farm growth. Such efforts should be complemented by parallel investments in education, technology, and equitable land access to added support Bangladesh's transition to a more diversified economy.

1. Introduction

Bangladesh has made electricity accessible to all in the last few decades, but making it reliable and adequate is still a challenge. The shortage in infrastructure, including internet, electricity, and telecommunications, delays economic prospects and the quality of life for millions (Mani, 2024). Frequent power outages, voltage fluctuations, and affordability issues persist, especially in rural areas where the majority of the population still depends heavily on agriculture (Rahman et al., 2022). Electricity plays an important role in enabling various economic activities, including agricultural and non-agricultural activities, fostering education, and improving healthcare outcomes. (Rarasati et al., 2019). The accessibility of electricity allows businesses, helps manufacturing development, and improves agricultural productivity, eventually contributing to increased rural income and reduced poverty. The expansion of e-commerce, facilitated by greater access to information and communication technologies, offers new opportunities for economic development, particularly in rural areas where traditional markets may be limited (Islam et al., 2016). The theoretical supporting for this study is that electricity facilitates production in all the non-agricultural sectors and augments productivity and

efficiency. Additionally, the availability of electricity provides an opportunity for people to be educated, healthier, and informed, resulting in a more competent and productive labor force. Since the government proposed to reach universal access to electricity by 2030, it has shown political will in preventing energy poverty and promoting inclusive economic growth. An underlying question in all of these studies is the extent to which expanded availability of electricity leads to a meaningful expansion of industrial opportunity and other economic activity beyond agriculture, notably for purposes of diversification and job creation. The prospects and trends of renewable energy in Bangladesh study show that demand can be met with clean energy options (Hossain et al., 2017).

Nevertheless, despite the considerable progress made in electrification, disparities remain (rural versus urban connection and breakdown of electricity supply). In rural Bangladesh, where the overwhelming majority of the poor derive their income from agriculture, the spread of electrical access has led to improved provision for non-agriculture occupations (such as the small industrial and service sector) in these areas (Saha et al. 2025). Unequal remuneration and power access between rural and urban

zones, as well as the difficulties with affordability and infrequent power outages due to electric control problems, are obstacles inhibiting getting the complete potential of economic benefits of electrification including in remote areas (Rahman et al., 2022). There are also social factors, such as health and education, which extend beyond the purely economic productivity that access to electricity can also influence. Electricity access can enhance education levels with better study conditions and information technology accessibility (S. K. Saha, 2025). Better health services are also promoted using electricity in healthcare centers, which is indispensable for running medical equipment and immunizing medicines as well as improving adequate delivery of health services (Saha et al. 2025).

Electricity access is central to economic development, but so are energy security and sustainability. In this perspective, solar and wind energies have been recognized as the possible remedies against mounting energy demand in Bangladesh with a sustainable approach (Al Abbasi et al., 2024). Reaching universal, reliable, and sustainable access is essential; the government's efforts to increase renewables are core to making it happen – as is strengthening the grid and making energy supplies more diverse. To our knowledge, there has been no empirical study specifically examining the relationship between access to electricity and non-agricultural GDP growth in Bangladesh. This study addresses this significant research gap by offering the first district-level panel data analysis (2000-2022) that systematically quantifies the role of electricity in facilitating the structural transformation from an agrarian-based economy to a more diversified non-agrarian one. The findings are highly relevant for policy and provide concrete recommendations for policymakers, private sector stakeholders, and development planners aimed at accelerating non-farm growth, reducing rural-urban inequalities, and assisting Bangladesh in achieving its long-term goals for sustainable and inclusive economic development through targeted investments in electricity infrastructure and complementary initiatives in education, technology, and land distribution. For this reason, the purpose of this study is to examine in detail the relationship between access to electricity and growth of non-agriculture output (for which electricity use has been shown by previous works as an important source), with a specific focus on how electrification may enhance non-agriculture GDP via energy infrastructure development (e.g., industrial and service sectors). With the rapid economic progress that Bangladesh has been experiencing for many years now, it is important to understand this link in order to develop policies that can continue and accelerate change.

The subsequent sections of this study are organized as follows: Section 2 provides a review of literature on electricity and non-agricultural GDP. Section 3 outlines the data collection sources, variables, and methods used in this empirical study. Empirical results are set out in

Section 4, where we discuss the findings compared with previous work and the robustness of analysis. We conclude with Section 5 and discuss some policy implications.

2. Literature Review:

The empirical link between electricity consumption and the expansion of non-agricultural GDP has been a popular topic for economic research, particularly in developing nations like India. It is, however, found that in the agricultural sector an increase in the electricity use can have a negative impact on economic growth, while this same effect on electricity consumption contributes positively to the industrial and commercial sectors. For example, from literature we found that industrial and commercial electricity use, which includes high-voltage and medium-voltage electricity, had a significant positive impact on economic growth (Bal et al., 2022; Shameem P et al., 2022). This is additionally evidenced by the fact that industrial electricity use has a significant positive relationship with total factor productivity, proving efficient energy use even in industries could promote better economic performance (Bal et al., 2022).

However, empirical evidence shows that agricultural electricity consumption and overall economic growth are negatively correlated (Shameem P et al., 2022). This is most notably the case in parts of Sub-Saharan Africa, which exhibit a positive relation between electricity consumption and economic growth, but whose impacts on non-agricultural sectors are less certain (Akinlo & Apanisile, 2014). Finally, the importance of resilient energy infrastructure is highlighted given that industrial and service sector requirements for electricity have led to increased demands for secure and efficient power distribution. For instance, Buhaerah (2018) emphasizes how the link between electricity consumption and growth is a long-run one, and infrastructure plays an important role in maintaining this type of growth. Governments would also be well advised to invest in power grids and energy infrastructure within industrial regions as custom made energy policies which are specifically aimed at increasing electricity access and reliability can drive economic growth (Bal et al., 2022; Stern et al., 2018). But there are remaining issues, evidenced by Ghana, which has seen non-homogeneous trends with more electricity use not always translating into increased output in manufacturing and the challenge of linking up electricity use to growth in non-farming industries (Abokyi et al., 2018).

Electricity is a critical input for economic growth among developing countries like Bangladesh since it necessitates for electrical power has increased significantly with an increasing trend of GDP (Islam & Khan, 2017). Electricity consumption also has a positive correlation with economic growth and this relationship has been demonstrated by scholars in many papers (Olanrele, 2018). However, most of these studies suffer from

significant limitations. First, most studies look at aggregate GDP or aggregate electricity use, not access to electricity or its effect on the non-agriculture sector. Second, they are largely based on national time-series or cross-country data that masks a lot of regional heterogeneity within countries. Third, findings from other geographical and socio-economic contexts may not be directly applicable in Bangladesh because of differences in economic and social structure, institutional setting, rural-urban disparity and level of electrification. For instance, although the effect of industrial electricity use is strong for more industrialized economies, the relevance of industrial electricity uses for non-farm diversification in a predominantly rural economy such as Bangladesh calls for context-specific evidence.

This paper investigates the impact of electricity access on the growth of non-agricultural GDP in Bangladesh, with a focus on understanding the nuanced relationship between these variables within the specific context of the country's developing economy. Internationally, there still exists a large proportion of the population (estimated 840 million people), predominantly in developing countries that does not have access to electricity (Miskat et al., 2021). The rural areas are obviously overrepresented among such people who lack access to electricity, and this inhibits the activities that generate income and advances (Bose et al., 2013; Henry et al., 2021). For some countries such as India, where 70% of the population resides in rural areas, and a significant proportion still lives below the poverty line, an uninterrupted supply of electricity may generate income-generating activities and modern household/ agricultural appliances over polluting kerosene lamps (Cust et al., 2016). The literature on electricity access and economic growth is extensive; a survey of the research finds that electrification is correlated with higher levels of many economic indicators. Multiple studies have explored the direct and indirect effect of electrification on economic development and/or results like GDP growth, industrialization or poverty alleviation. The literature is unanimous that having electricity is enabling for economic prosperity, and the evidence shows that regardless of a few exceptions, even in developing countries, energy poverty is severely constraining development. Other work has also considered the contributions of technological development and innovation in supporting energy efficiency and increasing the availability of clean energy. In Bangladesh, studies have investigated how rural electrification has impacted household income, agricultural productivity and job creation. When we are assessing the relationship between electricity-access and non-agriculture sector GDP growth, one should also take into account Bangladesh's cobweb of trade-relationship, topographical bits and bobs and elbow room in policy-making. ECOM is driven by the fact that the economy increasingly will digitize with ICT being applied in all industries to improve productivity.

This literature review is a first valuable step in comprehending the complex connection between access to electricity and economic growth, although there still seems to be further scope for research particularly in non-agricultural sectors of Bangladesh.

To the best of our knowledge, no empirical study has examined the relationship between non-agricultural GDP and electricity. The current research on Bangladesh's non-agricultural sector has primarily concentrated on high-value agriculture, gender dynamics, foreign aid, school attendance, irrigation practices, the integration of rural and urban economies, human capital development, the informal economy, credit access, land rentals, and remittances (Saha et al., 2025; Saha S.K., 2023; Saha et al., 2025; Subrata Saha et al., 2020; S. K. Saha et al., 2021; S. Saha et al., 2022; Saha et al., 2026; Baten R.H. et al., 2022; Saha et al., 2025). This research aims to address the critical gaps in understanding the structure of trade in Bangladesh, with a particular focus on selected economies. Our study uniquely contributes to the domain of non-agricultural sector research in Bangladesh. By addressing these methodological and contextual limitations and employing a district-level panel dataset covering 64 districts over 2000–2022, this study fills a critical gap in the literature and provides timely evidence to support Bangladesh's ongoing economic diversification and rural transformation.

2.1. Conceptual Framework

This conceptual framework aims to investigate the relationship between education, farm size, mobile connectivity, and access to electricity with respect to non-agricultural GDP growth at a regional scale in Bangladesh (Figure 1). The framework's fundamental contention is that, with significant contributions from the non-agricultural sector, electricity access is a key driver of the transition from agrarian to non agrarian economy. We consider several factors that affect non-agricultural GDP growth to better understand this relationship, including infrastructure, education, technological access, and agricultural factors. Access to electricity is a key sustaining factor for growth in industry (both light manufacturing and the production of non-farm goods and services), entrepreneurship, and the digital economy, even beyond agriculture. Manufacturing needs uninterrupted power because it drives machines and enables production to take place continually, and it also powers the use of modern technologies that ramp up productivity. This advantage also boosts the competitiveness of the manufacturing sector, adding substantially to the non-agricultural GDP. In enterprises, the entrepreneurs can use modern systems of infrastructure and edge technology to do digital businesses, be innovative; developing an entrepreneur environment. Then there's electricity, which is essential for the digital economy, powering infrastructure such as the internet and e-commerce platforms and cloud-computing services.

Spreading the digital economy, it will give an impetus to fintech, e-commerce and IT services and grow non-agricultural GDP.

Access to mobile phones is similarly important in promoting non-farm GDP from financial deepening. People and micro-enterprises are able to access banking, make digital payments or even participate in e-commerce through their mobile phone, even from rural areas or un-banked sites. These drives capital availability to allow entrepreneurs to scale businesses and produce jobs. The growing penetration of mobile financial services fosters diversification into non-farm activities by building personal and business finance skills. In addition, education also has a large impact on non-agriculture GDP through human capital formation. Then there are IT, finance and services workforces that need skill but also education. Education equips workers with the ability to innovate, adapt to new technologies, and enhance productivity in these important sectors. With higher levels of education for more people, they bring with them the creation of new industries of high value that are essential to diversifying the economy. Lastly, a smaller farm size and rural-urban migration cause change in non-agricultural GDP. With population growth and the fragmentation of what land is left for agriculture, many rural workers are increasingly forced to migrate to urban areas seeking alternative employment. Such migration expands the size of urban labor forces and stimulates growth in non-agricultural sectors such as construction, retail trade, and services, etc. It also encourages economic diversity and the development of the non-agricultural part of GDP. Many other government policies within

transport infrastructure, business services, server business policy, and IT-driven industries are positively associated with metropolitan areas. The combined influence of access to electricity, mobile phone usage, education, and migration exerted a reinforcing effect on the process of moving away from a predominantly agriculture-based economy toward one that is more diversified, productive, and propelled by non-agricultural activities.

3. Methodology

3.1. Data sources

This study uses data from five waves (2000, 2005, 2010, 2016, and 2022) of the nationally-representative Household Income and Expenditure Survey (HIES) conducted by the Bangladesh Bureau of Statistics (BBS). A total of 320 district-level observations encompassing non-agricultural GDP, electricity, and control variables, specifically education, farm size, and mobile phone availability from all 64 districts in Bangladesh, are being used. Table 1 presents the variables used along with their definitions and sources.

The analysis involved a descriptive assessment that is succeeded by econometric modeling to analyze the effect of electricity access on non-agricultural GDP. Data analysis is conducted to examine the trend in NagGDP and access to electricity on a district-wise basis, using descriptive statistics, graphs, and tables. This study provides diagrams illustrating NagGDP alongside access to electricity. The summary statistics table presents a comprehensive overview of the central tendency and dispersion of the studied variables, employing mean and standard deviation as key metrics. The mean indicates the

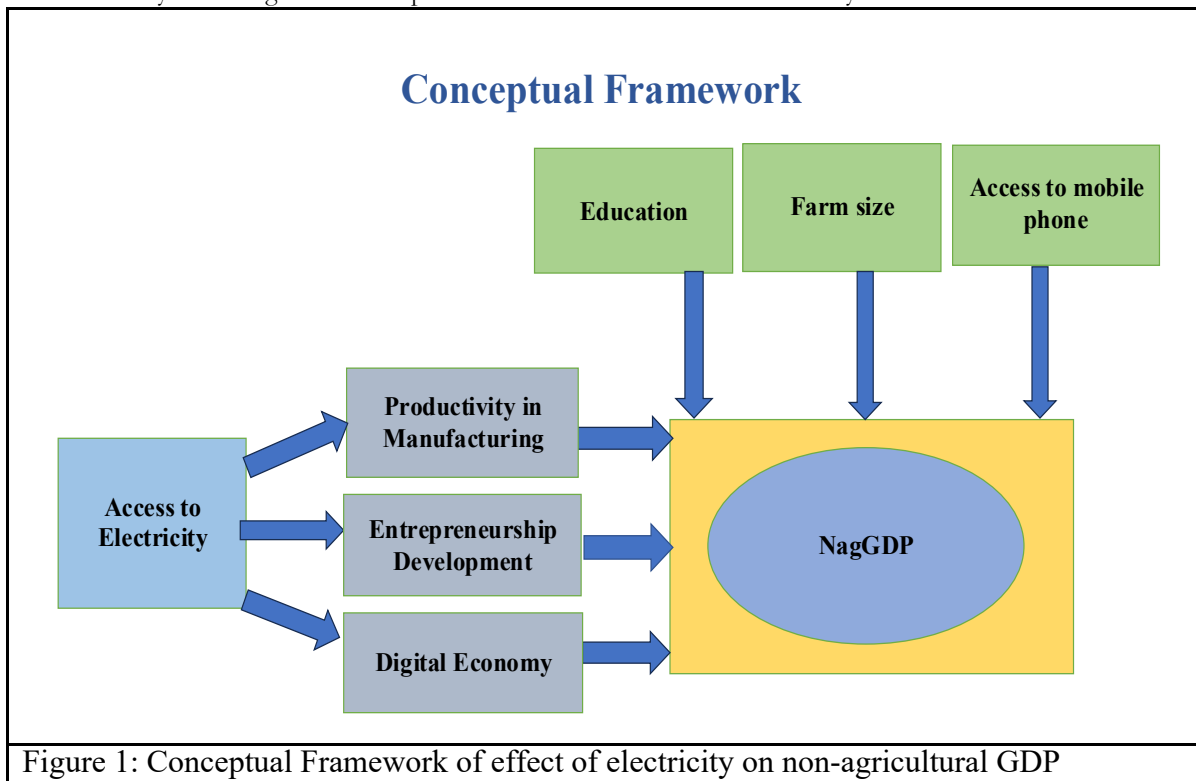


Figure 1: Conceptual Framework of effect of electricity on non-agricultural GDP

Table 1: Definitions of variables and sources

Name of variables	Definition	Sources	Units
The share of non-agricultural GDP	Proportion of non-agricultural GDP in total GDP in rural areas	HIES data (BBS)	Proportion
Access to electricity	The proportion of households with access to electricity for various uses	HIES data (BBS)	Proportion
Farm Size	The mean land allocation per capita within a specified population	HIES data (BBS)	Acre
Access to education	The proportion of individuals with access to educational opportunities	HIES data (BBS)	Proportion
Access to mobile phone	The proportion of individuals with mobile access	HIES data (BBS)	Proportion

average value of the variable, whereas the standard deviation measures the extent of variation or dispersion of values in relation to the mean. A correlation analysis has been performed to assess the relationship between access to electricity and NagGDP.

To explore the relationship between electricity and expansion on NagGDP in Bangladesh, this paper applies quantitative analysis method of panel data. We use panel data for a group of variables, such as NagGDP, access to electricity, access to education, farm size and access to mobile phones. The study applies econometric models Ordinary Least Squares, Fixed Effects Model and Random Effects Model to estimate the effect of electricity access on NagGDP growth holding other factors constant. The choice of econometric methods used will be driven by the data and type of relationship being examined and special attention needs to be given when endogeneity, heteroscedasticity and multicollinearity are present. The purpose of using these models is to adjust the estimates for time-invariant and times-variant unobserved heterogeneity among regions, thereby obtaining more robust and consistent estimates for impact of electricity access on NagGDP growth.

3.2. Econometric model specification

The selection of these control variables is guided by the study's conceptual framework (Figure 1) and supported by the existing literature, ensuring that the estimated effect of electricity access is isolated from other key drivers of non-agricultural GDP growth and thereby strengthening the robustness of the analysis. Access to education is included to account for human capital formation, as higher levels of education enhance workers' skills, innovation capacity, and ability to engage in non-farm sectors such as services, manufacturing, and entrepreneurship (Saha et al., 2025; Islam & Mia, 2007). Access to mobile phone is chosen as a proxy for technological access and digital inclusion, which facilitates financial deepening, market information, e-commerce, and entrepreneurial activities even in rural and unbanked areas (Danquah & Iddrisu, 2018; Fu & Akter, 2016). Farm

size is incorporated to capture the agricultural "push" factor; declining per capita farm size due to population pressure and land fragmentation compels rural households to diversify into non-agricultural activities (Ho & Lin, 2004; Tuyen, 2014).

This paper employed ordinary least squares (OLS), fixed effects model (FEM) and random effects model (REM) regressions to examine the effect of electricity access and control variables on NagGDP. OLS served as the baseline pooled model, assuming no unobserved district-specific effects. The FEM was chosen because it controls for time-invariant unobserved heterogeneity across districts (such as geography, historical infrastructure differences, local institutions, or cultural factors) that may be correlated with both electricity access and non-agricultural GDP growth, thereby eliminating potential bias from omitted variables that are constant over time. The REM was estimated as an alternative specification under the assumption that these district-specific effects are random and uncorrelated with the explanatory variables, which would allow for more efficient estimation and the inclusion of time-invariant regressors if needed. Panel data is now widely used in the econometric analysis due to its advantages than both cross-sectional and time series data (Hsiao, 2007). This study allows for unobserved year dummies (fixed effects) to mitigate unobserved yearly variations (Li et al., 2014). The choice of these models is based on an applicability judgment. OLS has been widely used to derive estimates of GDP (Arouna et al., 2021), while FEM is noting a value for the forecast of GDP in different time period (Aiyar et al., 2021; Rufai et al., 2021). The objective of this study is to explore the impact of access and utilization of electricity at the district level on social-economic transformation in Bangladeshi communities which have transformed from an agriculture-based economy to a non-agriculture-based economy. This study also uses education access, access to mobile phone and farm size as control variables.

This model can be mathematically represented as follows:

$$NagGDP_{it} = \beta_0 + \beta_1 AET + \beta_2 AED + \beta_3 AMF + \beta_4 FS + \mu_i \dots \dots \dots \quad (1)$$

$$NagGDP_{it} = \alpha_0 + \alpha_1 AET + \alpha_2 AED + \alpha_3 AMF + \alpha_4 FS + \mu_i + \tau_i \dots \dots \quad (2)$$

Where NagGDP is expressed as the share of non-agricultural GDP in total GDP (Model 1 and 2); Equation 1, i represents the district, and j represents the year. "AET" represents the access to electricity; and "AED", "AMF", and "FS" indicate access to education, access to mobile phone, and farm size, respectively. Equation 1&2 employs ordinary least square and fixed effect model.

Panel diagnostic tests have been performed to identify the most suitable model for application. Panel diagnostic evaluations offer structured recommendations concerning the appropriateness of particular panel models (Ullan Awan et al., 2018; Jaba, 2017; Baltagi, 2005). The F-test serves as a diagnostic tool in panel data analysis, helping to ascertain the appropriate choice between the pooled OLS model and the FEM. A P-value exceeding 0.05 indicates that the pooled OLS model is deemed valid. The Hausman test is often used as a panel diagnostic tool to assess the suitability of either FEM or REM. When the p-value exceeds 0.05, REM is deemed valid (Jaba, 2017). The diagnostic tests conducted above indicated that FEM is the appropriate method for analysis. To fulfill the requirements of economic modeling, we conducted a test for multicollinearity using the maximum variance inflation factor (VIF). According to Kim (2019), a VIF value below 5 signifies low or absent multicollinearity. The examination revealed low multicollinearity among the variables, with a VIF of 2.04. Alongside the calculation of the VIF, we also generated a correlation matrix. This matrix offers a comprehensive overview of the relationships between each pair of variables in the analysis presented in Table A1, located in Appendix A. The Breusch-Pagan/Cook-Weisberg test is used to assess the presence of heteroscedasticity in the regression model, as detailed in Appendix B. This study reveals no heteroscedasticity issue in this analysis.

A cross-sectional dependency (CD) test was also conducted. The CD test table presented in Appendix C shows that there is no CD among the cross-sectional units in this study. The probability value is greater than 5% for

each model. So, there is no cross-sectional dependency among cross-sectional units (Pesaran, 2004). To assess the robustness of the baseline estimations, we employed feasible generalized least squares (FGLS) instead of FEM. Robustness analysis is a method employed to assess the consistency and reliability of research findings by examining their sensitivity to variations in model or variables. This ensures that the main findings of the baseline analysis remain valid when employing different variables or methods. The results largely corroborate our baseline findings.

4. Results and discussion

4.1. Descriptive statistics

Table 2 presents data on selected variables over time: non-agricultural GDP, access to electricity, farm Size, access to education, and access to mobile phone. The data demonstrates that mean non-agricultural GDP increased with time, from 0.72 in 2000 to 0.84 in 2012. This indicates that a greater number of households successfully obtained non-agricultural income. Increase in access to electricity from approximately 37% in the year 2000 to 66% in the year 2022 might reflect potential advancement for households' ability to fulfil needs including investment outside agriculture, business and education. The government has pursued a set of strategic actions toward increased electricity access, particularly in rural areas, since the early 2000s. These attempts entailed building or extending projects to other regions of the country. Higher grid power availability brings investment, growth of small and microenterprises, societal development, and enhanced lifestyle (Kirubi et al., 2009).

Increases in farm Size, education and access to mobile phone were found across the same period (2000–2022). Access to education leads to a more educated and skilled workforce, which improves the quality of life in rural areas (Zhang et al., 2002). Education-centered workforce development can help Bangladesh improve its skills, productivity, and entrepreneurship (Islam & Mia, 2007).

Table 2 . Summary statistics of non-agricultural GDP, electricity and control variables between 2000-2022

Variables	Total (N=320)		2000 (N=64)		2005 (N=64)		2010 (N=64)		2016 (N=64)		2022 (N=64)	
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
Share of non-agricultural GDP	0.77	0.05	0.72	0.04	0.75	0.04	0.79	0.03	0.82	0.04	0.84	0.04
Access to electricity	0.51	0.14	0.37	0.08	0.46	0.08	0.54	0.09	0.61	0.11	0.66	0.12
Farm Size	0.34	0.09	0.41	0.08	0.36	0.07	0.33	0.07	0.29	0.06	0.26	0.06
Access to education	0.45	0.08	0.36	0.05	0.42	0.06	0.48	0.06	0.54	0.05	0.61	0.05
Access to mobile phone	0.32	0.09	0.14	0.05	0.18	0.06	0.44	0.06	0.50	0.07	0.58	0.07

Source: Author's calculations

Table 3: Correlation matrix

	NagGDP	AET	AED	AMF	FS
NagGDP	1.0000				
AET	0.6806	1.0000			
AED	-0.4948	-0.6059	1.0000		
AMF	0.6795	0.6557	-0.5559	1.0000	
FS	0.7137	0.6392	-0.4330	0.6260	1.0000

Decreasing farm size has subsequently resulted in less access to arable land and many of them have been compelled either to take up non-farm activities or search new means of livelihood (Ho & Lin, 2004). According to Tuyen (2014), land limitation generated jobs for working outside of agriculture. Similar results, we discovered mobile phone subscriptions ramped-up between 2005 and 2013 from 1.2 billion in developing nations to 5.2 billion (Umali, 2024).

All variables showed trends of increasing over time except farm size; overall, there has been improvement in the socio-economic situation of rural Bangladesh. These findings add to the knowledge base on trends and transitions, as well as potential implications for policy and programming in Bangladesh.

4.2. Pairwise correlation Matrix

Pearson's correlation coefficient was performed in order to check for multicollinearity between the variables. According to Senaviratna & Cooray (2019), suggests that high problems of multicollinearity exists when r is greater than or equal to 0.8 between two independent variables. In Table 3, our findings suggest the absence of a strong correlation among independent variables and thus we may safely rule out multicollinearity. The correlation matrix, presented for seven variables, reveals the relationships with coefficients from perfect negative (-1), through no (0) to perfect positive (1) correlations and points up significant positive relationships among a number of the variables like non-agricultural GDP, access to electricity, farm Size, education status and mobile phone access. This matrix is useful to determine if there might be any data issues such as multicollinearity.

4.3. Correlation between access to education and non-agricultural GDP

The interaction between non-agricultural GDP and access to electricity variable captures availability of infrastructural access rather than non-agricultural output. In Figure 2, we observe that non-agricultural GDP growth between 2000 and 2022 is positively correlated with electricity access at the district level in Bangladesh. This indicates that access to electricity is allowing households to diversify away from agriculture. It also indicates that regions with a greater level of electricity

access will experience more non-agricultural output share than their lower access counterparts. This is also corroborated by the study of Chakravorty et al., (2014) that finds that electricity has a significant impact on non-agricultural income and production in India. This result underscores the significance of household electricity for diversification and non-farm income generation.

4.4. Econometric results of the effect of access to electricity on non-agricultural GDP

This study empirically examines the impact of electricity on non-agricultural GDP at the regional level in Bangladesh. The results are derived by three econometric models, namely OLS, FEM and REM in panel database of 320 observations. Estimation results from the FEM show that access to electricity has a statistically significant but relatively modest effects on non-agricultural GDP growth with the coefficient on access to electricity as 0.027 at 10% level of significance. It means that when the share of households with access to electricity rises by 1 percentage point, the share of non-agricultural GDP in total GDP increases by about 0.027 percentage points, all else equal. This result is statistically significant at the 10% level, indicating we can be reasonably confident that the positive relationship between electricity access and non-agricultural GDP is genuine and not simply due to random chance. In Table 4. This effect persists, although a little diminished from the magnitude in the OLS model, despite controlling for time-invariant regional heterogeneity. The strongly positive effect of electricity access in NagGDP growth underscores the importance of infrastructure extension as a leading factor for shaping economic activity beyond agriculture, especially in backward areas.

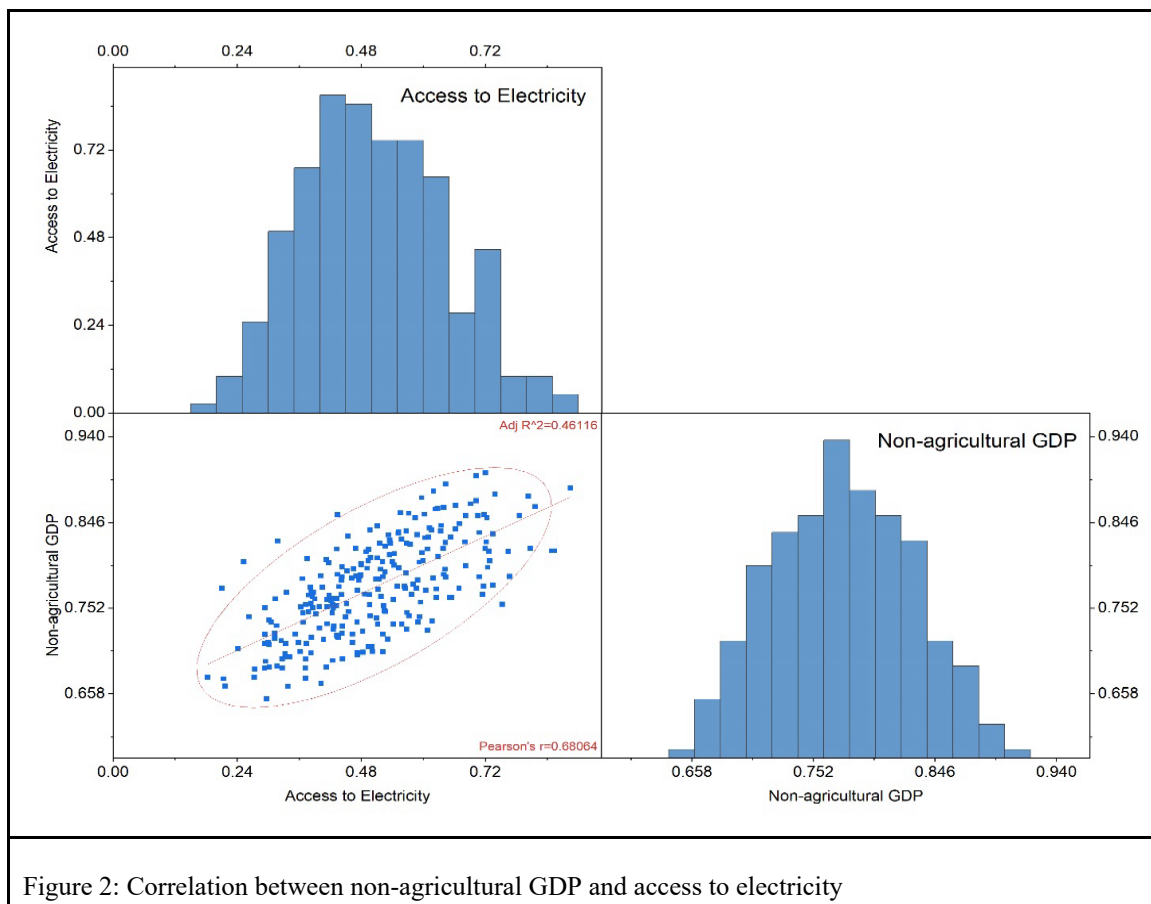
In contrast, the electricity coefficient is much lower in FEM (0.094, significant at the 1% level) but it continues to be positive and significant, indicating that lack of access to electricity still matters for diversification into new lines of business. The marginal reduction in the coefficient in the FEM suggests that regional unobserved heterogeneity, which is controlled by time-invariant effects (e.g., historical/geographical differences across regions) in the FEM, will influence risk preference. Our results are in line with some other studies, for instance: there is positively related between electricity access and rural economy of

Bangladeshi people by Chowdhury & Khan (2025). Moreover, Subrata Saha et al. (2025) stresses that there is a dire need for infrastructure improvements, including electricity to speed up the process of economic diversification in rural areas of Bangladesh.

The regression coefficient for education on non-agricultural GDP is also significant in all three models and is considerably large in the FEM, 0.479 (significant at 1%). This means that more years of schooling are positively associated with non-agricultural growth. The coefficient indicates that the more advanced the education infrastructure, the higher the share of its economy generated through non-agricultural sectors. This

NagGDP reveals the need to invest in them to attain successful long-run growth.

The significance of the relationship between farm size and non-agricultural GDP is consistent across all specifications, whether in FEM (where it is found to be negative (-0.010) at 10% level). This inverse relationship may indicate that larger farms are dragging feet with respect to economic diversification, especially in non-farming occupations. One potential reason for this negative impact is that on average the larger farms are more dependent on traditional agricultural practices and subsequently are less likely to adopt new non-agricultural technologies/practices. In addition, larger farms might



highlights the importance of human capital formation in economic diversification, since educated individuals became less dependent on farming and more involved in non-farming activities, promoting innovation and entrepreneurship.

This is consistent with the findings of Barro & Lee, (2019) that increasing educational levels have significantly increased non-agriculture GDP growth and also labor productivity and competitiveness. Furthermore, Saha et al. (2025) have been of the view that the accumulation of human capital has significant role in driving economic growth, particularly for less developed countries. A positive association between these social drivers and

require more labour force resulting in an oversupply of labor force and subsequently fewer resources for other economic activities while contributing less to the non-agricultural GDP. This is in line with studies which report that the decrease in per capita land has reduced access to land for agricultural activity and encouraged people to move into non-farm work activities (Ho & Lin, 2004). Describing this perspective, Tuyen (2014) find that smaller and relatively more diversified holdings are typically in a better position to adapt to new technologies and enter non-agricultural activities such as rural entrepreneurship or off-farm employment. By size of farm, the larger a farm, the less flexible of its economic

Table 4: Effect of electricity on non-agricultural GDP

	(OLS) Nag GDP	(FEM) Nag GDP	(REM) Nag GDP
Electricity	0.094*** (0.000)	0.027* (0.075)	0.038** (0.011)
Education	0.157*** (0.000)	0.479*** (0.000)	0.433*** (0.000)
Farm size	-0.022* (0.094)	-0.010* (0.083)	-0.009* (0.075)
Access to mobile phone	0.227*** (0.000)	0.015* (0.081)	0.049** (0.048)
_cons	0.568*** (0.000)	0.542*** (0.000)	0.542*** (0.000)
<i>N</i>	320	320	320
<i>R</i> ²	0.632	0.979	

p-values in parentheses: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

activity and hence slower in venturing into other economic activities.

Mobile phone access also significantly increases non-agricultural GDP growth, as suggested by the FEM coefficient of 0.015 at 10%. This finding is consistent with earlier research (Danquah & Iddrisu, 2018), which accentuates the function of mobile phones for information dissemination, market access and inclusion into financial services; these eventually support non-agricultural sector growth. The coefficient is weaker than in the OLS model (0.227, significant at 1%) but still positive and significant, which emphasizes that mobile connectivity helps support non-agricultural economic activities. This indicates that mobiles are a significant catalyst for non-agricultural growth, particularly in areas without established infrastructure. Further, as noted in studies, like Fu & Akter (2016), mobile phone access is likely to lead to increased market efficiency by lowering transaction costs which permit a better price of goods and services for rural people.

The use of multiple estimators (OLS, FEM, and REM) allows us to assess the robustness of the results under different assumptions regarding unobserved heterogeneity. The high degree of consistency observed across these models, particularly in the sign, statistical significance, and magnitude of the coefficients (especially for access to electricity), indicates that time-invariant

district-specific effects do not substantially bias the pooled OLS estimates. This similarity in coefficient sizes suggests that the relationship between access to electricity and non-agricultural GDP is stable and not driven by unobserved regional heterogeneity, thereby providing stronger confidence in the reliability and robustness of the findings.

4.5. Robustness check with Feasible Generalized Least Squares (FGLS) Model

FGLS can address the potential problems of heteroskedasticity and serial correlation in the panel data, leading to improved efficiency and consistency of the coefficient estimates (Saha et al., 2025). That is, our findings indicate that there is a positive effect of electricity on non-agricultural GDP regardless of the model used (FGLS, FEM and OLS), as shown in Table 5_while simple cross-sectional projections support this conclusion. FGLS provides some reduction in coefficients because of its ability to handle panel-specific variances. This helps to confirm the stability of the relationship between non-agricultural GDP and electricity, which provides credibility to our analysis results and ensures it is not model dependent.

5. Conclusion

This paper examines the relationship between access to electricity and non-agricultural GDP growth in

Table 5: Robustness check with FGLS Model

	NagGDP	Standard Dev.
Electricity	0.080***	(0.001)
Farm size	-0.022	(0.420)
Education	0.142***	(0.002)
AMF	0.250***	(0.006)
_cons	0.572***	(0.000)
<i>N</i>	320	
<i>R</i> ²	0.642	

p-values in parentheses: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Bangladesh and demonstrates empirically that lack of access is a major constraint on economic diversification. In addition, the analysis shows that education, having access to a mobile phone, as well as farm size are complementary factors that increase the intensity with which the correlation of electricity access and economic growth is seen. That payoff from mobile phone access illustrates the power of digital connections to foster economic activity, particularly outside agriculture, through better information exchange and market access as well as greater financial inclusion. The study, therefore, recommends the subsequent concrete measures. In order to ensure a reliable 24/7 supply in non-farm industrial areas, the government and stockholders, particularly the Ministry of Power, Energy and Mineral Resources, Bangladesh Rural Electrification Board, and local government institutions, should prioritize large-scale grid extension and modernization in lagging districts, accelerate renewable mini-grid and solar home system programs, introduce targeted subsidies or performance-based incentives, and integrate electricity access targets into national rural development and digital Bangladesh initiatives. The private sector, which includes power distribution companies, renewable energy developers, telecom operators, and microfinance institutions, should establish public-private partnerships for off-grid electrification projects, invest in last-mile connectivity solutions, develop bundled electricity-plus-digital service packages for rural micro-enterprises, and provide customized financing products for electricity-powered businesses and non-farm entrepreneurship. The acceleration of Bangladesh's structural transformation toward a diversified, productive, and inclusive economy will be contingent upon the simultaneous investments in education and mobile connectivity, as well as the coordinated efforts of government bodies and private sector stakeholders.

Although the analysis yields important policy insights on the linkage between electricity access and non-agricultural GDP growth in Bangladesh, a study of this nature does not come without its limitations. To begin, the data utilized in this study is based on panel data from the Household Income and Expenditure Survey, which, though comprehensive, may suffer for one reason or another, including measurement errors (under coverage) with regard to accounting for all pertinent variables that may affect the growth of non-agricultural GDP. Second, our study does not sufficiently control for potential endogeneity between electricity access and economic growth, although we address this issue using methods (e.g., panel data models). The models may not account for unobserved heterogeneity that influences both electricity access and GDP growth. Omitted variable bias can be of concern, as a sudden excessive abuse or lack of government regulation will influence the results where the absence of (enforcement) quality infrastructure, finance access, or policies of government were not all embodied

in our analysis. In addition, the analysis mainly focused on electricity access as a critical factor of interest without delving into the potential implications of renewable energy, which may be increasingly important for achieving Bangladesh's increasing energy demand sustainably.

Future study could extend this by investigating the varying effects of electricity access on non-agriculture activities. Although we have examined the aggregate GDP growth of non-agricultural sectors, separate examination of different sub-sectors such as manufacturing, services, and construction would help to unravel the differentiated effects of access to electricity. Moreover, the analysis of renewable energy (such as solar and wind) in expanding access to electricity sustainably would also be an important policy lesson, considering that Bangladesh is moving towards diversified sources of energy and distancing itself from fossil fuel dependence. Future research might also consider the socio-economic implications of access to electricity for socially excluded communities in general, whether they are tea laborers or marginalized people living in rural areas (where better energy infrastructure may not automatically lead to better standards of living). With reference to these communities, a study of the constraints to the efficient use of power (in terms of accessibility, affordability, firmness, and adoption of energy-efficient technologies) would offer more targeted interventions, which will ensure inclusive growth. In addition, it would be useful to explore the role of digital technologies (such as mobile money and e-commerce) in realizing socio-economic benefits of electricity access. Furthermore, given Bangladesh's commitments towards sustainable development and climate goals, an important area for future research is to explore the role of renewable energy sources especially solar and wind power to expand reliable and affordable access to electricity by assessing their cost-effectiveness, environmental benefits and specific contribution to long-term non-agricultural GDP growth.

Analyzing the interrelation between electricity access, digital infrastructure, and economic outcomes may offer important policy lessons on how to exploit electricity access for broader socio-economic development. Furthermore, gathering primary data from firms and households would also help to supplement the shortcomings of secondary data and yield a clear image of the effects of electricity access on economic activities. By filling in these research gaps, future studies should improve our understanding of the electricity-growth nexus and offer valuable policy implications for policymakers intending to bolster sustainable and inclusive economic growth in Bangladesh as well as other developing countries.

Appendix A

Table A 1: Mean VIF

Variables	VIF
Access to electricity	2.38
Farm Size	1.70
Access to education	2.15
Access to mobile phone	1.94
Mean VIF	2.04

Appendix B

The Breusch-Pagan/Cook-Weisberg test for heteroskedasticity

This study performed the Breusch-Pagan/Cook-Weisberg test to assess if a regression model violates the assumption of constant variance (homoskedasticity). The null hypothesis (H0) in this test suggests that variance remains constant, indicating that error terms exhibit uniform variation across all independent variable levels. If the p-value of the chi-squared test result is greater than the significance level (usually 0.05), the null hypothesis cannot be rejected, suggesting no presence of heteroskedasticity. Heteroskedasticity is indicated if the p-value is lower than the significance level. The p-values of 0.1013, 0.2092, and 0.1255 correspond to small, medium, and large farm sizes, respectively. These values are significantly higher than the conventional significance level of 0.05, indicating that the null hypothesis (H0: constant variance) cannot be rejected. These models exhibit no evidence of heteroskedasticity.

Appendix C

Pesaran CD test is cross-sectional independence

Pesaran CD test	
Probability value	0.9569
T-statistics	0.054

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