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THE BOTTOM LINE

Many of the enterprises that make up Bangladesh's dominant nonfarm sector (85 percent of GDP) are located in rural areas (World Bank 2015). Electrifying them can be a major driving force behind economic growth. This study is a product of the Status of Energy Access Report (SEAR), an initiative of the Energy Sector Management Assistance Program at the World Bank. By documenting the effects of energy access programs on beneficiaries' welfare, SEAR enables policy makers and other stakeholders to understand better the linkage between energy interventions and benefits and to make informed decisions about projects.

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How Do Enterprises Benefit from Grid Connection? The Case of Rural Electrification in Bangladesh

Does electrification increase productivity?

Cross-country evidence suggests that it does

Rural electrification increases enterprise productivity in several ways: It allows businesses to operate well into the evening, giving them more hours per day to generate sales and profits; it creates a more comfortable work environment; and it allows enterprises to use machinery and tools that are more efficient and productive than their nonelectrical counterparts.

In rural Bangladesh, output increased by 78 percent in grid-connected industries but only 8 percent in unconnected industries over a five-year period (Barkat and others 2002). Grid-connected industries generated 11 times more employment than unconnected industries; profits were higher (35 percent of sales in grid-connected industries and just 16 percent in unconnected enterprises); and turnover at grid-connected retail shops was more than twice that of unconnected shops.

In rural Tanzania, grid connectivity increased the financial and physical assets of enterprise owners, and people in the community benefitted from the use of electrical machinery (Maleko 2005). In small carpentry and tailoring shops in rural Kenya, adoption of electricity increased productivity per worker, lowered unit prices, and increased gross daily revenues (Kirubi 2006). Some agro-based industries also benefited from electrification. Maize processed by an electric milling machine fetched a much higher price than unprocessed maize, and electric-powered cold storage allowed farmers to preserve meat and milk longer and command prices that were four times higher over time.

How much progress has been made with rural electrification in Bangladesh?

A dense network of rural electric cooperatives has been very successful in expanding access to electricity

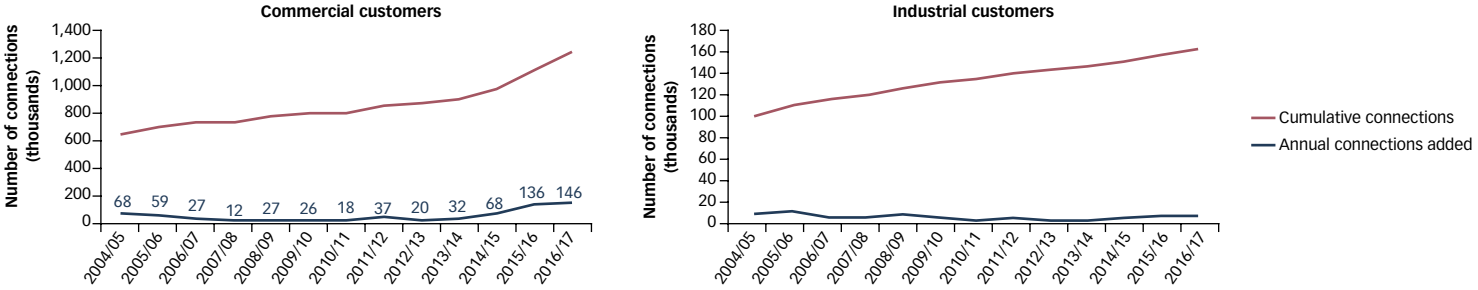
Responsibility for providing electricity in rural areas falls under the purview of the Bangladesh Rural Electrification Board (BREB), a semi-autonomous government agency established in 1977 within the Ministry of Power. Based on the U.S. model of consumer-owned rural electric cooperatives, BREB organizes prospective consumers into autonomous rural electric cooperatives called *palli bidyut samitis* that own, operate, and manage rural distribution systems within their areas of jurisdiction. BREB monitors the operation, administration, and financial management of the cooperatives.

The 80 cooperatives in Bangladesh are active in more than 75,000 villages in 61 districts. Serving 12 million residential, 1.5 million commercial, and more than 160,000 industrial customers, they have been highly successful in expanding access to electricity (figure 1). Average system loss is less than 12 percent (much less than the national average), and the bill collection rate exceeds 99 percent.[1]

[1] The cooperatives' financial sustainability is not always guaranteed. During periods of delayed tariff adjustments, operations and maintenance and debt service suffer. Commercial customers are customers engaged primarily in retail business (trade) or services. Industrial customers are engaged in production and processing activities.

The 80 rural electric cooperatives in Bangladesh have been highly successful in expanding access to electricity.

Figure 1. Annual and cumulative number of connections of BREB commercial and industrial customers, 2004/05–2016/17



Source: Information obtained by authors from Chief Engineer's Office, BREB.

How are the benefits of electrification measured?

Several techniques were applied to gauge the gains from electrification

An impact evaluation compares outcomes between a treatment group (enterprises that are connected to the grid) and a control group (enterprises not connected to the grid), called the counterfactual. Determining the counterfactual is at the heart of any impact evaluation endeavor; different evaluation techniques make different assumptions about how to construct it.

Two evaluation techniques were used to measure the impact of electrification in rural Bangladesh.

- **Fixed-effects (FE) method:** In its simplest form, the FE method consists of first measuring the difference in the outcome variables between two periods for the treatment and control groups and then taking a second difference between the two differences measured earlier (a technique known as "difference of differences" modeling). The second difference is the estimated impact. In a more advanced form, regression is used to control for factors other than the intervention that might have influenced outcomes. FE controls for unobserved factors as long as they do not change between survey periods.[2]
- **Inverse probability-weighted FE estimation (IPW-FE):** IPW-FE is a two-step process that controls for time-varying unobserved factors. In the first step, the probability of grid connectivity of each enterprise (called the propensity score) is calculated using the first-round data based on a wide range of control variables.[3] The probability is measured for both the treatment and the control groups. In the second stage, the propensity score is used to create a weight, which is then used in the FE regression (similar to the one described earlier) to estimate impacts.[4] IPW-FE provides more unbiased estimates of impacts than does simple FE, and thus is preferable to it.

The data for this study came from two panel surveys of commercial and industrial enterprises carried out in 2005 and 2010 in rural Bangladesh.

More than 3,000 commercial enterprises were surveyed in 2005, of which about 2,000 were resurveyed in 2010. After data cleaning 1,571 commercial units were deemed suitable for panel data

[2] Unobserved factors are factors that may influence the outcomes but that are not (or cannot be) measured. Examples include the entrepreneurship skills of the enterprise owner or foresight about market trends.

[3] Control variables include sex of the enterprise owner, sole proprietorship, size of the enterprise, years of operation, enterprise capital, share of hired labor, operating cost, use of alternate sources of electricity (such as generator sets) or fuels by the enterprise (kerosene, for example), prices of alternate fuels, and so on.

[4] The weight is the inverse of the probability of grid connectivity. That is, it is given by $w = \frac{1}{p}$, for grid-connected enterprises, and $w = \frac{1}{(1-p)}$ for enterprises not connected to the grid, where p is the probability of grid-connectivity.

The electrification rate increased between 2005 and 2010, rising from 52 percent to 69 percent for commercial enterprises, and from 88 percent to 93 percent for industrial enterprises.

Table 1. Electrification rate in commercial and industrial enterprises (percent)

Division	Commercial enterprises		Industrial enterprises	
	2005	2010	2005	2010
Barisal	55.6	67.5	88.6	90.1
Chittagong	52.4	69.2	85.6	92.6
Dhaka	54.3	64.0	86.7	97.0
Khulna	55.6	85.9	94.2	95.3
Rajshahi	49.5	67.1	88.9	93.3
Sylhet	41.2	57.1	80.9	83.8
Total	52.0	69.0	88.2	93.4

Source: BREB surveys 2005, 2010.

Table 2. Revenues, profits, and profit margins of grid-connected and nonconnected commercial enterprises, 2010

Item	Enterprises with grid connection	Enterprises without grid connection	Statistical significance of the difference
Revenue (thousand Tk/year)			
Trading enterprises	1,097.1	753.4	***
Service enterprises	199.1	233.9	—
All enterprises	982.0	689.4	***
Profit (thousand Tk/year)			
Trading enterprises	381.0	318.4	*
Service enterprises	89.0	70.6	**
All enterprises	343.5	287.9	*
Profit margin			
Trading enterprises	0.294	0.298	—
Service enterprises	0.438	0.486	—
All enterprises	0.312	0.320	—

Source: BREB surveys 2010.

***, ** and * indicate statistical significance of 1, 5, and 10 percent, respectively.

— no statistical significance.

analysis. Similarly, about 1,600 industrial enterprises were surveyed in 2005, of which about 1,175 were resurveyed in 2010. After data cleaning, about 1,025 industrial enterprises remained for analysis.

The surveys collected information on basic characteristics of commercial and industrial enterprises (type of activity and ownership, years of operation, months of operation per year, capital assets, labor use, operating cost) as well as information on their energy use (source, type of use, and consumption of electricity). In addition, for grid-connected enterprises, information on reliability and quality of service was collected. The surveys covered 287 villages from 40 districts in 6 divisions.

The data revealed that the electrification rate increased between 2005 and 2010, rising from 52 percent to 69 percent for commercial enterprises, and from 88 percent to 93 percent for industrial enterprises (table 1).

How did electrification affect enterprises in rural Bangladesh?

Electrification effects on revenues, profits, and profit margins varied with the type and size of the enterprise and with the reliability of service

We begin with a short review of descriptive statistics before moving on to a discussion of the results of impact evaluations conducted using the rigorous techniques discussed in the previous section.

The revenue and profit of grid-connected commercial enterprises were mostly higher than those of unconnected enterprises, and the differences were statistically significant (table 2). In contrast, the profit margin of unconnected commercial enterprises was higher than that of grid-connected enterprises, although the difference was not statistically significant.

Among small and micro industrial enterprises, grid-connected enterprises performed better than unconnected enterprises (table 3). In contrast, for medium-size and large industrial enterprises, unconnected enterprises performed better. Most of the differences

Causality between grid electrification and the observed outcomes can be ascertained only through rigorous impact evaluations. Impacts varied by the type of activity and the size of the enterprises.

Table 3. Revenues profits, and profit margins of grid-connected and nonconnected industrial enterprises, 2010

Item	Enterprises with grid connection	Enterprises without grid connection	Statistical significance of the difference
Revenue (thousand Tk/year)			
Small and microenterprises	1,313	697	***
Medium-size and large enterprises	8,840	12,976	**
All enterprises	2,933	1,948	***
Profit (thousand Tk/year)			
Small and microenterprises	653	263	***
Medium-size and large enterprises	6,012	9,979	—
All enterprises	1,807	1,264	**
Profit margin			
Small and microenterprises	0.30	0.23	**
Medium-size and large enterprises	0.34	0.43	—
All enterprises	0.31	0.25	*

Source: BREB surveys 2010.

***, ** and * indicate statistical significance of 1, 5, and 10 percent, respectively.

— no statistical significance

in outcomes between grid and unconnected enterprises were statistically significant.

While descriptive statistics, such as those reported in tables 2 and 3, are indicative of the status of outcomes of grid-connected enterprises relative to unconnected ones, they do not imply causality between grid electrification and the observed outcomes. Causality can be ascertained only through rigorous impact evaluations, using techniques such as those described in the previous section. Findings from evaluations using the FE and IPW-FE methods are discussed below.

Grid electrification raised the revenue of commercial enterprises by 25–28 percent and increased their profits by 35–39 percent (table 4). For profit margins, the FE estimates were not statistically significant, whereas the IPW-FE estimates found that profit margins were 14 percentage points higher for grid-connected enterprises. The revenues and profits of industrial enterprises also increased substantially after connection to the grid—by 43 percent and 32 percent, respectively based on IPW-FE estimates (table 5). Grid access did not affect the profit margins of industrial enterprises, however—possibly because of diminishing returns on profits as revenue grows.

Impacts varied by the type of activity and the size of the enterprises. The IPW-FE estimation revealed that grid connectivity appeared to have had a greater effect on the revenue of trading enterprises (27.1 percent increase) than service enterprises (17.6 percent increase) but that profits increased more for service enterprises (46.1 percent) than for trading enterprises (31.6 percent). The effect of grid connection on profit margins was the same for trading and services enterprises (table 6).

Table 4. Impact of grid electrification on revenues, profits, and profit margins of commercial enterprises

Item	FE estimates	IPW-FE estimates
Revenue (percent change)	25.3***	28.0***
Profit (percent change)	35.0**	39.1**
Profit margin (change in percentage points)	—	14*

Source: BREB surveys 2005, 2010.

***, ** and * indicate statistical significance of 1, 5, and 10 percent, respectively.

— no statistical significance.

Table 5. Impact of grid electrification on revenues, profits, and profit margins of industrial enterprises

Item	FE estimates	IPW-FE estimates
Revenue (percent change)	35.7*	43.3*
Profit (percent change)	23.1*	32.1*
Profit margin (change in percentage points)	—	—

Source: BREB surveys 2005, 2010.

***, ** and * indicate statistical significance of 1, 5, and 10 percent, respectively.

— no statistical significance.

Grid electrification raised the revenue of commercial enterprises by 25–28 percent and increased their profits by 35–39 percent. The revenues and profits of industrial enterprises also increased substantially after connection to the grid—by 43 percent and 32 percent.

Table 6. Impact of grid electrification on revenues, profits, and profit margins of trading and services enterprises

Item	FE estimates	IPW-FE estimates
Revenue (percent change)		
Trading enterprises	27.5***	27.1***
Service enterprises	20.2**	17.6**
Profit (percent change)		
Trading enterprises	37.0**	31.6**
Service enterprises	43.4 ***	46.1**
Profit margin (change in percentage points)		
Trading enterprises	—	18*
Service enterprises	18*	18*

Source: BREB surveys 2005, 2010.

***, ** and * indicate statistical significance of 1, 5, and 10 percent, respectively.

— no statistical significance.

Table 7. Impact of grid electrification on industrial enterprises, by size

Item	FE estimates	IPW-FE estimates
Revenue (percent change)		
Small and microenterprises	37.6*	—
Medium-size and large enterprises	46.9**	45.2**
Profit (percent change)		
Small and microenterprises	26.4*	25.7*
Medium-size and large enterprises	22.7**	33.7**
Profit margin (change in percentage points)		
Small and microenterprises	—	—
Medium-size and large enterprises	0.12*	0.22*

Source: BREB surveys 2005, 2010.

** and * indicate statistical significance of 5 and 10 percent, respectively.

— no statistical significance.

Table 8. Average daily duration of power outages (hours) in commercial and industrial enterprises, 2005 and 2010

Enterprise type	2005	2010
Commercial	7.3	5.6
Industrial	7.0	5.2

Source: BREB surveys 2005, 2010.

Among industrial enterprises, medium-size and large firms gained more from grid electrification than did small and microenterprises (table 7). This is not surprising. Medium-size and large enterprises use higher-capacity machinery, consuming more power than smaller and microenterprises. One would therefore expect them to make more productive and efficient use of electricity.

Grid connectivity alone may not be enough to yield the maximum benefits from electrification. Lack of reliability and service interruptions increase the cost of using electricity, as enterprises are forced to rely on alternate sources of energy or back-up generators. So, it is important to look at the effects of the reliability of electricity service on the outcomes.

The duration of daily power outages declined between 2005 and 2010 (table 8). Still, firms faced more than five hours of outages a day.

As tables 9 and 10 show, improving the reliability of service can substantially increase the benefits of electrification for enterprises. For each additional hour of power outage, revenues of commercial enterprises fall by 4.6 percent and profits by 6.0 percent. In the absence of power outages, grid electrification can increase commercial enterprises' revenues by 48 percent and profits by almost 60 percent (table 9). For industrial enterprises, the gains associated with reliability are even greater: 59 percent for revenue and 60 percent for profit (table 10)

Improving the reliability of service can substantially increase the benefits of electrification. In the absence of power outages, grid electrification can increase commercial enterprises' revenues by 48 percent and profits by almost 60 percent. For industrial enterprises, the gains associated with reliability are even greater.

Table 9. Impact of service reliability on commercial enterprises

Item	FE estimates	IPW-FE estimates
Revenue (percent change)		
Impact with no outage	56.8***	47.5**
Impact of one hour of outage	–4.2**	–4.6**
Profit (percent change)		
Impact with no outage	64.4***	59.5
Impact of one hour of outage	–4.7*	–6.0**
Profit margin (change in percentage points)		
Impact with no outage	—	19.5*
Impact of one hour of outage	—	–1.4**

Source: BREB surveys 2005, 2010.

***, ** and * indicate statistical significance of 1, 5, and 10 percent, respectively.

— no statistical significance.

Table 10. Impact of service reliability on industrial enterprises

Item	FE estimates	IPW-FE estimates
Revenue (percent change)		
Impact with no outage	66.6*	68.9*
Impact of one hour of outage	–6.7*	–7.6**
Profit (percent change)		
Impact with no outage	65.2*	59.7*
Impact of one hour of outage	–7.4**	–6.3**
Profit margin (change in percentage points)		
Impact with no outage	—	—
Impact of one hour of outage	—	—

Source: BREB surveys 2005, 2010.

***, ** and * indicate statistical significance of 1, 5, and 10 percent, respectively.

— no statistical significance.

What are the policy implications?

Policy makers can multiply the beneficial effects of electricity by expanding grid coverage, increasing grid reliability, and promoting off-grid electrification where appropriate

In 2013, only about one million of the Bangladesh's three million rural enterprises were connected to the electrical grid.[5] This rate has to be raised.

Increasing grid reliability will require more transmission and distribution lines. During 2009–18, about 200,000 kilometers of transmission line were installed, and 370 substations (with a total capacity of about 5,500 MVA) were built. BREB has recently undertaken 15 projects to improve transmission and distribution. These are positive signs.

Off-grid electrification should be promoted in areas where extension of the grid is not feasible. Bangladesh's Infrastructure Development Company Limited (IDCOL) has been promoting solar mini-grids to serve household and enterprise energy needs in remote and isolated areas, especially on riverine islands. Seventeen solar mini-grid projects are in operation, and IDCOL has a target of installing 200 solar mini-grids by 2025.

Energy from solar mini-grids is expensive—more than Tk 30/kWh, compared with an average of Tk 8/kWh for grid energy. Instead of connecting to a mini-grid, some enterprises can use large stand-alone solar panel systems, which are now feasible because of the sharp decline in the price of solar panels and storage technology. These systems can charge electric vehicles and power solar freezers for dairy farms, agricultural produce storage, fish storage, and egg incubators.

[5] Some unconnected establishments have access to solar home systems or solar mini-grids. The actual electrification rate is therefore higher than the grid connectivity rate.

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References

Barkat, A., M. Rahman, S. Zaman, A. Podder, S. Halim, N. Ratna, M. Majid, A. Maksud, A. Karim, and S. Islam. 2002. "Economic and Social Impact Evaluation Study of the Rural Electrification Program in Bangladesh," Report to the National Rural Electric Cooperative Association International. Dhaka: Human Development Research Centre.

Kirubi, C. 2006. "How Important Is Modern Energy for Micro-enterprises? Evidence from Rural Kenya," Thesis, Master of Science in Energy and Resources, University of California, Berkeley.

Maleko, Godwin C. 2005. "Impact of Electricity Services on Micro-Enterprise in Rural Tanzania." University of Twente, Department of Energy and Sustainable Development, Enschede, Netherlands.

World Bank. 2015. "Bangladesh: More and Better Jobs to Accelerate Shared Growth and End Extreme Poverty. A Systematic Country Diagnostic." Discussion Draft.

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