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The Welfare Impact of Rural Electrification: A Reassessment of the Costs and Benefits

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Abstract

Electrification brings more than light. Its second most common use is for television, which brings both entertainment and information. The people who live in rural areas greatly appreciate these benefits and are willing to pay for them at levels more than sufficient to cover the costs. However, the evaluation of these and other benefits (for example, in terms of public goods), as well as of their distribution, has been sparse. This report reviews recent methodological advances made in measuring the benefits of rural electrification (RE) and commends them. It also notes that the understanding of the techniques shown in project documents is sometimes weak, and quality control for the economic analysis in project documents lacking. This study shows that willingness to pay (WTP) for electricity is high, exceeding the long-run marginal cost of supply. Hence, in principle, RE investments can have good rates of return and be financially sustainable. But caveats are in order. The first caveat is that attention needs to be paid to ensuring least cost supply, including limiting system losses. Second, continued attention needs to be paid to achieving the right balance between financial sustainability and reaching the poor. The World Bank has been financing RE for decades in Asia, and it has been expanding such activities in Latin America and Africa. Its support for RE has focused on outputs—building infrastructure and institutions. Yet outcomes have often been missing from project objectives; when present, they are assumed to follow automatically from the outputs. But the connection cannot be taken for granted. Project design components to ensure that outputs do result in the intended outcomes are rare, though they are increasing. To give this results orientation further impetus, this assessment by the Independent Evaluation Group (IEG) examines anew the costs and benefits of RE for Bank-supported projects in several Regions of the world

Keywords: RE, IEG, WTP, ESMAP, Impact.

1. Introduction

The World Bank has made loans for power generation, transmission, and distribution since its earliest years. By the 1980s it was lending substantial amounts for expanding coverage into rural areas. However, a 1994 IEG report, *Rural Electrification in Asia*, cast doubt on these investments, arguing that the rates of return were low because many of the claimed benefits were not realized and that the costs of these programs imposed a financial burden on the provider. Since that time, financial reforms have been implemented in a number of countries, and the RE portfolio has seen significant shifts in terms of project objectives and design. In addition, in response to that IEG report, the Energy Sector Management Assistance Program (ESMAP) carried out a study in the Philippines to quantify a broader range of benefits from RE. Most notably, that study developed a new methodology for measuring the benefits of electric lighting that has been widely adopted in project appraisals has long been claimed that rural electrification greatly improves the quality of life. Lighting alone brings benefits such as increased study time and improved study environment for school children, extended hours for small businesses, and greater security. Giving very acceptable rates of return. The main focus of IEG's current study is to review these claims and examine the extent to which changes in the portfolio have addressed earlier concerns regarding the limited poverty impact of lending to RE. The study analyzed data from a range of sources, including IEG's own analysis of existing data sets for a dozen countries (three energy surveys, nine Demographic and Health Surveys, and two income and expenditure surveys) and a review of Bank and external studies. The analysis unpacks the causal chain from the provision of electricity to the various benefits it is claimed to bring, and quantifies these benefits where possible to address the balance of costs and benefits. The data were used to test the impact of RE on several variables, such as the quantity of lighting used, opening hours of clinics, female health knowledge, and income from home businesses.

2. The Bank's Portfolio

The Bank's strategy for the energy sector has evolved considerably in the last 15 years. In 1993two policy papers were published that gave greater emphasis to the role of the private sector and highlighted environmental concerns (World Bank1993a, 1993b). A 1996 paper discussed the 2 billion Poor people around the world lacking access to modern energy services and how the Bank may best meet their needs (World Bank 1996), and 2001 sector board paper increased the emphasis on both poverty and the environment (World Bank 2001b). How have these strategy changes been reflected in the RE portfolio? IEG identified 120 Bank-supported projects wither activities since 1980, falling roughly equally into three categories: dedicated projects (such as Bangladesh Rural Electrification I, II, and III), energy sector projects with RE components (such as the Jordan Energy Development Project), and multi sector projects with RE components (such as Brazil's Northeast Rural Poverty Alleviation Projects). A growing number of these projects are in Latin America, where RE is common in multi sectoral community-driven development projects, and Sub-Saharan Africa. Another recent trend is the growth of support for off-grid electrification, usually as a subcomponent of a larger project, as in the Southern Provinces Rural Electrification Project and follow on Rural Electrification Project in Lao People's Democratic Republic. Most off-grid projects relyon renewable energy technologies, which have also become more prominent in the Bank's lending in the last 15 years. Three-quarters of RE projects have objectives related to improving energy supply, and the same proportion has objectives related to institutional development. Only 60 percent have the objective of increasing welfare (including environmental benefits), and this objective is mostly stated in general terms, such as improving incomes. Moreover, this objective is most common in the multi sectoral projects. Only 7 percent of dedicated projects and energy sector projects have an explicit poverty-reduction objective. Hence, poverty has not become a central concern of RE projects, and there is rarely any explicit consideration either of how the poor will be included or of any poor-specific activities. Similarly, although mention of gender in project documents has increased greatly in the last decade, these concerns rarely affect project design. Where the Bank finances a series of dedicated projects it can make a substantial contribution to increasing coverage: in Indonesia coverage rose from 33 percent in 1991 to 85 percent by 2003, with about 45 percent of these additional connections being paid for with Bank financing. In Bangladesh, the number of rural connections grew from practically zero in 1980 to more than4 million by 2002; 600,000 of these connections were made with Bank financing. By and large, Bank-supported projects have successfully created the physical infrastructure for RE, although technical problems have often mean thigh system losses—which have reached as high as 50 percent in Albania and India (Rajasthan).These losses drive a wedge between the cost of generation and the cost of supply, thus undermining financial performance. Many Bank projects

3. What we know of Impacts and Expected Outcomes

Rural areas of poor countries are often at a disadvantage in terms of access to electricity. The high cost of providing this service in low populated, remote places with difficult terrain and low consumption result in rural electricity schemes that are usually more costly to implement than urban schemes. In addition, low rural incomes can lead to problems of affordability1, and the long distances mean greater electricity losses and more expensive customer support and equipment maintenance. Despite this, rural electrification has been claimed to have substantial benefits, promoting production and better health and education for households. Moreover, in the report of the Independent Evaluation Group of the World Bank (IEG 2008) empirical support is found for many of these links and rates of return on rural electrification projects are sufficient to warrant the investment. Additionally, it shows that consumer willingness to pay for electricity is almost always at or above supply cost. Despite the findings reported in the IEG report, and as Ramírez and Esfahani (1999) point out, the estimates of the impacts of infrastructure access and specifically rural electrification access have been subject to numerous criticisms, which are fundamentally associated with endogeneity problems and causality directions. Although access to infrastructure affects productivity, income, and economic growth, it also affects the supply and demand of infrastructure. By neglecting this simultaneity, there is a possibility of biasing estimated impacts. Until very recently, the possibility of identifying causal relationships between electrification access and its impacts on productivity or rural incomes was limited to macroeconomic studies based upon time series. These studies attempted to identify whether or not these investment preceded the supposed effects that are attributed to such investments. In recent years, however, with the development of evaluation methodologies Rosenbaum and Rubin (1983) or Heckman, Ichimura and Todd (1998)], advances have been made in establishing causal links from microeconomic evidence, comparing the trajectory of individuals subject to interventions, in relation to the trajectory of other comparable individuals that have not been subject to interventions [see for example IEG (2008), van de Walle (2003), Galiani, Gertler and Schargrodsky (2005) and Escobal and Torero (2005)].Recent work by Bernard and Torero (2009) implemented a randomized evaluation of the impacts of rural electrification. They use discount vouchers to incentivize households to connect to the electricity grid and

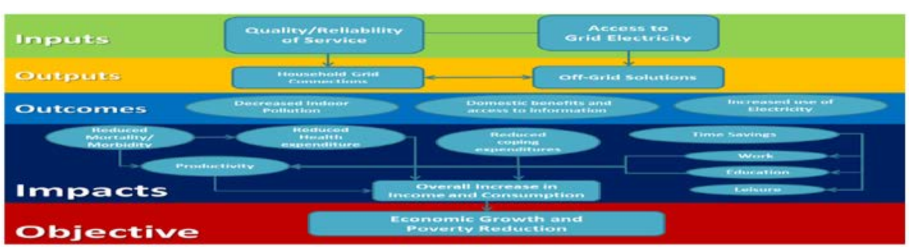

Figure 1: Impacts and Expected Outcomes

Impact Pathways of Rural Electrification Programs

To estimate impacts across the different pathways, we propose a series of indicators that are proxies for different impacts. We present these indicators in Table 1, where we indicate when one would expect to observe these impacts (immediate, short term, long term), and the direction of the impact and if one could expect the effects to be different for females.

Furthermore, we use this framework to illustrate the effects found in Bernard and Torero (2009) and Barron and Torero (2014) in Table 2 through Table 4. The presentation of the tables makes clear the links across the two evaluations. For example, the increase in access that would expect to be realized in the immediate short term and spillovers that can increase electricity connections rates in the communities where a number of household were selected to receive a discount voucher. The tables also provide some contrasting effects. The results in Bernard and Torero (2009) are mainly in the short term mainly due to the short time period of the study; while Barron and Torero (2014) are able to provide more evidence throughout the impact pathways described above. They find the increase in access to electricity, reflecting *outputs*; decreases in indoor polluting and access to electric appliances, reflecting the changes in *outcomes*. These changes are clearly linked to specific impact in the framework, namely changes in time allocation across labor activities, improved health outcomes of vulnerable groups, etc. reflecting the expected impacts reflected in the framework. Finally, the changes in labor allocation are casually related

To income changes that reflect the overall objective of the electrification intervention economic growth

And increases in overall economic wellbeing

Table 1: Primary Indicators in Rural Electrification Impact Evaluations

Term	Theme	Indicator	Expected Impact	Gender heterogeneity
Immediate	**Coverage and Access**	• Percentage of households connected to the grid	**Positive**	No differentiated effect
		• Cost of electricity	**Negative**	No differentiated effect
		• Reliability of electric services	**Positive**	No differentiated effect
Short term	**Coping costs**	• Number of sources used	**Negative**	No differentiated effect
		• Consumption of electricity	**Positive**	No differentiated effect
		• Energy input collection time use	**Negative**	Larger effect for females
		• Coping expenses in other energy sources	**Negative**	No differentiated effect
	Health	• Indoor pollution	**Negative**	No differentiated effect
		• Incidence of acute respiratory disease among vulnerable groups	**Negative**	No differentiated effect
	Education, Leisure, and Information	• Hours in education or studying in the home	**Positive**	No differentiated effect
		• Hours spent in childcare	**No change**	No differentiated effect
		• Hours spent in entertainment and other leisure activities	**Positive**	Larger effect for females
	Productivity	• Total hours of work	**Positive**	Larger effect for females
		• Percentage of hours of agricultural	**Negative**	Larger effect for females
		• Percentage of hours of non-agricultural work	**Positive**	Larger effect for females
		• In home business productivity/revenue	**Positive**	Larger effect for females
Long term	**Economic Growth**	• Change in total income and expenditure	**Positive**	Larger effect for females
		• Percentage of poor households	**Negative**	Larger effect for females

Table 2 Immediate and Short Term Results of Electrification Impact Evaluations in Ethiopia and El Salvador, Part 1.

Term	Theme	Study	Impact	Size of Effects	Heterogeneity
Immediate	Coverage and Access	Bernard and Torero (2009)	• Neighbors' connection behavior has large effects on a household's connection decision. • Social effect also decreases by distance, leading to sub-village clusters of high/low density of electrified households.	• Each additional household that received a voucher within a 30 meter radius increases the probability that an individual will connect by close to 2 percentage points from a 41 percent baseline connection rate.	No differentiated effect
		Barron and Torero (2014)	• Both the low- and high-discount vouchers increase the probability of adoption of a formal connection.	• Individual discount vouchers made households 11 to 19 percentage points more likely to connect to the grid. The effect of low-discount and high discount vouchers is roughly similar.	No differentiated effect
			• Spillover effects are large. A neighbors' connection decision explains one's own connection decision.	• A voucher allocated to a neighbor has 25% of the effect of a voucher allocated directly to a household.	No differentiated effect

Term	Theme	Study	Impact	Size of Effects	Heterogeneity
Short term	Coping costs	Barron and Torero (2014)	• Decrease in the likelihood of using non-electric lighting sources.	• Most fuel changes are due to reductions in kerosene use, while other sources show economically small and statistically insignificant changes.	No differentiated effect
			• Electrification caused large reductions in kerosene expenditures.		No differentiated effect
			• No evidence of changes in cooking practices; neither in the use of wood for cooking nor in the probability of cooking outdoors.	• This effect would be unlikely since the use of wood for cooking was around 85% at baseline and cooking with electricity is much more expensive.	No differentiated effect
					No differentiated effect

4. Methodological Challenges in Impact evaluations of Rural Electrification

We now turn to highlight the challenges in doing impact evaluations of rural electrification problems. We organize the discussion around four challenges and propose some solutions as well the caveats of these solutions. The first challenge is selection. The link of causality between a rural electrification program and the impacts is not identified by simple before-and-after comparisons or connected and non-connected groups conditional on having access to the grid because households that connect to the grid are likely different in unobservable ways to the households that decided not to connect. This would bias estimates of the impact, which would be confounded with the unobservable variables. For example, if household that decided to connect are more dynamic, then we can observe large increases in income after connecting to the grid, but a large part of this increase is due to the innate dynamism of the household members and not necessarily because of electricity. These households would have been better of regardless of the electrification program. A solution for this selection problem is a randomized encouragement design (RED). For example, Bernard and Torero (2009) use a voucher to incentivize households in Ethiopia to connect to a new electric grid that was coming to their town and find much larger connection rates among voucher recipients. This design provides a strong instrumental variable for a household's connection status. The limitations when implementing the RED are logistical. It is essential to give an incentive that is sufficiently large so households can connect and that the electricity providers comply with a strict protocol when distributing and cashing the incentives. This will limit any contagion effect and prevent an underground market for the incentive to develop and jeopardize the evaluation design. When implementing this design, it is important to have local partnerships that guarantee that the incentives are perceived as official by the recipients. Other characteristics of the incentives necessary to maintain the validity of the impact evaluation design are:

- The benefit of the incentive needs to be clear and understandable to all possible beneficiaries;
- The incentive needs to be non-transferable to prevent shadow/exchange markets to arise; and
- The incentive should be distributed publicly to improve credibility on the lottery nature of the

Allocation of the incentives. The second challenge in rural electrification impact evaluations is endogenous infrastructure placement. Program designers would place the electric grid in areas where they are likely to get higher paying customers, in denser population areas, etc., which would bias comparison between connected and nonconnected areas. A solution for this is a Pipeline Design that identifies intervention areas early in the design stage and determines evaluation areas based on the sequencing of the intervention. By using the sequencing of the program, we ensure that both treatment and control areas are comparable, as both have been selected to be connected to the grid at some point. Ideally, evaluators would also try to randomize the order of implementation. However, this is seldom times possible in infrastructure interventions. The main limitation of this design is that even when evaluators are not able to randomize the order, the order planned and proposed by the implementers can have deviations in practice. In this design is important that evaluators monitor the implementation of the program to adjust for any delay sand or contamination of previously selected control areas because of circumstances unforeseen at the design stage. Combining the pipeline design with the randomized encouragement design allows us to identify the impact of the program without the biases of program placement and selection, thus providing rigorous evidence of the causal links between rural electrification and development outcomes. With this design we can use the randomly assigned discount and an instrumental variable for a household's connection status. Furthermore, we can use the random assignment in a "reduced form" difference in difference or fixed effects estimation that uses the baseline survey (used to characterized interventions areas) and follow-up Surveys (to evaluate the impact).

This strategy uses the panel of households to define the impact of the:

Program as the differential differences across time between the households that received the incentive.

And those that did not while allowing for fixed unobserved heterogeneity across households that might.

Help explain the decision to connect (selection).

In addition, one needs to take into account the political.

Feasibility and budgetary constraints when distributing the incentives.

The exclusion of some areas from

The incentive might not be politically favorable for a policy maker, though implementing a sequencing of the voucher distribution where control households get the voucher at a later time might be a feasible option.

An example of this design is from Barron and Torero (2014), where they use the sequencing of the deployment of the electric grid to select treatment and control areas and provide a discount voucher to a random selection of households in treatment areas. In their study, they address both program placement bias (by selecting control areas that are scheduled to be electrified in the near future) and households'self-selection bias (by providing the random incentive and using the voucher as an instrumental variable for connection status). The limitations of this compounded design are the same we discussed above; however, this is the strongest design to identify causal links between electrification and the welfare of households in rural areas. The third problem stems from the objective function that policymakers and program designers use when deciding what projects are cost effective. The evidence suggests that the implementer solve a cost minimization problem when deciding where to extend an existing grid. There seems to be little attention paid to profit maximization; that is, taking into account that more remote (and thus more expensive) areas might have high productive potential that would be realized by electrification thus making the electrification investment ex-post profitable. The duality of cost minimization and profit maximization depends on the quasi-concavity of the production function and complete markets, situations that are not characteristic of the electricity sector-- one can easily argue that there are increasing returns to scale in some parts of the production function-- and less so in developing countries. This implies that a planner using cost functions or profit functions as objective functions would make different decisions. To illustrate the point, suppose that we have three households, A, B and C, that we want to connect to the electric grid. As shown in Figure 2, if we connect household A at minimum cost we obtain the negative profits, and only connect household A and adjacent households. If we included the potential profits that can be obtained from connecting A to B and C we would arrive to a different conclusion. We would move southwest in the quadrant, to find the allocation that maximizes profit at a minimum cost. We arrive at point (A, B) where profits are positive and household A, B and adjacent are connected to the grid. Note that is not always profitable to connect all households, as evidenced by the point (A, B, C) being at the zero is profit curve. We can further illustrate this problem in spatial terms using the rural electrification intervention in Barron and Torero

(2014).Figure 3 shows the roads available in the area of the intervention and the electricity grid that was constructed. By using only minimum cost as the objective function when implementing the grid, one will expect that most households would be near the roads. This is what we overwhelmingly observe in including the potential profits, as we propose, can be illustrated in Figure 4 by using the agricultural Potential to proxy for potential profits (see appendix on how potential is calculated). Agricultural potential is estimated using the stochastic profit frontier. This methodology uses the production possibility frontier that describe all the possible production combinations in the area under current conditions and categorizes them depending on their efficiency in the use of resources (how near are the areas to the boundary or frontier). Rural areas in green are areas that have agricultural production potential and consequently could have higher return from being connected to the grid. Under this framework, we would prioritize the areas that have high potential (dark green) to maximize profits and also take into account the access to roads to minimize costs. In this case, while most of the new grid covers areas that have agricultural potential, there are considerable clusters that are in areas with low productive potential. While we do not assert that there are no merits to connecting households with low productive potential(in red), this framework provides us some context of what kind of outcomes we should expect to change in these areas in terms of the cost effectiveness and the sustainability of projects in these areas

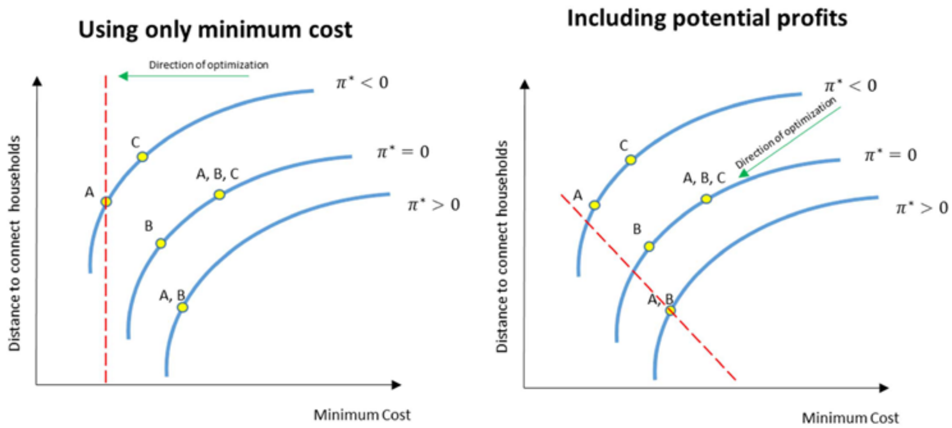

Figure: Poor households and have larger impacts in the lives of the rural poor by providing new opportunities and enhancing the synergies between the agricultural and non-agricultural sector.

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