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Development Effects of Rural Electrification[1]

Raul Jimenez

Abstract

What do we know about the effects of improved access to electricity? Does the research tell a unified story? To answer these questions, this brief examines 50 impact evaluation studies, focusing on the effects of electrification on education, labor, and income indicators. Overall, the literature finds substantial welfare gains, which tend to be greatest for women and small firms. On average, electrification leads increases of around 7% in school enrollment, 25% in employment, and 30% in incomes. However, the estimates vary widely, with many studies finding no effects, indicating weak links in the empirical literature. This review suggests that addressing the sources of such variance could be a means to fill the persistent knowledge gaps and to improve the effectiveness of electrification policies.

JEL Classification: O13, O38, Q48, Q49

Key words: rural electrification, Latin American countries, economic development, education, employment, income, impact evaluation.

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1. Introduction

Starting in early 1930s, with the implementation of the Rural Electrification Administration in the United States, rural electrification programs have expanded around the world, providing access to millions of people. Still, as of 2014, lack of electricity services affects around 16% of the global population,[2] particularly in the poorest and most isolated areas. In this context, a better understanding of the effects of electricity on socioeconomic development, and how those effects could be enhanced, may improve public policy in this area.

Since the beginning, policies and programs have operated under the widely-accepted premise that access to electricity would make households better off and increase the productivity of rural areas (Dow 1937; Erdman 1930). Only recently, mainly over the past decade, has an increasing body of impact evaluation studies begun to quantify such effects. This literature does not challenge the premise that electrification promotes welfare, but aims to clarify how and to what extent access to electricity and improvements in such infrastructure contribute to economic and social development. In doing so, these studies have the potential to provide important inputs to improve electrification policies, and inform cost-benefit analysis. For example, the extent to which household gains in income due to electricity access can cover the costs of such services is key, in the long run, both for affordability and for the financial sustainability of the utilities.

This brief provides a synthesis of the literature evaluating the impacts of access to and improvements in electricity services, with a focus on education, labor, and income outcomes. The brief reviews 50 studies published between 1983 and 2015, summarizing their main estimates, which are expressed as percentage changes relative to the control mean. Although other impacts are also relevant, such as health, expenditure patterns, and firm productivity, few available papers evaluate homogeneous indicators, making it difficult to summarize their findings into an indicative ballpark of estimated effects.

Altogether, the studies reviewed here strongly suggest that access to reliable electricity represents a structural condition that supports development, mainly benefiting

[2] International Energy Agency, World Energy Outlook 2016.

poorer households, women, and smaller firms. Estimations suggest that electrification leads to average (median) increases of around 7% (4%) in school enrollment, 25% (20%) in employment, and 30% (18%) in incomes. Still, there is substantial variance among the estimates, with several studies finding no significant effects. More research is needed to investigate what drives this variance. Further, this review suggests that, in addition to quantifying the effects of electrification, impact evaluations should also engage with the early phases of the interventions, framing the factors that increase their effectiveness in terms of outputs (new connections and quality improvements) and medium- and long-term effects (for example, electricity use, employment, and household income).

The next section briefly outlines how access to improved electricity services leads to welfare gains. Section 3 presents the data set used in this paper, along with the procedures used to systematize the estimations from the different studies. Section 4 synthesizes the findings of the literature. Section 5 concludes.

2. Theory of Change from Electricity to Development

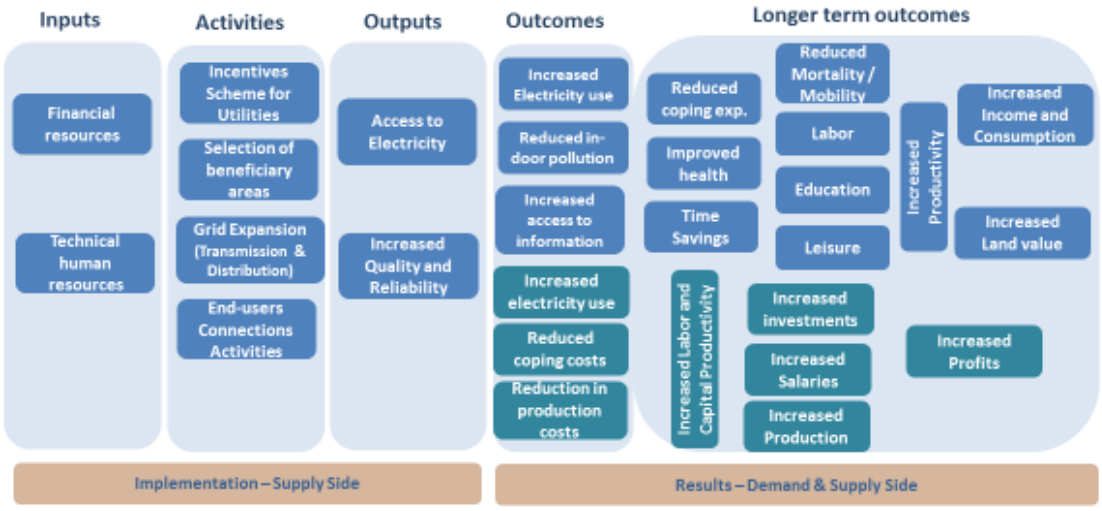
Establishing a theoretical framework for this development process is essential for quantifying the expected effects, and for evaluating the effectiveness of electrification policies. Based on Torero (2014) and Gertler et al. (2011), Figure 1 presents a simplified causal chain, from the inputs to the final expected effects of electrification. This causal grid can be separated into an implementation side and a results side. The former groups the inputs (including financial and human resources) and the activities (such as grid expansion, installation of isolated systems, implementation of connection fee subsidies, and/or social tariff programs) aimed at delivering the target output. The output can be divided into new connections and increased quality of the services. From institutional arrangements to procurement decisions, all the steps in this phase are necessary to successfully meet the policy objective. Flaws in implementation may translate into flaws in the effectiveness of electrification programs.

Many of the appealing policy features of impact evaluations, such as their ability to facilitate transparency and accountability, identify best practices, and determine policy alternatives, are severely restricted if evaluations do not start at the early stages of the

programs, engaging in the details of policy making (Torero 2014; Gertler et al. 2011; Duflo 2017). Despite the relevance of the implementation phase, an apparent limitation of the literature is that most impact evaluations, especially ex post evaluations, start later and are limited mostly to the results side, reducing their capacity to inform the design and implementation of later programs.

On the results side, at the household level, the literature suggests three main outcomes: decreased indoor pollution, increased electricity use, and changes in time allocation. As for the first, it is argued that access to electricity reduces the consumption of low-quality, dirty fuels for lighting (such as kerosene or candles), thereby reducing intra-house emissions of polluting gases. This would in turn produce improvements in health outcomes, mainly respiratory illness, especially among household members who spend more time inside the dwelling (women and children). New access to electricity, in addition to offering an equivalent and cheaper lighting source, could also reduce coping costs and energy expenditures, and increase disposable income at the household level. Access to and use of electricity also tend to imply an extension of usable hours during the night, potentially allowing for increased leisure and/or productive activities (educational or labor-related).

Figure 1: Causal Grid from Electricity to Development



Sources: Adapted from Torero (2014), Gertler et al. (2011), and the literature review.

The potential intermediate effects on health, labor, and education would be expected to improve the quality of human capital, leading to income gains over the long run. These income gains occur as a result of the more productive use of current capacities, or as a result of gains in human and physical capital. Over time, the electricity infrastructure would have external effects on variables such as land and household value, labor opportunities, and productive investments in electrified areas.

The quality and reliability of electricity services operate via similar channels, with the same long-term impacts. That is, having low-quality or unreliable service limits the extent to which households can take full advantage of the available infrastructure.

In the case of firms, the availability of electricity infrastructure and changes in its quality affect patterns of electricity use and related production factors. Systematic outages may severely limit the extent to which firms can take full advantage of physical and human factors of production, reducing overall productivity. The extent to which less reliable service is spread across a country may translate into substantial losses of competitiveness for the country's economy. Further, in the long run, low-quality electricity services may dis-incentivize investments, shifting the economy toward less energy-intensive economic activities.

A key point is that the realization and size of the long-term effects depends on behavioral considerations at the household and firm levels. In households, time allocation among labor, education, and leisure plays a crucial role in defining impacts in the medium and long term. For firms, investment decisions may depend on the quality and reliability of electricity, and on the costs of coping with energy scarcity.

3. Data and Approach

The data set prepared for this paper contains 50 studies published between 1986 and 2015. The search for papers ended in mid-October 2016,[3] and was restricted to only those studies that attempt to estimate the causal effects of electricity access or improvements in electricity services. The final collection includes journal articles (27) and working

[3] Only three studies were published before 2000, six between 2000 and 2005, and 41 after 2005.

papers/reports (23) encompassing three continents: Africa, the Americas (North, Central, and South), and Asia. Most of the studies are country specific, with only three of the 50 studies performing a multi-country analysis. India and Peru are the most represented countries, analyzed in seven and five studies, respectively. Twelve studies address effects on firms' outcomes; the remainder use households as the unit of observation. Most of the studies focus on the effects of access to electricity; six studies analyze the effects of improvements in the quality of electricity. None of the latter examines Latin American countries.

Since the studies usually apply more than one type of estimation, the data set contains only the results from the most robust estimation. When this is not expressed in the study, the estimation results are selected according to the following hierarchy: randomization, regression discontinuity, instrumental variable, double differences, propensity score matching, and before and after (including cross-section and pooled cross-section). Due to the difficulty of randomly allocating electricity to specific households or businesses, experimental techniques are rarely implemented. In this review, the only examples of experimental approaches are Barron and Torero (2014), Rud (2012), and Furukawa (2012). Quasi-experimental techniques are used in the studies by Dinkelman (2011), Grogan and Sadanand (2013), and Khandker et al. (2013).[4] Other studies apply propensity score matching techniques (e.g. Bensch et al. 2011), fixed effects methods (e.g. van de Walle 2013), and difference-in-differences with propensity score matching (such as in Khandker et al. 2009).

Comparison between studies with heterogeneous characteristics (variables with different metrics or scales, evaluation periods, populations with different variance, and so forth) requires expressing their estimated effects on a comparable basis, which is usually some transformation of the standard deviation. However, missing information may make it impossible to calculate such a standard. Not only are results presented in very different ways in the included studies, but, in addition, very few studies make their datasets publicly available for replication. However, it is important to emphasize that, for this exercise, no

[4] These authors use as instrumental variables the allocation of electricity services with the land gradient, population density at the municipal level, and proportion of households with electricity in a community, respectively.

author was contacted to request the dataset. Therefore, the estimated effects are expressed as percentage changes with respect to the control mean, reducing differences in scale.[5] Although such a measure is an intuitive way to present the average effect, the above considerations indicate that it may not be perfectly comparable across studies.[6] Based on the information available, the standard errors for the average effects are also estimated. Also, due to the heterogeneity of the indicators, similar indicators are grouped within the three main categories of the analysis: education, labor, and income.

4. Evidence at the Household Level: Education, Labor, and Income

This section synthesizes the findings for the three impacts that are more broadly covered in the empirical literature: education, labor, and income. The main message is that access to electricity leads to better educational outcomes, implying greater and better human capital accumulation, and further translating into increased labor supply and household incomes. The evidence also suggests that access to electricity particularly supports women's participation in economic activities, by liberating them from activities such as biomass collection, and generally by allowing more efficient use of their time. Along these lines, increases in women's employment mainly derive from increases in small-scale self-employment activities.

A word of caution: these estimates must be taken carefully, as they involve evaluations under very different circumstances, including different evaluation periods. For example, over time the effect of electricity access may behave in a nonlinear manner; therefore, the average effects from different studies with different periods may not be perfectly comparable.

Regarding *education*, Figure 2 reports the effects of access to electricity on school enrollment, with the lower and upper bounds represented by LB and UB, respectively, at 95% confidence. The x-axis indicates the country where the study took place. The

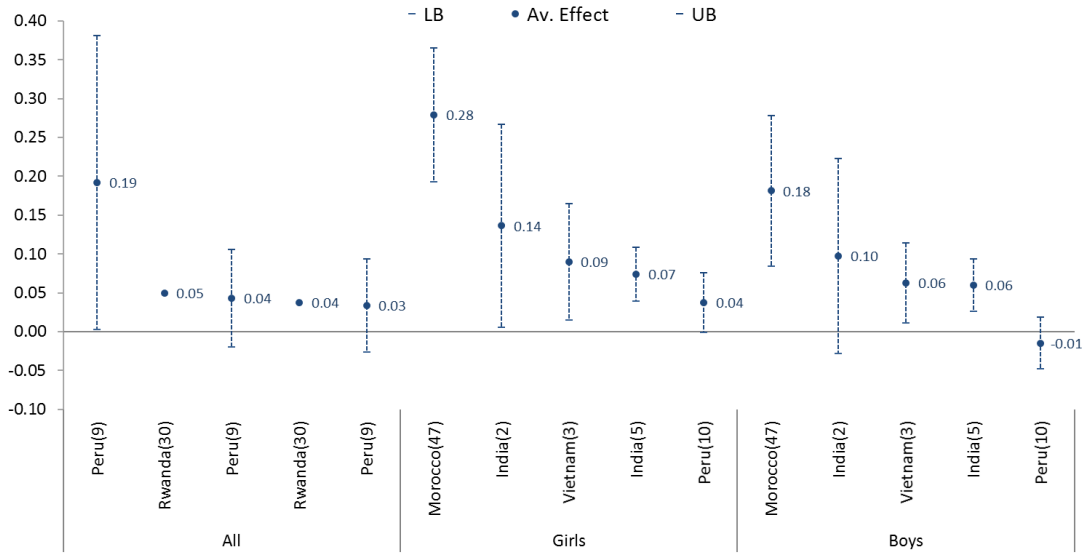
[5] For example, in the before and after case, this is the percentage change after the treatment. In the difference in differences case, it is the percentage change for the treatment group with respect to the change in the control group.

[6] For example, a difference in the variance between the populations of different studies would reduce comparability. Estimations may also contain the time-effect of exposure to the treatment; therefore studies with different evaluation periods may not be perfectly comparable.

estimated effect on enrollment is generally positive across countries, with an average increase of around 7% and a median increase of 4%. The figure suggests systematic gender differences, as the estimated benefits tend to be greater for girls than for boys. Similar patterns are observed for other variables, such as years of schooling, attendance, literacy, and time allocated to study at home; see annex 2.

Notice that the estimates vary widely, and are in many cases nonsignificant or even negative. Nine studies find nonsignificant results for several educational outcomes. The study by Dasso et al. (2015) finds a significant and negative effect of rural electrification on boys' enrollment in Peru, and the study by Squire (2015) finds a large and negative effect on both boys' school attendance (-4.3%) and girls' years of schooling (-34.7%) in Honduras. Although the results appear counterintuitive, the author provides convincing evidence that the negative impact is driven by the fact that electrification increases childhood employment.

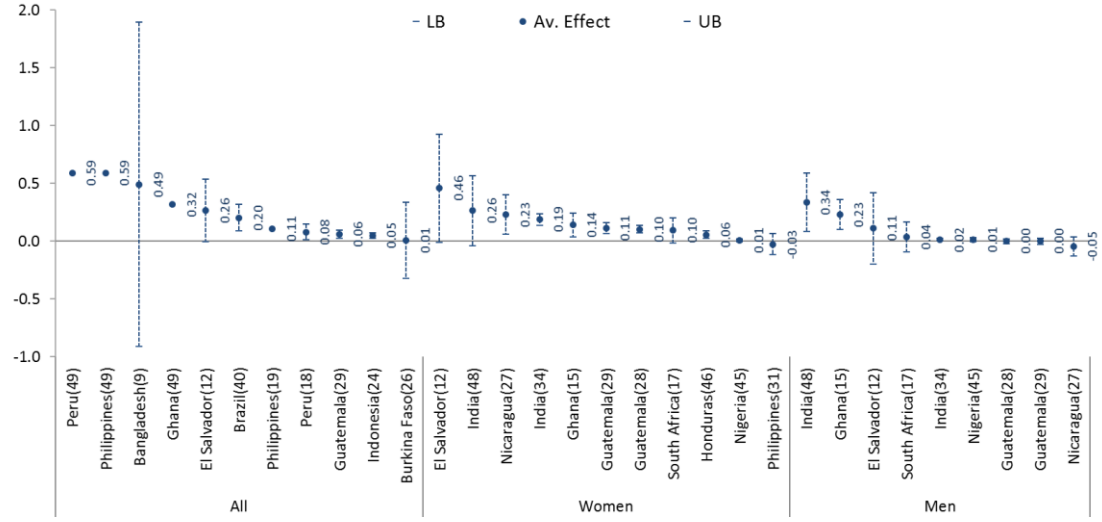
Figure 2: Effects of Access to Electricity on School Enrollment



Note: X-axis indicates the country, with authors identified in parentheses. See list of authors in annex 1.

Figure 3 summarizes the effect on *labor* market participation, compressing two main types of indicators, employment and hours worked per month[7]. Measured by those indicators, literature suggest that access to electricity leads to a 25% increase in labor market participation on average, with a median of 20%. The figure also suggests systematic differences by gender, with women tending to benefit more in terms of labor outcomes. The effects on women's labor market participation are significant and positive in the majority of cases, with an average impact of around 15% (median 11%). In contrast, the estimated effects for men are small, and mostly nonsignificant.[8]

Figure 3: Effects of Access to Electricity on Employment



Note: X-axis indicates the country, with authors identified in parentheses. See list of authors in annex 1.

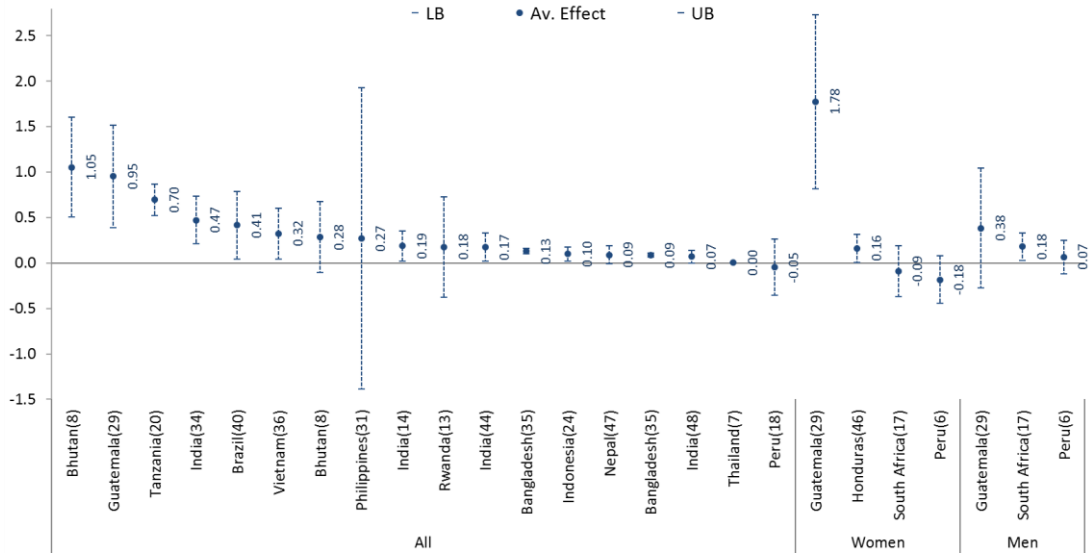
Figure 4 roughly suggests that better educational outcomes and greater labor force participation lead to increased *incomes*, although with marked heterogeneity. Of 24 studies that directly evaluate the impact on income, eight do not find a significant impact. Also, the magnitude of the estimated average effect is volatile, ranging from an 18% drop in income (although not significant, Peru(6)), to a more than 100% increase. Nonetheless, the average across the studies is sizeable around 30% with a median effect of 18%. There is

[7] The indicator for employment depends on the unit of observation used in each study. At the individual level, it refers to the probability of being employed. At the village level, it refers to the share of people employed.
[8] It is worth noting that in the paper by van de Walle et al. (2013), men's employment in India is negatively affected by electrification.

still scarce evidence for causality from improvements in women's time allocation to greater labor participation, maternal income, and educational outcomes of children.

A further question is whether the size of the income effect alone is enough to lift people out of poverty. While poverty itself is a less studied variable, there is some consistent evidence that electrification leads to a significant reduction in poverty rates (Fan et al. 2005; Lipscomb et al. 2013; Khandker et al. 2014). Similarly, rural electrification is found to have a positive effect on quality of life, measured in perceptional terms (Barnes 1988) or by the Human Development Index (Lipscomb et al. 2013).

Figure 4: Effects of Access to Electricity on Income



Note: X-axis indicates the country, with authors identified in parentheses. See list of authors in annex 1.

Other Impacts at the Household Level

The empirical evidence also tends to support the expected effects on health, fertility, energy expenditures, lighting time, and migration flows. ADB (2010) stresses the decrease in cough and respiratory illnesses in Bhutan due to electrification, and Kitchens and Fishback (2013) find that infant mortality rates decreased substantially in the United States between 1930 and 1940, following electrification.

For fertility rates, the findings are mixed. World Bank (2008), Grogan and Sadanand (2008), and Pieters and Vance (2011) find that fertility rates in rural areas decline

in response to electrification (studies in Bangladesh, Ghana, Indonesia, Morocco, Nepal, Peru, the Philippines, Senegal, Guatemala, and Côte d'Ivoire).[9] Arraiz and Calero (2015), Herrin (1983), Lipscomb et al. (2013), and van de Walle et al. (2013) present statistically nonsignificant outcomes, indicating that there is still room to investigate these relationships.

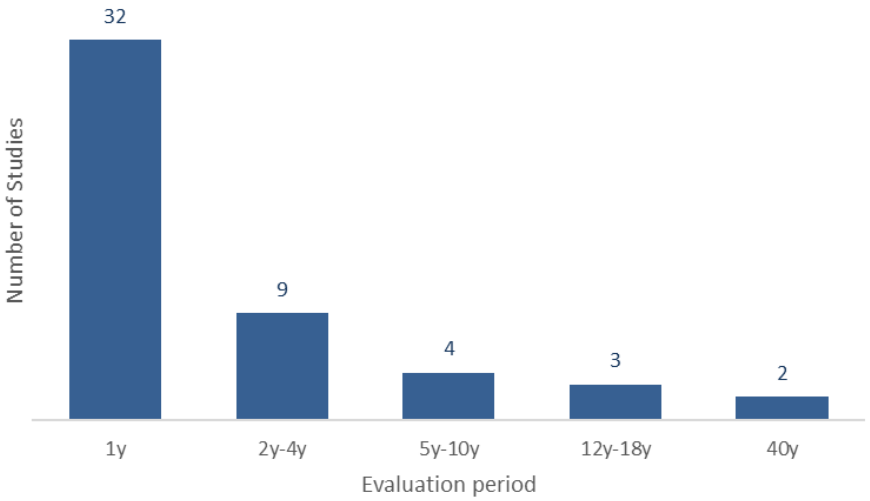
Groh (2013) on Peru and UNDP (2011) on Nepal report large reductions in energy expenditures due to the use of electricity. Bensch et al. (2011) document a strikingly large (but expected) effect of access to electricity on lighting time. Kitchens and Fishback (2013) and Barnes and Binswanger (1986) find that electrification increases the value of land and agricultural innovation, respectively. Dinkelman (2011) and Lipscomb et al. (2013) analyze the potential confounding impact of migration on the effect of electrification on employment. The results from the latter are not significant, but Dinkelman finds that the presence or imminent rollout of electricity influences migration patterns in South Africa.

About the Evaluation Periods

The duration of the evaluation period is of particular interest here. A short exposure may make it difficult to observe income gains from electrification, especially via education, which tends to materialize gradually in the medium to long term. For example, one of the greatest increases in income found in the sample, and one of the most robust methodologies, comes from Lipscomb, Mobarak, and Barham (2013), who evaluate the effects of electrification in Brazil over four decades. They find a 40% increase in average income. As shown in Figure 5, most studies analyze cross-sectional datasets involving only one point in time, which constrains what can be learned about the dynamic effects of electrification.

[9] It is interesting to note how the effect changes in urban areas. Pieters and Vance (2011) show that, in contrast to rural electrification, urban electrification enhances fertility.

Figure 5: Number of Studies per Evaluation Period



Evidence on Firm Productivity

Evidence at the firm level is much scarcer, and this review did not identify studies for the Latin American region. At the same time, the outcomes are widely heterogeneous, making it difficult to perform a similar layout of the estimated effects. Nonetheless, altogether, the empirical evidence indicates that improvements in electricity access and reliability have a positive influence on productivity, and that the negative effects of unreliable electricity services are concentrated among small firms. In the long term, structural deficiencies in the electricity sector may bias the economic structure toward less electricity-intensive industries, potentially leading to competitive disadvantages.

With respect to access to electricity, Rud (2012) finds a positive effect on manufacturing output in India, and Grimm et al. (2011) and World Bank (2008) find a positive effect on firm revenues in Burkina Faso and Ghana, respectively.[10] By contrast, Pieters et al. (2011, 2013); Akpan, Essien, and Isihak (2013); World Bank (2008); and Kinda and Loening (2010) find that, when controlling for other factors, electrification does

[10] However, Grimm et al. (2011) find a negative impact on value added when analyzing firms in the capital cities of several African countries. The result is consistent across all sectors, except for clothing, where a more intuitive significant positive effect is found.

not significantly affect firm performance (measured by profits, business income, and employment growth).[11]

On the quality of electricity, several studies find that unreliable access to electricity reduces output, total factor productivity, or revenues (Fisher-Vanden et al. 2015; Allcott et al. 2014; Arnold, Mattoo, and Narciso 2008; Kinda and Loening 2010; Adenikinju 2005).[12] Electricity scarcity also seems to have effects on the unit cost of output and labor outcomes. Fisher-Vanden et al. (2015) document a 7.8% increase in unit costs, and Gibson and Olivia (2009) and Salmon and Tanguy (2014) find that the effects on labor outcomes are negligible in magnitude.

In identifying the effects of unreliable electricity supply, it is important to understand how firms respond to these challenges. Based on the available literature, firms may choose to leave the market or move to another area with a better business environment. Firms may also take measures to smooth the negative effects of unreliable infrastructure. In any case, it seems that unreliable electricity services have a greater effect on smaller firms that do not have the means to smooth negative shocks from poor infrastructure. For example, in the literature, self-generation is a common response of firms facing unreliable electricity services. Allcott et al. (2014) include the holding of generators in their model, showing that a positive probability of blackouts limits the maximum output firms may obtain. Fisher-Vanden et al. (2015) add that investments in self-generation can crowd out other more productive investment opportunities. Alby et al. (2013) introduce firm size and credit constraints to show that unreliable electricity input may have heterogeneous negative effects, which are concentrated in small firms in sectors that are more reliant on electricity.

Other potential responses include the outsourcing of energy-intensive inputs and energy-efficiency improvements. That is, firms may outsource energy-intensive inputs, leading to productivity losses as more materials are used and production factors are employed less. On the other hand, firms may invest less in energy-efficient technologies,

[11] Interestingly, Kitchens and Fishback (2013) propose an analytical framework in which access to electricity translates into improvements in productivity through reductions in electricity prices.
[12] However, Allcott et al. (2014), when employing productivity as the dependent variable, and Fernandes (2008) find the effect to be statistically nonsignificant.

increasing capital inputs. These channels are studied empirically by Fisher-Vanden et al. (2015).

5. Final Remarks

This brief provides a ballpark view of the socioeconomic effects of improving electricity access. Overall, the empirical evidence supports the theoretical expectations; rural electrification and improving the quality of electricity services lead to welfare gains that are statistically significant and relevant to policymaking. However, the estimates of these impacts vary greatly across the studies, with many of them finding nonsignificant effects. This variation should not be interpreted as evidence that electrification does not improve welfare, but instead as a call for further research to explain the roots of such heterogeneity. Explanatory factors may include the different settings and countries under study, the different empirical strategies used, the quality and availability of data, and deficiencies in the electrification programs and policies, among others.

From a policy point of view, it is important to determine whether the studies were unable to find conclusive results due to methodological limitations or to flaws in the program designs. Evaluation designs must place greater emphasis on the implementation phase of the results chain and on external factors, investigating the drivers behind the successful materialization of electrification benefits, as this is one of the main inputs that may improve the effectiveness of electrification programs.

This review certainly presents room for improvement. Although the brief has the flavor of a meta-analysis, it is not a meta-analysis, and the results presented should be taken carefully. Further work could improve the dataset and refine the analysis. If more datasets were to be made available, better comparisons of the effects among different studies would be possible. As a potential extension, researchers could perform a similar exercise for other infrastructures, such as water/sanitation and transport. Since causal studies identify effects that can be solely attributed to a specific treatment, the estimated effects of different types of infrastructure can be added to provide a glimpse of the overall benefits of these complementary services. With respect to the theory of change, this review detects missing and weak links requiring more comprehensive studies over longer periods of time, ideally

using experimental approaches. For example, changes in patterns of time use are less analyzed, and very few studies have focused on the quality of electricity services, both at the household and the firm level. Further, to provide timely policy advice, impact evaluators must be engaged from the early stages of the intervention and policy design.

Regarding the reporting of effects in this review, it is important to mention that it does not consider potential sources of bias in the overall literature, such as publication bias. Although the inclusion of working papers and reports would reduce this type of bias, it may still prevail due to a tendency to argue the benefits of electrification. This may not be a problem here, because several of the studies present nonsignificant effects.

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Annex 1: List of Studies IDs

Authors	id
Adenikinju, 2005)	1
Aguirre, 2014	2
Akpan, Essien, Isihak, 2013	3
Allcott, Collard-Wexler, & Connell, 2014	4
Arnold, Mattoo, Narciso, 2008	5
Arraiz & Calero, 2015	6
Asian Development Bank Report, 2005	7
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Barkat et al, 2002	9
Barnes & Binswanger, 1986	10
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Annex 2: Estimated Effects on Educational Outcomes (several indicators)