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Agricultural Production and Access to Energy in Bolivia, Peru, and Colombia

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Abstract

In this paper, we explore the link between energy and agricultural production in Bolivia, Peru, and Colombia. The economic literature and policy reports discussed here indicate that access to energy can increase agricultural production. To test this hypothesis, we look at agricultural censuses (Bolivia and Colombia) and a national survey (Peru) to estimate how energy use affects the value of production using the propensity score matching (PSM) technique. We find that in all three countries access to energy is associated with greater value of agricultural production.

Keywords: treatment effect, energy, agriculture

JEL Codes: C31, Q12, Q14, Q40

1. Introduction

Since the first decades of the twentieth century, investments in infrastructure such as irrigation, communication, roads, and electrification have been seen as the path to rural development by many different actors (Kirubi et al., 2009). The World Bank, for example, has directed a large part of its funds to the financing of infrastructure projects involving these elements, as have other important bodies, such as the Inter-American Development Bank (Adrian et al., 2019). The attention devoted specifically to electricity seems to be echoed by many authors who, while pointing out challenges and regional singularities, see rural electrification as a way of reducing poverty and increasing productivity (Burlig & Preonas, 2016; Chakravorty, Emerick, & Ravago, 2016; Dinkelman, 2011; Fan, Jitsuchon, & Methakunnavut, 2004; Ferguson, Wilkinson, & Hill, 2000; Kirubi et al., 2009; Lipscomb, Mobarak, & Barham, 2013).

In the rural areas of Latin America, about 17 million people still live without electricity (IEA, 2017). In Bolivia, Colombia, and Peru 758,000, 147,200, and 1.64 million people, respectively, live without electricity (FAO, 2020). According to Eras-Almeida et al. (2019), many of these people live in small, isolated, dispersed, and low-income communities. They live in poverty or extreme poverty and their income depends mainly on agriculture and livestock husbandry. Considering this scenario, several studies have investigated the effects of access to energy in rural areas in the countries studied in this working paper—Bolivia, Colombia, and Peru (Aguirre, 2017; Dasso & Fernandez, 2015; Eras-Almeida et al., 2019; Hentschel & Waters, 2002; Kooijman-van Dijk & Clancy, 2010).

Hentschel & Waters (2002) found that access to electricity in Ecuador can diminish poverty, especially in rural areas. Kooijman-van Dijk & Clancy (2010) criticized the reliability of the access to electricity, as well as institutional issues, such as lack in mayors' efforts to bring quality energy to their communities, while finding that access to electricity does not necessarily lead to increased production in rural Bolivia. Even though the study by Dasso & Fernandez (2015) was not on the impact of access to energy on agricultural production, its findings can be associated with our results. Using a difference-in-differences approach and household surveys, they found that rural electrification in Peru increases employment and earnings. Also relevant to our analysis for Peru is Aguirre (2017), who used a 2013 survey to estimate the impact of rural electrification on child education. The study found that children living in households with access to electricity spend an extra 94–137 minutes at home each day, on average, reducing the likelihood of repeating a grade. Eras-Almeida et al. (2019) demonstrated that it is feasible to bring electricity to rural areas in countries such as Bolivia and Peru as a development strategy, mixing the use of traditional and new technologies, the latter of which are cheaper and more sustainable. These studies' findings indicate the relevance of access to reliable sources of energy to economic development, which we explore in this working paper through the lens of agricultural production.

In this working paper, we investigate whether access to energy is associated with an increase in the value of agricultural production for Bolivia, Colombia, and Peru. The datasets used do not allow us to estimate pre and post-policy. We use cross-sectional agricultural census for Bolivia and Colombia and a survey for Peru. To overcome this data limitation, we use matching techniques to identify empirically the control group (farmers without access to energy) and estimate the average treatment effect on the treated with access to energy on agricultural production. Our simple analysis focus on estimating the association between access to energy and the value of agricultural production and was built as a step towards better understanding this association. We found that access to energy is associated with a higher value of agricultural production for the three countries studied.

2. Background[1]

The topic of rural electrification has been addressed in studies in different fields of economics. Some of these studies examined the effect of rural electrification on the agricultural productivity and income of rural populations. Ferguson et al. (2000) investigated the effect of energy consumption and wealth generation for almost a hundred countries and found a positive and significant correlation between the use of electricity specifically and wealth generation, stronger than the correlation between general energy use and wealth generation. Kirubi et al. (2009) investigated a community-based electric microgrid initiative in rural Kenya and concluded that improvements in agricultural productivity and revenues are also related to more widely available social services (e.g., related to education and health) supported by electrification. Lipscomb et al. (2013) investigated the Brazilian electric sector from 1960 to 2000 and found that electrification reduces poverty and increases formal employment in rural areas. Burlig & Preonas (2016) investigated the Indian national electrification program designed for rural villages and found that it led to an increase in productivity and income. Similar results were obtained by Chakravorty et al. (2016) for the electricity expansion in rural areas in the Philippines, who found that increases in agricultural income are related to electrification. Fan et al. (2004) investigated the link between investment in rural electrification and agricultural labor productivity growth in Thailand and found that investment in electricity was the second-largest contributor to agricultural productivity growth, behind only investment in agricultural research and development. Dinkelman (2011)

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[1] This section presents a brief discussion of some papers relevant to this working paper. There is a vast literature composed of papers, private company reports, and government reports discussing rural electrification for these countries that is not covered in this section.

showed that rural electrification was responsible for the increase in labor hours for both men and, mainly, women in rural South Africa.

In Bolivia, Colombia, and Peru, several policies have been implemented and projects are underway aimed at increasing access to electricity, as well as the quality (comprising more reliable, sustainable, and cheaper energy sources) of this source of energy. There are also some studies of the electricity sector and its characteristics, demonstrating the relevance accorded to this infrastructure. In the following paragraphs, we discuss some of the initiatives and studies carried out in these countries.

Access to electricity is widespread in urban areas of Bolivia. However, electricity is not yet universal in rural households, where only 8.5% of farms have indicated that electricity is their main source of energy according to the Agricultural Census of 2013 (INE, 2020). Energy consumption has increased across Bolivia, especially from nonhydroelectric sources such as natural gas. However, providing energy to the entire population will be a challenge (Adrian et al., 2019). Morato, Vaezi, & Kumar (2019) argue that Bolivia could use its specific advantages to produce energy from agricultural residues and reduce its production costs. Pansera (2012) analyzes the status of renewable energy in Bolivia and contended that more research and public policies are needed to propagate this type of energy. Moura et al. (2017) found that Bolivia could produce sufficient energy to both satisfy national demand and export to other Latin American countries. Among these countries, Brazil would be the country benefiting the most, given its proximity to the El Bala and Cachuela Esperanza dams.

Balderrama et al. (2017) investigated the energy system in Bolivia by estimating an energy demand model at the national level and exploring different alternatives based on government projections on energy saving, fuel substitution, and aggregated effects of a combined scenario.

They predicted a considerable increase in energy consumption by 2035. However, their results indicated an 8.5% lower energy demand under the energy-saving scenario, a 1.5% lower energy demand under the fuel substitution scenario, and a 9.4% lower energy demand under the combined scenario. They highlighted the relevance of the energy sector to social and economic development, outlining the necessity of adequate policies and management to guarantee future energy supply. Bojanic & Krakowski (2003) also stated that energy access plays an important role in economic development. These authors argued that structural reforms in Bolivia alongside the privatization process had exacerbated the disparities between rural and urban areas. Energy coverage has grown in urban areas, even for the lowest-income population, but in rural areas access to electricity has been stagnant. Kooijman-van Dijk & Clancy (2010) found that electricity can reduce poverty through income generation in small farms in Bolivia and other developing countries.

In Colombia not all households have access to electricity, despite changes instituted in the energy sector after fiscal issues and climatic events disrupted energy provision in 1994. Energy system reform sought to overcome failures in energy provision and the lack of preparation of state agents (Ayala & Millán, 2003). The subsidizing of low-income households is in place, paid by high-income households, industry, and businesses (Santa María et al., 2009). The reliability of energy distribution suffers from weather variability because of the energy matrix: the country is dependent on hydro and thermal power (Adrian et al., 2019). This issue is accentuated in rural areas, where the service is often discontinued and scarce. Arango-Aramburo et al. (2019) investigated energy vulnerability to exogenous shocks (climate) using a general equilibrium model, given that climate change may affect water availability and therefore energy production. They found that although climate change thus far has not resulted in abrupt changes in hydroelectric power generation capacity, it has led to a greater likelihood of (and demand for) the use of renewable energy sources, such as solar and wind. Duque, González, & Restrepo (2016) argued that there are unexplored rivers that could be used to generate hydroelectric power to address domestic demand, with the remaining production available for export.

Peru also faces several challenges regarding energy provision to households, especially in rural areas. Adrian et al. (2019) argued that there is a shortfall of approximately USD 31 million in energy infrastructure investments in Peru, and indicated that rural areas are the most affected by distribution and quality deficiencies. Cámac, Ormeño, & Espinoza (2006) found that even after several reforms, the Peruvian energy sector still faces risks of excessive prices and prolonged deficits in energy production. Along the same lines, Pérez-Reyes & Tovar (2009) affirmed that the energy sector faces some challenges and could benefit from the introduction of an incentive mechanism for the state electricity distribution companies. Torero, Alcázar, & Nakasone (2007) found that electricity companies managed by the private sector were more efficient, with rural areas, in particular, seeing the benefits, where individuals are having more time for nonagricultural jobs and leisure. Cherni & Preston (2007) criticized the energy-sector reforms in Peru because even though the reforms had led to substantial changes and improvements, the needs of rural households regarding coverage and quality still had not been addressed. In rural areas, demand is lower, so private companies have less incentive (lower profits) to invest (Cherni & Preston, 2007).

This brief overview of the literature highlights the relevance of identifying how energy use is associated with the value of agricultural production in these countries. In this working paper, our explanatory analysis sheds light on the importance of energy access for agriculture.

3. Empirical Strategy

In this working paper, we compare farms that have had access to energy with similar farms that have not had access using the propensity score matching (PSM) technique, developed by Rosenbaum & Rubin (1983) and widely used in the literature to study quasi-experiments (e.g., Heckman & Vytlacil, 2005; Pufahl & Weiss, 2009; Silva, Freitas, & Costa, 2018). In this working paper, access to energy was considered the treatment while the value of agricultural production was the outcome variable. This technique enabled us to estimate the average treatment effect on the treated while controlling for observable characteristics that determine the treatment. Specifically, we used it to compose a similar sample of farms that do not have access to energy (control group) using a *matching* technique based on observable characteristics such as land in agriculture, travel time to urban centers, demographic characteristics, and fixed effects to control for regional heterogeneity within each country.

When implementing the PSM, propensity scores are generated for each observation in the sample, which represent the conditional probability of a producer accessing energy, based on a set of observable characteristics represented by the vector X ($P(X) = Pr(T = 1|X)$[2] (Cameron & Trivedi, 2005). Then, the estimated propensity scores are used to "match" producers with access to energy with those without access who are allocated within a "common support." The hypothesis of the existence of common support guarantees that there will be producers with the same distribution of observable characteristics, regardless of whether such a producer has access to energy or not. Specifically, $D \perp X|P(X)$.

To ensure that the common support encompasses a sample in which there are producers with the same distribution of observable characteristics, one should perform the balance test. The

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[2] In this working paper, propensity scores were obtained by estimating the logit model.

vector of observable characteristics X has to have a similar distribution between the control and treatment groups (Lee, 2006).

After defining the appropriate matching,[3] the impact of a policy or adoption is estimated by the average treatment effect on the treated (ATET) (Rosenbaum & Rubin, 1983; Khandker, Koolwal, & Samad, 2010). The ATET, in this working paper, represents the average impact of accessing energy on the value of production of the treated producers:

$$ATET = E(Y_1|T = 1) - E(Y_0|T = 0) \tag{1}$$

To construct the control group, we used the nearest neighbor matching technique. There are several matching techniques used in the literature; another common technique is the "1-to-1 nearest neighbor without replacement" technique used in Bravo-Ureta, Greene, & Solís (2012). Our results did not change considerably using this technique or others such as kernel matching. The test of means by group (treatment and control) for each of the treatment variables and countries was performed to verify whether the matching technique was successful and indicated that the matching technique applied successfully identified the control group.

4. Data

To investigate the effect of access to energy on agricultural production, we use two agricultural censuses and a survey for these three countries. For Bolivia, we use the Agricultural Census of 2013 (Primer Censo Agropecuario 2013); for Colombia, we use the Agricultural Census of 2014 (Tercero Censo Nacional Agropecuario 2014); and we use the Encuesta Provincial a Hogares Rurales of 2014 for Peru.

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[3] The sample matching approach ensures that $E(Y_0|T = 0)$ = $E(Y_0|T = 1)$ at (x).

4.1 Peru

The data used to perform the analyses for Peru (Encuesta Provincial a Hogares Rurales (EPHR) of 2014) is available at the National Institute of Statistics and Informatics (INEI) website. EPHR provides representative statistical, demographic, social, and economic information at the provincial level for rural families across Peru (INEI, 2020). From the survey, we considered producer and farm characteristics such as education, employment, and access to services. In this sample, less than 6% declared that they had more than secondary education. The average age was approximately 32 years, and 50.3% were male. Our variable of interest, energy[4], was measured by whether households had access to electricity (question: *¿El tipo de alumbrado que tiene su hogares?*). In this sample, 72.2% of households had electricity in 2014.

Also relevant to agricultural production and potentially correlated to access to energy is access to rural extension services, for which we accounted. Less than 7% of the households had access to extension services. The value of agricultural production and land used was calculated for all permanent crops, temporary crops, and livestock (including subproducts).

4.2 Bolivia

For Bolivia, we used the Agricultural Census of 2013 (INE, 2020), which has information on 871,927 farms (Unidades de Producción Agropecuaria, UPA). In 2013, 475,589 farms used firewood as an energy source, followed by gasoline with 166,493 farms, and residues with 122,767 (question: *¿Para sus actividades agropecuarias utiliza Energía eléctrica de red?*). Only 73,984 farms reported electricity as the main source of energy for agricultural production. To estimate the

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[4] It is not possible to identify the use of energy in agricultural production in the EPHR database.

value of production, we considered winter and summer crops,[5] cattle,[6] and milk. The census does not provide information on prices; we used average prices for domestic markets by the department for each of these products from the Encuesta Agropecuaria 2015. We converted the value of production to 2015 USD (Bs$1 = USD 0.14). In 2013, 73,413 (8.4%) farmers had access to credit (question: *¿Obtuvo el crédito solicitado?*), 147,725 (17%) had access to at least one type of rural extension (53,952 had access to an extension associated with equipment, 18,853 to one associated with machinery, 86,585 to one associated with inputs, 45,534 to one associated with technical assistance, and 48,953 to one associated with courses) (question*: ¿Tipo de asistencia o apoyo recibido?*).

The Agricultural Census of 2013 also reports the age of everyone in the household, including the head of the house/farm. In a few cases, we observed that a single farm would assign two or more people as the head of the farm. Age was then created as the average age reported for these people. The average age was 49 years old. The census also reports the years of schooling for the producer; the average years of education found was 5.75 years. We built three categorical variables based on years of education: (1) 0 to 8 years, (2) between 8 and 11 years, and (3) more than 11 years.

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[5] Wheat, corn, rice with husk, sorghum, barley, oats, quinoa, amaranth, cassava, cabbage, cauliflower, broccoli, lettuce, spinach, celery, parsley, chard, coriander, wild marigold, heart of palm, watermelon, melon, *locoto*, green chili pepper, chili pepper pod, bell pepper, cucumber, eggplant, tomato, pumpkin, squash, *achojcha*, green pea, green bean, vanilla, carrot, beet, turnip, radish, garlic, onion, avocado, banana (banana), banana (dessert), fig, mango, papaya, pineapple, *achachairú*, star fruit, passionfruit, custard apple, *noni*, *copoazu*, *ocoró*, grapefruit, lemon, orange, tangerine, lime, grape, strawberry, blackberry, apple, pear, quince, peach, plum, almond in shell, nut, *pacay*, *tuna*, *camu camu*, soy, peanut, linseed, sesame, chia, coconuts in shell, palm nuts, potato, sweet potato, *hualuza*, *izaño*, *oca*, *papaliza*, *racacha*, *maca*, *ajipa*, *aricoma*, coffee, cocoa, pepper, chili, anise, chamomile, annatto, peppermint, stevia, rue, oregano, jamaica, bean, chickpea, *tarwi*, rowing sugar cane, sugar cane, alfalfa, fodder barley, fodder oats, forage sorghum, broom sorghum, fodder *cana*, fiber cotton, coca, carnation, gladiolus, illusion, poplin, broom, cardigan, *bombomose* (flower), *beiby* (flower), sparkle flower, *quico*, *bara de San Jose*, and tobacco.

[6] We assume that only 80% of the cattle two or three years old are sold and are therefore included in the value of production.

We only considered farms that had a positive value of production and land that produced at least one of the products considered. To control for outliers, we dropped all observations in the bottom 1% and top 1% of the distribution of the value of production. Finally, we only retained in the model farms that are individual producers[7].

4.3 Colombia

For Colombia, we used the Agricultural Census of 2014 (Tercero Censo Nacional Agropecuario 2014), which has information on 2,913,163 observations, of which 81.4% are farms (Unidades de Produccion Agropecuaria). Energy was used for agricultural production by 32.8% of the farms (question: *¿Para el desarrollo de las actividades agropecuarias la energia que utiliza es?*), mostly electricity from major grids (83.4%), fuels (10.8%), and own electrical plants (7.1%). To estimate the value of production, we considered crops,[8] cattle,[9] and milk. The census does not provide information on prices; we used prices from the Food and Agriculture Organization (FAO) for 2014. We converted the value of production to 2015 USD (Col$1 = USD 0.0003). In terms of requesting credit, 10.7% of the farmers did so, with 88.4% of those obtaining credit, which implies that 9.5% of farms overall obtained credit. The census reports information on 10 different types of extensions (question: *¿Durante el 2013, Usted recibió asistencia o asesoría para el desarrollo de las actividades agropecuarias?*).[10] In terms of rural extension, 16.5% of the farms had access to this service.

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[7] Farms belonging to agro-industries, farmer associations or that carry out collective production are not considered.

[8] Coffee, grape, banana, avocado, guava, sugar cane, sugarcane, potato chips, yellow corn, white corn, pineapple, apple, barley, green bean, carrot, cocoa beans, lemon, mango, bighead bait, bait long, cebola leek, papaya, orange, peach, soybean, strawberry, tomato, wheat grain, sorghum, pear, cotton, beans, sorgof, rice, palm, potatoes, coconut, blackberry, soursop, and celeriac.

[9] We assume that 80% of the cattle two or three years old are sold and therefore included in the value of production.

[10] Extension services included technical assistance associated with agricultural practices for crop and livestock production, environmental practices, soil management, postharvest management, commercialization, and business management.

We only considered farms that had a positive value of production and land that produced at least one of the products considered. To control for outliers, we dropped all observations in the bottom 1% and top 1% of the distribution of the value of production. In addition, in all three countries, the data were further organized into 7 farm size classes: 0–5 hectares (ha), 5–10 ha, 10–50 ha, 50–100 ha, 100–500 ha, 500–1,000 ha, and more than 1,000 ha.

To control for farm location, we use the research outcome of Weiss et al. (2018) to estimate the average travel time at the lowest available level of geographic information. For Colombia, it is *veredas* and for Bolivia *municipios*. Weiss et al. (2018) find that accessibility is positively correlated to income. That study uses both Open Street Map and Google to capture the transportation network to estimate the travel time to the nearest urban center with 1,500 or more inhabitants per square kilometer or, coincidently, to cities with at least 50,000 inhabitants. They argue that travel time is a more accurate measure of accessibility than Euclidian and network distance because it considers the transportation network (roads and railroads) and local geography (elevation and slope angle, rivers and other bodies of water, and topographical conditions). Their measure captures the effect of road quality on accessibility. To estimate the travel time, they consider unpaved roads and exurban residential streets and use the Global Human Settlement Grid of high-density land cover.

5. Results

Table 5.1 summarizes the key variables used in the estimation. Proportionally, more producers accessed rural extension services in Peru (11.8%) than Colombia and Bolivia, where were more producers had access to credit (14.4% and 8.5%, respectively). The differences in characteristics between producers who access energy sources in the agricultural activity and the others are also shown in Table 5.1 (unmatched and matched sample). Before the sample was matched, producers with access to energy had greater access to credit and rural extension in all countries analyzed.

Although there were no major differences between the groups with and without access to energy in relation to travel time in Bolivia, it was observed that in Peru and Colombia the average distance from large cities was much higher among the group without access to energy. In such countries, producers who declared that they did not access energy in the agricultural activity are located in relatively more distant areas, compared to those with access to some source of energy.

The results for the logit model are displayed in Table A.1. Based on this estimation, we used the propensity score generated to match the sample.[11] As expected, the results of this first step showed that rural extension and credit significantly increase the likelihood of accessing energy. For Peru and Bolivia, we also observed that producers with higher education (the base category in such models) were more likely to access energy than those with lower education. Regarding farm size classes, producers with an area of 0–5 ha were less likely to access any energy source, except in Peru.

The result of the matching can be seen in column b of Table 5.1, indicating that, after the PSM pairing was performed, the differences between the observable characteristics of the treated group (access to energy) and the control group were statistically similar. Thus, we can affirm that the main difference between such producers, in all countries analyzed, was whether the farm had access to energy.

[Table 5.1]

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[11] The balance quality was confirmed by B and R tests of Rubin (2001). For Bolivia, Peru, and Colombia, the values found were, respectively, 12.5, 11.2, and 6.7 for the B test, and 0.95, 1.10, and 1.02 for the R test.

Table 5.2 displays the results for the average treatment on the treated of energy on the value of production for Bolivia, Peru, and Colombia. Note that, before pairing, the values of production of the groups with and without access to energy for the three countries analyzed were different (Table 5.1). However, this difference cannot be interpreted as a direct effect of the treatment, since it may be related to educational levels, larger area, and other characteristics (see Table 5.1, column a).On average, producers that used energy in agricultural activities were associated with higher levels of production value.

After controlling for differences in the observable characteristics, we found that in all countries, access to energy in agricultural activities increased the value of agricultural production. For Bolivia, the ATET was USD 778.87. Caution is needed when comparing the results across countries, because the variable value of production is different across countries (see section 4).This implies that considering similar characteristics between the two groups of producers, using energy in agricultural activity has the potential to raise the value of production, on average, by 29% (considering the value of USD 2,699 for the control group). In Colombia, the ATET was USD 520.58. Although the average production value was relatively higher than that observed in Bolivia (USD 6,901 versus USD 3,478), the gain for the group with access to energy was greater in Bolivia. The ATET for Peru was USD 319.40. It is important to note that in the specific case of Peru, the survey associates access to energy with rural households and not specifically with agricultural production.

[Table 5.2]

Overall, after controlling for observable characteristics that may influence the likelihood of using energy in agricultural activities in Bolivia, Peru, and Colombia, our results confirmed the hypothesis that farms with access to energy are associated with a greater value of agricultural production. Access to energy services can improve working conditions on farms and facilitate access to better-quality services, products, and technologies, resulting in increased productivity (Kooijman-van Dijk & Clancy, 2010).

6. Summary

In this working paper, we explore the link between energy use and the value of agricultural production in Bolivia, Peru, and Colombia. We look at data from agricultural censuses and a national survey to estimate the average treatment effect on the treated of access to energy in agricultural activities on the value of production, using the propensity score matching (PSM) technique. In all countries, we find that using energy in agricultural activities increases the value of agricultural production. Considering similar characteristics between the two groups of producers, we observe a greater (positive) effect of energy on the value of production in Bolivia, with the potential to raise the agricultural value as much as 29% (an increase of USD 778.87). In Colombia and Peru, a positive ATET was also observed, indicating that farms with access to energy have higher production values of USD 520.58 and USD 319.40, respectively, compared to farms without access.

We focus on the average treatment effect on the treated of having access to energy based on a comparison between those that did have access and a counterfactual control group obtained using matching techniques. The datasets used here provide information for only one year. Future research should consider a pre- and posttreatment analysis of specific energy projects to estimate the effect of electrification on agriculture. The method used also does not account for potential endogeneity issues from unobserved characteristics. Future research could explore the spatial correlation at a higher level, such as at the municipalities level, and account for the potential endogeneity problem.

The datasets for Colombia and Bolivia do not provide information on prices or the value of production. We use prices from FAO to construct the variable value of production for selected products for Colombia and information on prices available from a national survey for Bolivia. There are two issues with this approach: it can potentially fail to capture a farm's entire production (a farmer could be producing two crops, one considered in this procedure and the other not), and it assumes a unique price for producers across the country (for Bolivia we calculated the average at the department level).

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Tables and Figures

Table 5.1 Descriptive statistics of key variables that explain the probability of having access to energy

	Overall mean	*(a) Unmatched sample*		*(b) Matched sample*	
		Control	Treated	Control	Treated
Bolivia					
Rural extension	0.053	0.035	0.085	0.078 ns	0.085
Credit	0.085	0.051	0.147	0.143 ns	0.147
Travel time	3.617	3.350	4.104	4.133 ns	4.104
Farm size classes:					
0 to 5 ha	0.881	0.948	0.758	0.766 a	0.758
5 to 10 ha	0.0565	0.034	0.097	0.095 ns	0.097
10 to 50 ha	0.0504	0.016	0.114	0.112 ns	0.114
50 to 100 ha	0.0086	0.001	0.022	0.019	0.022
100 to 500 ha	0.0032	3.83E-04	0.008	7.31E-03 ns	0.008
500 to 1,000 ha	0.0002	3.81E-05	0.001	4.42E-04	0.001
>1,000 ha	0.0001	8.46E-06	1.70E-04	6.19E-05	1.70E-04
Peru					
Rural extension	0.118	0.106	0.123	0.128 ns	0.123
Credit	0.116	0.077	0.133	0.138 ns	0.133
Travel time	4.512	7.510	3.201	3.323 ns	3.201
Farm size classes:					
0 to 5 ha	0.830	0.758	0.862	0.855 a	0.862
5 to 10 ha	0.068	0.087	0.060	0.064 ns	0.060
10 to 50 ha	0.064	0.105	0.046	0.049 ns	0.046
50 to 100 ha	0.009	0.018	0.006	0.006 ns	0.006
100 to 500 ha	0.010	0.016	0.008	0.007 ns	0.008
500 to 1,000 ha	0.004	0.003	0.004	0.005 ns	0.004
>1,000 ha	0.013	0.014	0.014	0.015 ns	0.014

Colombia					
Rural extension	0.102	0.082	0.135	0.131[ns]	0.135
Credit	0.144	0.115	0.193	0.195[ns]	0.193
Travel time	2.971	3.474	2.141	2.166[ns]	2.141
Farm size classes:					
0 to 5 ha	0.751	0.784	0.695	0.704[a]	0.695
5 to 10 ha	0.101	0.095	0.111	0.103	0.111
10 to 50 ha	0.117	0.101	0.144	0.141	0.144
50 to 100 ha	0.016	0.012	0.025	0.025[ns]	0.025
100 to 500 ha	0.012	0.007	0.021	0.022	0.021
500 to 1,000 ha	0.002	0.001	0.003	0.003[ns]	0.003
>1,000 ha	0.001	0.001	0.002	0.002	0.002

Note: Rural extension and credit represent the share of producers with access to these services. Travel time represents the number of hours taken to reach the nearest town of at least 50,000 inhabitants. In addition to these variables, we included state fixed effects and farm size. For Peru and Bolivia, we also controlled for producers' gender, education, and age.

[a] The dummy variable representing the group of area 0 to 5 ha was not included in the model (base category). [ns] means are statistically the same as the control group at 1%.

Table 5.2 Energy treatment effect on the treated – ATET on the value of production (USD) for all Andean countries

	Bolivia	Peru	Colombia
Unmatched sample (before PSM)			
No energy	1,187.64	2,321.37	4,603.49
Access to energy	3,478.41	2,909.22	6,901.94
Matched sample (after PSM)			
No energy (control)	2,699.54	2,589.78	6,381.36
Access to energy (treated)	3,478.41	2,909.22	6,901.94
ATET (energy effect)	*778.87*	*319.44*	*520.58*

Note: All treatment effects are significant at 1%.

Appendix

Table A.1 Logit estimates (PSM first step) for Bolivia, Peru, and Colombia

	(1)	(2)	(3)
Variables	Bolivia	Peru	Colombia
Rural extension	0.564***	0.159***	0.425***
	(0.0124)	(0.0280)	(0.00693)
Credit	0.780***	0.423***	0.546***
	(0.00999)	(0.0305)	(0.00592)
Age	-0.00119***	0.00944***	-
	(0.000191)	(0.000573)	-
Gender	0.248***	-0.0718**	-
	(0.00670)	(0.0351)	-
Farm size classes:			
5 to 10 ha	0.683***	-0.452***	0.230***
	(0.0117)	(0.0329)	(0.00700)
10 to 50 ha	1.086***	-0.771***	0.416***
	(0.0153)	(0.0336)	(0.00672)
50 to 100 ha	1.596***	-1.120***	0.778***
	(0.0469)	(0.0817)	(0.0163)
100 to 500 ha	1.836***	-1.023***	1.139***
	(0.0799)	(0.0767)	(0.0193)
500 to 1,000 ha	1.638***	0.0602 ^{ns}	1.234***
	(0.260)	(0.147)	(0.0540)
>1,000 ha	1.888***	-0.0764 ^{ns}	1.321***
	(0.563)	(0.0735)	(0.0673)
Time (mean hours)	0.0387***	-0.134***	-0.0706***
	(0.00295)	(0.00406)	(0.00103)
Time (mean hours)^2	-0.00128***	0.00237***	0.000686***
	(0.000151)	(0.000107)	(2.29e-05)
Population density	0.000440***	0.000244***	8.71e-05***
	(2.19e-05)	(8.64e-05)	(6.56e-06)
Schooling:			
None	-	-1.858***	-
	-	(0.440)	-
Basic education	-	-1.273***	-
	-	(0.488)	-
Primary (incomplete)	-	-1.401***	-
	-	(0.439)	-
Primary (complete)	-0.160***	-1.215***	-

	(0.00838)	(0.439)	-
Secondary (incomplete)	-	-0.901**	-
	-	(0.439)	-
Secondary (complete)	-	-0.598 ns	-
	-	(0.439)	-
High (incomplete)	-	-0.428 ns	-
	-	(0.442)	-
High (complete)	0.00493 ns	-0.323 ns	-
	(0.0124)	(0.441)	-
Higher (incomplete)	-	-0.348 ns	-
	-	(0.443)	-
Higher (complete)	-	-0.191 NS	-
	-	(0.445)	-
Constant	-1.405***	2.062***	0.0396***
	(0.0260)	(0.443)	(0.00734)
Observations	731,140	78,885	1,083,026

Source: Own elaboration.
Note: Standard errors in parentheses. *** = significant at 1%, ** = significant at 5%, ns = not significant.
For Bolivia, we only consider three schooling classes: elementary, high, and higher school (basic category).
Estimated coefficients should not be interpreted as marginal effects.