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Rural Electrification and Manufacturing Firm Performance in Benin

An Ex-Ante Impact Assessment

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Jörg Peters, Colin Vance, and Marek Harsdorff[1]

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Abstract

Productive electricity use is widely believed to contribute to positive impacts of electrification projects. This paper investigates these impacts by comparing the performance of micro manufacturing enterprises in grid-covered and non-covered villages in Northern Benin. Using firm-level data, the empirical analysis employs a Propensity Score Matching. While beneficial impacts are found from firm creation after electrification, firms that existed before actually show a non-significantly inferior performance to their matched counterparts from a non-electrified region. Complementary measures that sensitize firms about the implications of a grid connection are recommended as important features of program design.

JEL Classification: C21, O14, O22, L69

Keywords: Impact evaluation; propensity score matching; productive electricity use

June 2010

1 *Jörg Peters, RWI; Colin Vance, RWI and Jacobs University Bremen; Marek Harsdorff, International Labour Organization.* *– We are grateful for valuable comments and suggestions by Benjamin Attigah, Gunther Bensch, John Haisken-DeNew, Wilhelm Löwenstein, Lucius Mayer-Tasch, Kilian Reiche, and, in particular, Christoph M. Schmidt. Research underlying this paper was financed by the joint GTZ/World Bank research project "Income Generation through Electricity and Complementary Services (INGENS)".* *– All correspondence to Jörg Peters, RWI, Hohenzollernstr. 1–3, 45128 Essen, Germany, e-mail: joerg.peters@rwi-essen.de.*

Rural Electrification and Manufacturing Firm Performance in Benin: An Ex-Ante Impact Assessment

1. Introduction

With a per-capita income of US$ 570 and a ranking of 163 out of 177 countries, Benin remains one of the poorest countries in the world (Watkins, 2007). While the coastal region enjoys some commercial advantages afforded by the combined influence of industrial activity and trade linkages, rural Benin is dominated by a subsistence-oriented agrarian economy that is largely detached from external markets. Benin's economic growth reached 4.8 percent in 2008, but the global financial crisis portends abated growth in the coming years owing largely to a 40% decrease in the world market price for cotton, the backbone of the economy.

Although rural Benin as a whole is still characterized by a predominantly agrarian economy, today some 40% of the rural population work at least part time in non-farming businesses. A growing number of farmers have attempted to diversify their incomes by establishing small enterprises in the service and manufacturing sectors. In some parts of north-eastern rural Benin, this transition has been facilitated by the installation of grid electricity beginning in 2000, which was accompanied by an eight percent increase in rural per capita income over a five year period. In the long run, lighting and small machinery can potentially foster further expansion of the service and small scale industry sector, thereby helping to diversify the rural economy.

In light of the growing relevance of the non-agricultural sector, this paper investigates the impacts of electricity provision by comparing the performance of micro manufacturing enterprises located in grid-connected and non-connected villages in Northern Benin. The data underlying this study was collected in April and May 2008 as baseline data for an electrification project implemented by Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ). The target region of the GTZ

project was not connected to the grid at the time of the survey. By including a second region that is already electrified, the survey design allows for evaluating electrification impacts before the GTZ project is implemented. This *ex-ante* impact assessment is done by cross-sectional comparison of firms with and without connection to the grid. A structured questionnaire was used that seeks to obtain mostly objective information on all areas of the firm's activity.

Following a literature survey on electricity usage in micro-enterprises in Section 2, Section 3 describes the survey design, followed by a description of the economic situation in the survey regions, including access to infrastructure, markets, Business Development Services (BDS) credits, and input factors in Section 4. Section 5 presents the identification strategy for the impact assessment and the results. Section 6 concludes. Our principal outcome indicator for firm performance is the firm's profit. One of the key findings of this analysis is that a substantial number of firms are created after electrification. Some of these newly created firms are fundamentally dependent on electricity for their operations. These firms exhibit profits that are considerably higher than non-connected firms.

For the firms that had either existed before or that were created after electrification but do not fundamentally depend on electricity, we examine the impact of a connection on profits using Propensity Score matching. This approach uses the information from the grid covered access region to predict the probability of getting connected of firms in both the access and non-access region. This propensity score is then used to match connected and non-connected firms and thereby to calculate the impact of electrification on firm performance. Thereby, we are able to avoid the likely selection bias emerging from comparison of connected and non-connected firms in one region only.

Overall, our analysis fails to find clear-cut economic benefits from electrification. While the emergence of new firms that need electricity suggests some evidence for

firm creation and positive impacts, among the old firms, no effect of being connected to the grid on firm profits can be detected. Implications for the project design and evaluation of electrification programs are drawn in the concluding section.

2. Micro-enterprises and the Role of Electricity in Developing Countries

The importance of rural non-farm activities and micro-enterprises for economic growth and rural development is the subject of a long and ongoing debate in the literature. Several studies highlight the contribution of small and micro-enterprises (SMEs) to employment and the economy in general. According to NICHTER AND GOLDMARK (2009), for example, the contribution of SMEs to employment in five African countries is twice as high as for large firms and the public sector. In Kenya, for example, 13 % of GDP stems from SMEs. REARDON ET AL. (1998) provide an estimate for the contribution of non-farm income to rural household incomes of 42% in sub-Sahara Africa. According to MASAKURE, CRANFIELD, AND HENSON (2008), in Ghana alone 1.9 million households run a non-farm business, which means that effectively every household is involved in some sort of non-agricultural activity. MANDELMAN AND MONTEJ-ROJAS (2009) emphasize the importance of distinguishing between one man businesses, which they refer to as own-account workers, and self-employed individuals with employees. Based on data from Argentina, they find the latter to be profitable and productive, while the own-account workers are depicted as a stagnant alternative to unemployment.

The manufacturing sector, the focus of this paper, is frequently "viewed as the leading edge of modernization and skilled job creation, as well as a fundamental source of various positive spillovers" (TYBOUT 2000). Using firm level data from Ghana, MENSAH, TRIBE AND WEISS (2007) confirm this view only partly. Small-scale manufacturing firms hardly make any profit (and even lose money when taking into

account the owner's labor input) and hire mostly unpaid apprentices. Nevertheless, the authors regard this training of apprentices as a positive contribution to development. It provides skills that enable further firm creation, thereby "creating a business oriented middle-class".

LITTLE (1987) investigates the meaning of small and micro enterprises and raises the importance of removing barriers to electricity access in order to enable firm development. TYBOUT (2000) also names power access as one of the decisive components of a firm's business environment in developing countries. FERNANDES (2008) confirms this view by providing evidence from the manufacturing sector in Bangladesh. In his analysis, power supply problems are of considerable relevance to firm productivity. BLALOCK AND VELOSO (2007) find a significant and positive effect of an electricity connection dummy in their specification of a production function estimated on firm level data from Indonesia, confirming earlier results from HILL AND KALIRAJAN (1993).

Using micro firm level data from World Bank's Enterprise Surveys, EIFERT, GELB AND RAMACHANDRAN (2008) find that what they call indirect costs are decisive in explaining the low productivity in Africa. As energy comprises the largest share of these indirect costs, they call for more investment in infrastructure and more efficient maintenance and business services to bring these costs down. ARNOLD, MATTOO AND NARCISCO (2008) confirm this result by investigating the effect of electricity reliability and generator usage on the firm's productivity in 10 African countries. They find that reliability problems of the electricity grid have a significant negative impact on firm total factor productivity, while generator possession has a significant and positive effect. Combining quantitative and qualitative survey instruments such as Participatory Rural Appraisals (PRA), KIRUBI (2006) discovers a positive contribution of electricity provision to micro-enterprise growth in rural Kenya. Yet, he also claims that "energy, unlike water and food, is valued as a means not an end".

While this review of the literature shows that there is some evidence for the relevance of energy and electricity to the performance of firms and the development of the private sector, most studies focus only indirectly on energy. They do not evaluate specifically the effect of having direct or indirect electricity access on the performance of firms.

3. Data collection

The findings presented in this paper emerge from a baseline study conducted for an electrification project implemented by GTZ to provide grid access to a collection of twelve villages in rural Benin. The project is part of the Dutch-German energy partnership *Energizing Development* (EnDev). EnDev envisages providing 5 Million people with access to modern energy, with one focus being on the productive use of electricity. The present research was conducted as part of the joint GTZ/World Bank study on *Income Generation through Electricity and Complementary Services* (INGENS).[1] INGENS collected data in three countries, Ghana, Uganda and Benin, and tries to shed light on productive electricity usage and potential synergies with Business Development Services (BDS) and financial services.

We collected the data for the Benin part of the INGENS study that are also used in this paper. All 276 manufacturing enterprises in five electrified and five non-electrified villages were interviewed between April and May 2008. In the following, we refer to the grid-covered region as the *access region* and to the region without electricity as the *non-access region*. The villages in the access region had been covered by the grid between 3 and 7 years prior to the survey. 130 manufacturers are located in the non-access region and 146 in the electrified region, of which 55 are connected.

[1] In addition, a household baseline study was conducted in 2007 (see HARSDORFF AND PETERS 2010). While the quantitative data of this study was not used in this paper, we built the survey on the established field work infrastructure and used to qualitative experiences for the present research.

We selected the villages in both regions with the aim of assuring sufficient comparability. To this end, key criteria were determined so that access and non-access villages are similar with respect to the characteristics hypothesized to be important determinants of enterprise performance. Eight such characteristics were identified. The villages

- are located in rural areas in northern Benin that are between 400 and 600 km from the economic capital Cotonou;
- have asphalt or dirt road access that is conductible in the dry and rain seasons by car and trucks;
- have a population between 500 and 1,500 households;
- have a secondary school;
- have a regular market in the village;
- enjoy some political relevance via the existence of a communal administrative office;
- have access to Business Development Services (BDS) and micro-finance services.

Selection based on these characteristics resulted in the exclusion of small villages with limited business opportunities in the project region, because comparable electrified villages do not exist.

Furthermore, we conducted qualitative key interviews with local key informants to collect complementary qualitative information about the overall socio-economic situation, the availability of energy, the main problems in the villages, and to assess potential long term trends in enterprise development. The survey work itself was undertaken by experienced enumerators who collected comprehensive data using a structured questionnaire in the French language. Since almost each village in the survey regions has its own local language, a further translation of the questionnaire was not feasible. Instead, enumerators were trained to translate the questions on-site

if required. Data was gathered on the key aspects of enterprise operation, including capital stock, labor inputs, customer base, access to credit and financial services, as well as owner attributes such as age and education.

During the enumerator training, it was ensured that each enumerator understood the intention of the study as well as the intention of each question. Accordingly, enumerators provided explanations during the interview if they realized that a question was not understood. Furthermore, the enumerators were trained to sit down after each interview to review the whole questionnaire. If responses to crucial questions were missing or had been apparently misunderstood, the enterprise was revisited. One of the authors was on the ground during the whole survey to assure the methodologically proper implementation of the survey and to undertake consistency checks of each questionnaire.

4. Economic Conditions in the Survey Regions

In this section we describe the business environment that the micro-enterprises surveyed for this study are facing. While the selection process presented in Section 3 assures comparability to the extent possible before the survey is implemented, the descriptive statistics presented in this section confirms the comparability of the two regions by looking into the collected data. In fact, it can be reasonably assumed that electricity access is the only structural difference between the access and the non-access region.

4.1 Business Environment and Infrastructure

The economy in the surveyed regions is dominated by agricultural activities. Nearly all households own a field and pursue some sort of agricultural work. The most important cash crop in the region is cotton, which is cultivated by 20 % of the households and can be sold directly to the national cotton export agency. Among the

40 % of households that earn incomes from additional activities outside of agriculture, men mostly work in manufacturing firms while women work in commerce.

To provide for a stylized example, we describe a typical medium-size village (1000 households) as surveyed for this study. It has around 12 tailors, 10 carpenters, 8 mechanics, 8 hair dressers, 12 cereal mills and two bars, in addition to some temporary businesses. Following access to grid electricity, some additional businesses such as welders, photocopy or fish shops and typically one sawmill are established in the village. A main road traverses the centre of the villages. Larger villages are connected to the next cities by asphalt roads, the smaller ones by dirt roads. The dirt roads are bulldozed and are also drivable during the rainy season. With varying degrees of difficulty, all villages are accessible by cars and trucks. The distance to the closest city varies between 20-50 km and the distance to the country's economic capital Cotonou ranges between 400 and 600 km. Although fixed telephone lines exist in some villages, the lines, phone cabins and phones are typically in disrepair and therefore rarely used. None of the non-electrified villages are officially covered by a cell phone network, which tends to be extended to villages that get connected to the electricity grid.

In rural Benin grid electricity is virtually non-existent. The surveyed electrified region is one of the few grid covered rural areas; villages therein were connected between 3 and 8 years prior to the survey. Tariffs vary between 56 FCFA/kWh to 95 FCFA/KWh for large consumers. Costs of an official connection – including the official fees and the in-house installation costs – are around 90,000 FCFA. Informal connections, also called secondary connections, account for around 25 % of all connections among manufacturing firms. Such connections cost between 5,000-50,000 FCFA depending on the distance to the neighbor. The electricity grid in the

surveyed region is relatively reliable. Unexpected blackouts occur around two times per week, but are of very short duration (2-30 minutes).

4.2. Subjective Growth Barriers and Market Access

Table 1 shows answers respondents gave to a qualitative question eliciting the major problems with respect to the development prospects faced by the firm. By far, the most frequent answer is the lack of access to equipment and machinery. Access to electricity is also seen as a barrier by more than half of interviewed firms – as a matter of course only in the non-access region. It is interesting to note that – apart from electricity access – the two regions are quite balanced in terms of perceived problems.

It comes as a surprise that less than a quarter of the surveyed firms believe that insufficient demand for their products is a bottleneck for their enterprise's perspectives, as limited market size and demand is widely believed to be a major bottleneck to growth in general in rural Africa (Tybout 2000). Intuitively, market access is clearly a decisive issue for the prospects of micro-enterprises in rural areas. Even firms with superior production technologies or product ideas have no chance to expand production if local demand is weak and other clients cannot be reached.

In the survey regions, only few enterprises sell products on main roads that are frequented by clients coming from other regions of Benin. The great majority of enterprises sell their products and services exclusively to locals directly at their shop or production site. As can be seen in Table 1, electrified and non-electrified firms do not differ in this regard. Virtually none of them sell products regionally or nationally. Some differences do emerge when looking at the customers instead of the location of selling the product.

Table 1: Perceptive problems and market access in the access and non-access region

	Access Region	No access Region
Number of firms	**146**	**130**
Perceived major problem with respect to development prospects of firm		
Access to equipments and machines	68 %	67 %
Access to credits	24 %	25 %
Lacking demand	23 %	24 %
Access to electricity	17 %	51 %
Access to primary products	15 %	22 %
Access to qualified workers	6 %	10 %
Access to further training	6 %	13 %
Access to telecommunication	0 %	7 %
Products are sold…		
- directly at the enterprise (clients are coming to the production site)	100%	100%
- on a market in the village (local market)	5%	6%
- on a market in a town close by (regional market)	1%	2%
- on a market in the capital (national market)	0%	0%
- on the international market	0%	0%

4.3 Energy Usage

Some sort of artificial lighting - be it electric or otherwise - is used in slightly more than 50 % of firms. It is widely expected that access to improved lighting services through electricity leads to extended operating hours, as electric lighting facilitates working after sunset. Firms in electrified villages start their work slightly earlier than in the non-electrified region, while in both regions firms end their work at virtually

the same time, namely a little before sunset at around 6:30 pm. Even looking at connected firms only, the closing time is only slightly after sunset at 7 pm. Most connected manufacturing firms use electric lighting – but obviously not in order to prolong their working hours but to illuminate their workshops when the day is hazy.

Beyond lighting, around 48 % of firms in the two regions use appliances that require non-human energy. What is striking is that 77 of 133 energy-using appliances are charcoal irons, mostly used by tailors. Obviously, irons are not replaced if electricity is available, as all connected firms that use an iron still run it with charcoal. Electric appliances in manufacturing enterprises are mostly welding equipment and radios.

4.4 Employment

Generally, as depicted in Table 2, most firms in the surveyed regions hire workers beyond the firm owner, in most cases on an informal basis. As these hired workers are typically unpaid apprentices without any written contract, many enterprises are effectively one man businesses. Firms in the access region have more workers, in particular if they are connected to the grid.

Table 2: Employment and capital usage

	Access region			No access region
	Total Access	Connected	Non-connected	
Number of firms	**146**	**55**	**91**	**130**
Employment:				
Share of firms that hire workers	0.83	0.93	0.77	0.85
Number of workers if workers are hired	2.4	2.7	2.1	1.9
Share of paid workers if workers are hired	33.2%	34.8%	32.5%	32.5%
Employed capital (in FCFA):				
Energy but not electricity using machines	171	0	274	360
Electric appliances	70,25	158,573	16,868	26,121
Transport	84,795	126,455	59,615	81,462
Tools and furniture used for production	162,901	286,909	87,951	196,299
Total	318,117	571,937	164,708	329,382

4.5 Capital

Capital is measured as the aggregated value of the capital stock possessed by the enterprise at resale values. For this purpose, data on all equipment, machinery, larger tools and vehicles was collected in the survey. To draw a conclusion on how the capital stock might change after electrification, subgroups for capital are created: electricity using machinery and appliances, appliances driven by other energy sources (i.e. generators), simple hand tools, and vehicles.

The access and the non-access region do not differ significantly from each other with respect to the value of the total capital stock, though its composition differs (see

Table 2). Firms with electricity access possess much more electricity-using appliances, which is plausible as enterprises invest in electric appliances and tools when electricity is available. This can be confirmed by comparing connected and non-connected enterprises, where a significantly higher capital stock among enterprises connected to the grid can be discerned. The electric capital seen in the non-access region is due to the few welders in the non-access region that occasionally use generators, which explains the amount of electric appliances there.

5. Impacts on Firm Performance

5.1 Identification Strategy

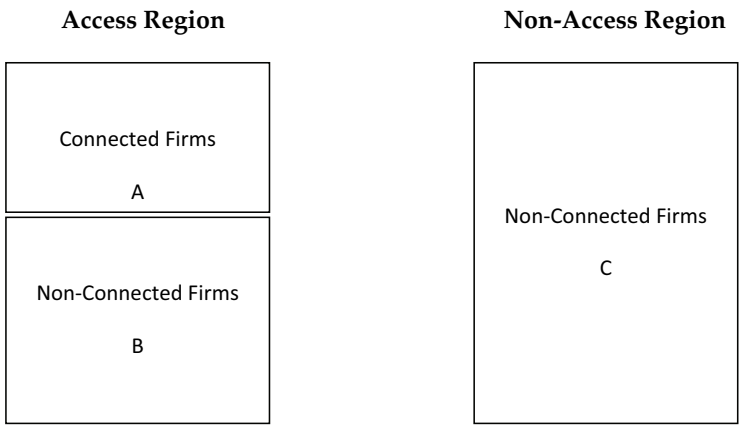
The assumption underlying this impact assessment is that electricity induces productivity gains by improving the production process, which would ultimately translate into higher firm profits. Profits are calculated on a monthly basis, subtracting total expenditures from turnover.

As presented in PETERS (2009), in general two treatments have to be distinguished in the evaluation of electrification interventions: Principle access to the grid and direct connection to it. In this paper, we mainly focus on evaluating the direct connection to the electricity grid. While we use data collected for a baseline of a GTZ electrification project, it bears emphasizing that we are not evaluating this GTZ intervention. Comparing the GTZ region that was not electrified at the time of the survey to the grid covered non-GTZ region enables us to derive insights about the impacts of electrification on firm performance using an ordinary cross-sectional approach.[2]

[2] See RAVALLION (2008) and FRONDEL AND SCHMIDT (2005) for a presentation of identification assumptions for different evaluation approaches. PETERS (2009) elaborates particularly on the idea of cross-sectional ex-ante impact assessments and underlying assumptions.

For this purpose, we created three subgroups to be compared (see Figure 1): (A) Connected firms in the access region; (B) Non-connected firms in the access region; and (C) All firms in the non-access region.[3]

Figure 1: Access and Non-Access Region



A priori, comparing Group A to Group B would yield the impacts of a grid connection. In fact, this comparison is frequently applied in the evaluation of electrification interventions. However, as discussed in PETERS (2009), determining the impact by comparing A and B is likely to suffer from strong simultaneity and selection biases. Selection biases arise from the fact that particular firms select themselves into the treatment group A. One might, for example, imagine an entrepreneur who is more risk taking and is, for this reason, more likely to get connected. At the same time, his weaker risk aversion is also associated with better performance and higher profits. In ignoring this risk behavior, one would spuriously ascribe the better performance exclusively to the grid connection. The simultaneity bias arises from the fact that more profitable firms are more inclined to get a

[3] For the ex-ante cross sectional analysis the electrified region constitutes the treatment region. Over time, though, it is the yet non-electrified GTZ target region that becomes the treatment region. In order to avoid confusion we abstain from using the term treatment region.

connection. Simply comparing A and B therefore does not allow one to disentangle to what extent the firm is more profitable because it is connected or vice versa.

One possibility to reduce such biases is to increase the comparability of treated and untreated firms using propensity score-matching (PSM, ROSENBAUM AND RUBIN 1983), For this purpose, variables are required that affect both the decision to connect and the outcome variable, firm profits.[4] In the optimal case, one has pre-intervention observations, for example profits at the time of the grid connection, at hand. Lacking these, we must resort to variables that we observe after the intervention, but for which we assume that they are not affected by the electrification intervention (ROSENBAUM 1984; HARDING 2003).

Originally developed in BENSCH, KLUVE AND PETERS (2010), the particularity of our approach is that we use one part of our total sample, the access region (Group A and B), to estimate a probit model reflecting the process of the decision to connect $P(connection = 1 \mid \mathbf{x}) = \Phi(\mathbf{x}\boldsymbol{\beta})$, where Φ is the cumulative normal function, $\mathbf{x}$ is the vector of covariates, and $\hat{\beta}$ is a vector of coefficient estimates. Including firms from the non-access region here does not make sense, since firms in this region do not have the possibility to get connected. We use the coefficients from this probit model to estimate the propensity scores for the whole sample, including the non-access region. These propensity scores, in turn, are used to match connected firms from Group A to comparable non-connected partners from Group B and C. By including firms from the non-access region we increase the probability of identifying proper counterfactual firms, as these firms have not had the opportunity to self-select into the treatment. Nevertheless, we also present results on PSM with firms from the access region only.

[4] See CALIENDO AND KOPEINIG (2005) and SCHMIDT AND AUGURZKY (2001).

5.2 Difference in Means

In assessing the impact of electricity on profits, we first investigate the simple difference in means, both for the access-non-access and the connected-non-connected comparison. Monthly profits of manufacturing firms are roughly 18 % higher in the access than in the non-access region, with a difference of 13,540 FCFA (see Table 3). The high standard error of 11,500 renders the difference statistically insignificant.

Table 3: Mean profits in access and non-access region

	Access region			No access region
	Total Access	Connected	Non-connected	
Number of firms	146	55	91	130
Monthly Profits (1,000 FCFA)	87,10	118,50	68,18	73,56

Turning to the figures for the access region only and comparing connected and non-connected firms in Table 3, the profits of connected firms, which comprise 38 % of the access-population, are considerably higher than those of non-connected firms. The former report average profits of 118,500 FCFAs, some 50,322 FCFAs more than their non-connected counterparts. With a standard error of 18,340, this difference is statistically significant.

Anecdotal evidence from the field work suggests that a particular group of connected firms is performing extraordinarily well: Those connected firms that were created *due to* electrification. In the quantitative data, this is taken into account by a question in the questionnaire asking the respondent for a self-judgment: Has this firm been created because electricity has become available? Firms in this group include welders, saw mills, and printing shops, most of which serve heretofore unoccupied niches. Such firms were created after electrification and require a

connection for their operation. In the following, we consequently refer to them as *electricity reliant firms*. Table 4 shows that far from all firms that were created since electrification declare themselves to be reliant: 59 of 79 newly created firms do not state that electricity is fundamental for their business. Of these 59, 16 are also connected.

Table 4: **Electricity reliant and non-reliant firms in the access region**

	Total	Electricity reliant firms	Non-reliant firms			
			Newly created firms		Firms existed before electrification	
Number of Firms	146	20	59		67	
			Connected	**Non-connected**	**Connected**	**Non-connected**
Number of Firms			16	43	23	44
Monthly Profits (1,000 FCFA)	87.10	197.62	80.68	55.34	67.96	80.22

The electricity reliant firms exhibit clearly higher profits than non-reliant connected and non connected firms. One might suspect that the reason for the higher profitability of reliant firms is that they have been created quite recently and are more dynamic.[5] Yet, as Table 4 shows, all non-reliant firms exhibit lower profits than the reliant firms irrespective of whether they were created before or after electrification and whether they are connected. Even compared to recently founded firms in the non-access region, the reliant firms in the access region perform substantially better (not depicted in the table).

Since the reliant firms are established as a result of electrification, they contribute to the intervention's impact on the regional level. To gain a sense for the magnitude of this contribution, Table 5 presents the share of the access region's total profits, turnover, employees, and electricity consumption that is accounted for by the reliant

[5] The question of whether newly entering firms are more productive than incumbent firms is addressed, for example, in WAGNER (2010).

and non-reliant firms. While the reliant enterprises comprise 14 % of all manufacturers, they make up 20 and 25 % of total profits and turnover, respectively. Their share of electricity consumption is even larger, reaching nearly half the total, undoubtedly due to the higher capital intensity of production. Capital reliance probably also explains why the share of workers employed by the new manufacturers, 15 %, is the only indicator that is roughly equal to that of the representation in the population.

Table 5: Contribution of Electricity reliant Firms to the Local Economy

		Percent of:				
	# of firms	**Firms**	**Profits**	**Turnover**	**Employees**	**Electricity consumption**
Electricity reliant firms	20	0.14	0.20	0.25	0.15	0.47
Electricity non-reliant firms	126	0.86	0.80	0.75	0.85	0.53

Although these figures convey seemingly impressive impacts of electrification via new firm creation, it bears recognizing that they obscure the broader implications for economic welfare by omitting any accounting of offsetting effects. The most immediate of these effects are job losses and decreased profits among competing traditional manufacturers, also referred to as crowding out effects, along with indirect impacts on the upstream businesses that supply the traditional manufacturers. Moreover, to the extent that local consumer purchasing power is diverted to the new electricity reliant manufacturers, existing non-reliant manufacturers are likely to suffer a drain on business.

5.3 Matching Approaches

The results in the last section indicate that the creation of electricity reliant firms constitutes an important factor of electrification impacts on economic activities. In

order to assess the effects of electrification on the individual firm, though, comparing electricity reliant firms to firms that do not have access to electricity makes little sense; as electricity-reliant firms cannot exist in regions without electricity, the two groups are fundamentally non-comparable. Therefore, for the further PSM analysis that explores the impact on the firm level, we consequently removed the 14 % of electricity-reliant manufacturing enterprises.

The PSM is based on a probit model with the connection status as dependent variable. A decisive step is the question of which covariates of the connection decision to include as explanatory variables. Going into the data, the following variables meet the requirements of affecting both the decision to connect and firm profits as well as being non-responsive to the treatment (see Section 5.1): line of business, gender, age of the owner, and the value of investment that was used to create the firm. All selected covariates are significantly correlated on bilateral basis with both firm profits and the connection status, respectively.

Table 6: Probit regression – Grid connection as dependent variable

Covariate	Coefficient	Standard Error
Mechanic	-0.479	0.500
Tailor	0.815	0.560
Carpenter	-0.679	0.529
Entrepreneur's age	0.043**	0.021
Male entrepreneur	0.672	0.437
Invested capital for firm creation (in FCFA)	2.26e-06**	9.33e-07
Pseudo R2	0.235	
Likelihood ratio test statistic (Chi Squared)	36.39***	

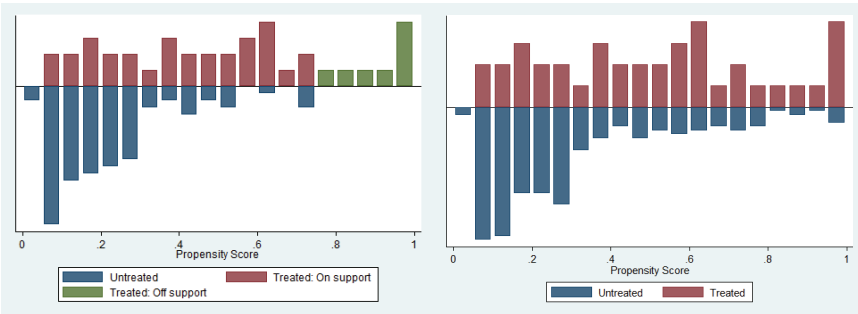
Note: ***,** and * indicate significance levels of 1%, 5% and 10%, respectively.

We see that there are moderate differences between industries, with all the sector dummy coefficients being statistically insignificant. The entrepreneur's age and the investment for firm creation are significant and both increase the likelihood of being connected. The Pseudo R^2 is 0.235 and a likelihood ratio test clearly rejects the null hypothesis that there is no joint effect of the included covariates on the connection status. This provides some evidence that the model will generate propensity scores that improve the balance in the covariates between connected and non-connected firms.

With the estimated coefficients in hand, we predict the propensity scores of firms in both the access and the non-access regions. In other words, we use the behavior of firms with regards to the connection decision in the access region to approximate the likelihood of each firm in the whole sample to get connected. Then we do PSM based on two samples:[6] As a first step we look at matched connected and non-connected firms from the access region only. In a second step, we take advantage of availability of data from the non-access region where firms could not self-select into the connection treatment. We assume to find more comparable firms in this second approach. In fact, looking at the area of common support depicted in Figure 2 shows that the overlap is much better for the case in which we recruit matching partners from both regions. Furthermore, the figure shows a bias in the distribution for both cases indicating the appropriateness of applying matching techniques to get more comparable firms.

[6] In the empirical analysis the STATA © commands *psmatch2*, the latest developed by Leuven and Sianesi (2003), were used.

Figure 2: Propensity score distribution and common support for propensity score estimation



2a: Firms access region only

2b: Firms from both regions

We apply both nearest neighbor and kernel matching. The former is conducted without replacement, the latter with replacement. The results are presented in Table 7. The unmatched treatment effect in the access-region only case shows that the difference in firm profits shrinks once the electricity reliant firms are pruned from the sample. The difference is positive, but now insignificant. It comes as a surprise that the matched treatment effect using firms from the access region only is higher than the simple unmatched difference in means. Parts of this increase is induced by the elimination of firms exhibiting high propensity scores off the support (see Figure 2a). The matched difference is even higher if kernel matching is applied. In both cases, though, the treatment effect is not significantly different from zero.

The more promising approach is the one that recruits non-connected firms from both regions, so including the non-access region, since we expect to find better matches here. The unmatched difference decreases further and is still not significantly different from zero. The matched treatment effect is for both the nearest neighbor and the kernel algorithm negative, in both cases non-significant.

Table 7: Treatment effects on firm profits

Comparison group sample: Non-treated firms recruited from…	Treatment effect unmatched *(Standard error)*	Nearest Neighbor: Treatment effect matched *(Standard error)*	Kernel: Treatment effect matched *(Standard error)*
electrified region only	5664 *(11983)*	8045 *(15114)*	14558 *(19683)*
electrified and non-electrified region	2031 *(12035)*	-14175 *(22475)*	-18721 *(13166)*

Even if we might not conclude from these non-significant negative differences that the comparable non-connected firms from both regions actually perform better than the connected ones, it provides for some evidence that positive effects on existing firms cannot be expected at all costs.

Although many applications of matching procedures do not check for whether comparability is increased (IACUS, KIND AND PORRO 2008), we scrutinize the value added of our PSM by looking at the differences in means of the covariates for connected and non-connected firms. As can be seen in Table 8, the respective t-statistics decrease in virtually all cases for both algorithms and both samples. In many cases a significant difference in the unmatched case becomes clearly insignificant by matching.

In addition, a further quality indicator is applied as proposed by SIANESI (2004): The probit model regressing the connection status on covariates is estimated first with all firms and then with the matched ones only. By comparing the pseudo-R^2 before and after we can see if any systematic difference in the distribution of covariates between connected and non-connected firms remains (BECERRIL AND ABDULAI 2010). The pseudo-R^2 will fall after matching if a balance improvement is expected.

Table 8: Balancing on covariates: t-statistics for test on difference in means between treament and comparison group

	Nearest neighbor				Kernel	
Comparison group sample: Non-treated firms recruited from…	**electrified region only**		**electrified and non-electrified region**		**electrified region only**	**electrified and non-electrified region**
	Un-matched	**Matched**	**Un-matched**	**Matched**	**Matched**	**Matched**
Mechanic	-2.52**	0.00	-2.06**	0.28	0.23	0.26
Tailor	2.87***	0.75	2.16**	-0.22	-0.29	0.02
Carpenter	-2.13**	-0.68	-1.58	0.39	0.07	0.06
Metalwork	2.51**	-0.40	2.04**	-0.27	0.07	-0.27
Entrepreneur's age	2.53**	-0.05	1.57	0.25	-0.33	-0.06
Male entrepreneur	-0.38	0.00	0.02	0.78	1.37	0.27
Invested capital for firm creation	4.45***	-0.25	1.58	-0.71	-0.51	-0.72

Note: ***,** and * indicate significance levels of 1%, 5% and 10%, respectively. The "Unmatched" comparisons are the same for Kernel and Nearest Neighbor matching.

In fact, Table 9 shows that the pseudo-R^2 decreases substantially. It has to be taken into account that the probit model underlying all PSM applications here is the one for the access region only. If one compares the pseudo-R^2 for the both-regions-scenario to this pseudo-R^2 of 0.235 is even starker than for the pseudo-R^2 obtained from both regions. This indicates that the firms in the non-access region are more comparable to the connected ones, even without matching.

The likelihood-ratio test on the joint significance of all variables also supports the judgment of a successful matching: While we are able to reject the null of no joint influence in most of the unmatched cases, it cannot be rejected for the matched samples.

Table 9: PSM quality indicators before and after matching

Matching algorithm	Comparison group sample: Non-treated firms recruited from…	Pseudo R2 before matching	Pseudo R2 after matching	Chi squared test statistic before matching	Chi squared test statistic after matching
Nearest Neighbor	electrified region only	0.235	0.015	36.29***	1.32
	electrified and non-electrified region	0.046	0.026	8.39	2.84
Kernel	electrified region only	0.235	0.032	36.29***	2.77
	electrified and non-electrified region	0.076	0.009	16.46**	0.95

Note: ***,** and * indicate significance levels of 1%, 5% and 10%, respectively. The probit model used to determine the propensity scores is always estimated using only firms from the electrified region. The respective Pseudo R2 is 0.235. The "Pseudo R2 before matching" for both regions is then estimated using firms in the two regions.

In order to check for the sensitivity of results with respect to the probit specification seen in Table 6, we use two further variables that theoretically and at the first glance qualify as covariates: Educational level of the firm owner and usage of bank loans. While the very weak bilateral correlation between these two variables and connection status and profits suggest not including them as covariates, we estimated the treatment effects in order to check robustness. The negative matched treatment effect becomes even stronger, but is still not significant. Furthermore and in line with expectation given the weak correlations, the balancing in covariates between connected and non-connected firms is worse than for the more parsimonious probit specification. As an alternative approach of how to treat the electricity reliant firms with respect to the impact determination, we left them in the sample and assigned a propensity score of 1 if the firm declares to be electricity-reliant. Both for the access region only and the both regions-case, the unmatched differences are significantly positive, but decrease substantially and become insignificant in the matched comparison.

Recapitulating, we observe that the initial difference of 50,322 FCFA revealed from a simple comparison of connected to non-connected firms in the access region conveys a misleading indicator of electrification impacts. Removing the electricity-reliant firms, which comprise a relatively small share of the sample, decreases this difference nearly ten-fold to 5,664 (see Table 7). Finally, by matching the treated to non-treated firms from both the access and non-access region, the difference actually reverses in sign, and suggests that non-connected firms have profits that exceed those of non-reliant connected ones by 14,000-19,000 FCFA. This negative difference, however, is not statistically significant.

Non-rigorous and qualitative information from the field work suggest that one reason for the lack of positive impacts and the potentially even weaker performance of non-reliant connected firms compared to comparable non-connected firms could be what one might refer to as the *electrification trap*: Firms decide to invest in the grid connection without having properly elaborated business plans and the required information at hand. As a consequence, they might overestimate the profitability of this investment given prevailing market conditions. While certainly many entrepreneurs take the decision to connect rationally, other´s may proceed on the premise that electricity is a prerequisite to modernize, neglecting the full implications for their business operations.[7] In addition, entrepreneurs get connected to the grid without expecting to increase their profits and do so rather for reasons of convenience related to lighting and radio usage, for example.

Furthermore, it bears recognizing that the connected firms in the access region are to some extent "methodological leftovers" after the electricity reliant firms were removed from the sample. As a consequence, they might have one disadvantage compared to the matched non-connected firms in the non-access region: They have to

[7] Thom (2000, p.36) reports a similar observation for households in South Africa, which acquire electric appliances for symbolic reasons. "Usefulness and cost are only one of the factors that influence" the decision to invest in equipment.

compete with the well performing reliant firms and potentially suffer from direct or indirect customer loss, particularly when the reliant firms produce substitutable but superior products. Even if the reliant firms produce non-substitutable new products, they may divert customer purchases and drain business from the non-reliant firms.

6. Conclusion

A core question among development practitioners is the extent to which electrification leads to productive use and improved firm performance. To contribute evidence to this discussion, we surveyed 276 manufacturing firms in two regions, one with and one without access to the electricity grid. For methodological reasons, it is important to differentiate between firms that require electricity and those that do not. The former are referred to as electricity reliant firms and are by necessity connected to the grid. To assess the impact of electrification, it is not reasonable to compare such reliant firms to those that do not necessarily need electricity – simply because the reliant firms cannot exist in the non-electrified scenario.

For the firms in the manufacturing sector established prior to electrification, we investigated firm profits as a performance indicator using Propensity Score Matching that identifies comparable firms among the non-connected firms in both the access and the non-access region. The principal finding emerging from this approach is that the provision of grid access does not unequivocally improve the performance of manufacturers in Northern Benin. To the contrary, our results even provide some indication that the performance of the already existing, non-reliant firms is inferior to that of their comparable counterparts in the non-access region. This negative difference, though, is not significantly different from zero. A potential explanation for the lack of impacts can be derived from qualitative insights from the

field work: Firms decide to get connected without having properly developed the business plan for the investment in the connection or electric equipment or simply for reasons of convenience related to lighting and radio usage, for example. If sales do not increase following the connection, it is straightforward that it yields a situation that is less advantageous than the non-connected status, since higher operating costs as well as the investment have to be covered.

A clearly positive effect of electrification can be observed by the creation of electricity reliant firms in the access region. They use more electric appliances and have better market access because they first, offer new products to the local population and, second, they sell semi-finished products to other enterprises in the region. As a consequence, the reliant firms perform better and generate profits exceeding those of other connected and non-connected manufacturing firms. Nevertheless, potential crowding out effects on firms that had existed already before electrification potentially reduces the net effect on the local economy.

Two implications for program design derive from these results. First, limited market access in our survey region can be suspected to be major reason for weak productive take up of electricity. Hence, if substantial productive electricity uses are desired, the electrification project should preferentially be targeted at regions that have sufficient market potential to accommodate expanded production. Second, the project should be accompanied by technical and possibly financial assistance to assess productive use potentials. In this regard, business development services can raise awareness about cost structures and existent and non-existent market opportunities. Moreover, improved access to credits can serve in helping manufacturers to finance the costs of switching to electrified production. Such assistance has to be open towards the result. In other words, business development services might also consult local firms to abstain from investing in a connection or machinery to avoid stepping into the electrification trap.

One methodological lesson from this study is that the evaluation of the program, be it ex-ante or ex-post, should strive to clearly disentangle the effects of grid-access on pre-existing manufacturers and on newcomers. To obtain the net impact of the newly created firms on the local economy, it is of particular importance to future research to examine crowding-out effects among already existing firms. Therefore, ex-post and maybe even intermediate surveys in the same regions should follow up on this baseline and ex-ante study. Such temporal data would enable the observation of firm creation in the project zone so that the origin of the performance difference between electricity reliant and traditional firms could be further investigated. Looking ahead, it is also important to enlarge the sample size with respect to both the number of observations and the covered sectors to comprehensively account for potential regional crowding out and budget effects. Furthermore, a conventional control region without access to the grid that will not be electrified between the baseline and the follow-up survey would help identifying the net total effect of electrification on both firm creation and existing firms.

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