Productive Use of Energy – PRODUSE

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

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ESMAP Energy Sector Management Assistance Program

THE AFRICA ELECTRIFICATION INITIATIVE

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

Jörg Peters, Colin Vance and Marek Harsdorff[28]

Abstract

This chapter investigates the impact of electricity on the performance of micro-enterprises by comparing the performance of firms in grid-covered and non-covered villages in Northern Benin. Using firm-level data, the empirical analysis employs Propensity Score Matching techniques. 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 sensitise firms about the implications of a grid connection are recommended as important features of programme design.

1. Introduction

With a per-capita income of US $ 771 in 2008 and a ranking of 146 out of 175 countries, Benin is one of the poorest countries in the world.[29] 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 is highly dependent on the world market price for cotton and fluctuated between 3.0 and 5.1 percent in recent years.[30]

In spite of the dominance of the agricultural sector, a growing number of farmers have attempted to diversify their incomes by establishing small enterprises in the service and manufacturing sectors. Today some 40 % of the rural population works at least part time in non- farming businesses. 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 8 % 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, the Benin PRODUSE study investigates the impacts of electricity provision by comparing the performance of micro-enterprises located in grid-connected and non-connected villages in Northern Benin. In the yet non-electrified region, the *Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH* is implementing an electrification project for which the data used in this study was collected in April and May 2008 as baseline information. While both manufacturing and service firms were interviewed, the focus of the study is on the manufacturing enterprises. A structured questionnaire was used that covers most activities and relevant characteristics of the firm.

Following a brief discussion of the survey design and the study's approach, the economic situation in the survey regions is described, including access to infrastructure, markets, Business Development Services (BDS) and credits (*Section 3*). This is followed by a presentation of some intermediate indicators for firm performance, mainly input factors such as labour and capital but with a particular focus on energy usage. During complementary qualitative interviews we found that it is reasonable to distinguish between firms that can be considered being dependent on electricity and those that can also work without. We hence differentiate between *electricity-reliant firms* and *non-reliant firms*. These two types differ substantially making an individual inspection of characteristics and outcome indicators reasonable.

The principal outcome indicator for firm performance is the firm's profit. The electricity-reliant firms exhibit profits that are considerably higher than those of the non-connected and non-reliant firms. For the non-reliant firms in the manufacturing sector we examine the impact on profits using a propensity score matching approach. This approach uses the information from the grid covered access region to predict a firm's probability of getting connected in the non-access region. Thereby, we estimate which firms will *hypothetically* get connected in the non-access region and use them as a more comparable comparison group for the impact assessment.

28) We are grateful for the valuable comments and suggestions by Benjamin Attigah, Gunther Bensch, John Haisken-DeNew, Wilhelm Löwenstein, Lucius Mayer-Tasch, Sven Neelsen, Kilian Reiche and, in particular, Christoph M. Schmidt.

29) Per capita GDP in current US $. Source: World Development Indicators (data.worldbank.org/indicator).

30) Source: *www.data.worldbank.org/indicator*

For the non-reliant firms no positive effect of being connected to the grid on firm profits can be attested. The discussion section of the chapter explains this result by highlighting the role of market constraints in stifling increased production following the shift to electrified technology. Implications for the project design and evaluation of electrification programmes are drawn in the concluding section.

2. Data Collection

The findings presented in this paper emerge from a project implemented by GIZ to provide grid access to a collection of twelve villages in rural Benin.[31] As part of this endeavor, a survey of 367 manufacturing and service enterprises in five electrified and five non-electrified villages was undertaken between April and May 2008. While the service sector includes classical service firms such as hairdressers or telephone shops, also bars and small commerce were assigned to this group. For the purposes of this study, the non-electrified villages in the project's target region located in the Atacora-Donga region in North-Western Benin form the *comparison group* for cross-sectional analysis. The electrified villages, the *treatment group*, are located in North-Eastern Benin around the rural centre of Parakou. In addition, the collected data serves as a baseline and can be used for ex-post evaluation after the electrification intervention will have been implemented. In the following, we refer to the grid-covered treatment group as the *access region* and to the control group as the *non-access region*.

As described in the overall methodology, the treatment villages had to be selected in a way that a sufficient comparability is warranted. Therefore, key criteria were determined to assure that treatment- and control villages are comparable with respect to the characteristics hypothesised 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 rainy seasons by car and trucks
- have a population of 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 and
- 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.

Table 10: Sampling

Sector	Non-Access Region	Access Region		Total
		Connected	Non-Connected	
Manufacturing (carpenter, welder, mechanic, tailor, saw mill, blacksmith)	130	55	91	276
Service (bars, shops, hairdressers, photocopy, telephone, electrician, photograph)	51	33	7	91

31) This project has been implemented under the Energising Development (EnDev) programme (*www.endev.info*). Another 105 villages are going to be electrified under the successor project, which is implemented by SBEE and GIZ and co-financed by the Government of Benin, AFD and the EU.

We interviewed all manufacturing firms that could be found in the villages. 146 of them are located in the electrified region (of which 38 % are connected) and 130 in the non-electrified region (see *Table 10*.). In addition, micro service enterprises were surveyed using simple random sampling; 51 out of 150 service firms in the non-electrified villages and 40 out of 170 in the electrified region. The connection rate among service firms is at 82.5 %. Therefore, it has to be kept in mind in the following that only seven out of 40 service firms interviewed in the access region are not connected to the grid. This low number makes a statistical analysis very difficult and calls for a prudent interpretation of the results for this subgroup.

Furthermore, we conducted 15 qualitative key interviews with local resource persons 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.

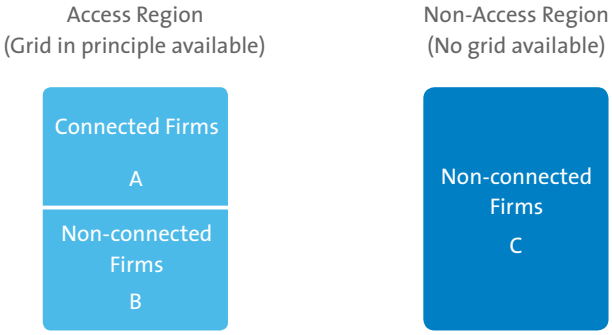
The survey work itself was undertaken by experienced enumerators who interviewed the firms using the PRODUSE questionnaire. Data was gathered on the key aspects of enterprise operation, including capital stock, labour inputs, customer base, access to credit and financial services as well as owner attributes 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 or not answered correctly. Furthermore, the enumerators were trained to sit down after each interview to review the whole questionnaire. If responses to crucial questions were missing or apparently had been misunderstood, the enterprise was revisited. One of the authors was present during the whole survey to assure the methodologically proper implementation of the survey and to undertake consistency checks of each questionnaire.

3. Research Approach and Focus

3.1. Identification Strategy

As discussed in the overall methodology (*Chapter 3*), two treatments have to be distinguished: principle availability of the grid in the *access* region and direct connection to it (see as well Peters 2009). We created three subgroups to be compared (see *Figure 6*): (a) connected firms in the access region, (b) non-connected firms in the access region and (c) firms in the non-access region. The *access* interpretation of the treatment calls for comparing (a) and (b) to (c), while the *connection* interpretation of the treatment a priori calls for comparing (a) to (b). The limited number of villages in the sample would not allow for investigating the access treatment, as variation in village characteristics could not be accounted for. Therefore, the focus is on the connection treatment. For the ultimate impact analysis in this report (*Section 6*) we create a further group that is a subgroup of (c): based on the connection behaviour of firms in the access region we predict *hypothetically* connected firms in the non-access region. These firms are likely to get connected once the grid is available. While we use data collected for a baseline of a GIZ electrification project, it bears emphasising that we are not evaluating this GIZ intervention.

Figure 6: Access and Non-Access Region



As ultimate outcome indicator, we investigate the impacts of electrification on firm performance, measured as the enterprise's monthly profits. Profit *Y* is defined as owner's income and calculated on a monthly basis, subtracting total expenditures from turnover. As all of the micro enterprises are owned by individuals, owner's income is equivalent to profit.

3.2. Electricity Dependency: Reliant and Non-Reliant Enterprises

It was observed during the field work that there is a systematic difference between firms that existed already before electrification and those that were founded after electrification. In particular, impressions from the field suggest that firms that *rely* on electricity have better opportunities and, hence, operate more successfully than others. To implement this observation into the systematic analysis the study distinguishes between firms that already existed before electrification and those that were created afterwards. In addition, these post-electrification firms were asked whether the firm's creation was independent of electrification or directly related to the availability of the grid. If the interviewee stated a direct relation of the firm creation to electrification we characterise the firm as a *reliant* firm in the following.[32] The other firms are referred to as *non-reliant*.

Table 11: Electricity Reliant and Non-Reliant Firms in the Access Region

	Total	Electricity-Reliant Firms	Non-Reliant Firms	
			Newly-Created Firms	Firms that Existed Before Electrification
Manufacturing	146	20	59	67
Service	40	10	15	15

The reasons for distinguishing between reliant and non-reliant firms are twofold: first, it is interesting to investigate those firms that seem to be established as a consequence of electrification. Second, from a methodological point of view, it is problematic for the impact analysis to compare non-treated firms to treated ones that also comprise firms that cannot, generally, be in the non-treated sample because of their reliance on electricity. In other words, electricity-reliant firms differ systematically from electricity non-reliant firms, so comparing them would be a comparison of something incomparable. Therefore, depending on the indicator under investigation we distinguish between electricity-reliant and non-reliant firms. In particular, for the analysis of the electrification impacts on firm performance, we exclude the electricity-reliant firms for reasons of non-comparability.

Electricity-reliant firms in the non-access region that use generators are rarely found. Welders are the only manufacturing firms that converted diesel mills into generators for powering welding equipment. Among service firms, only one bar owns a generator. In all firm types, investment costs to acquire a sufficiently powerful generator often exceed the costs of the electric equipment itself and are prohibitive in most cases. The availability of large generators poses another problem. To obtain one, entrepreneurs need contacts in Nigeria, Togo or the Cotonou harbour. But even if a machine is acquired, transport to the rural areas is expensive, requiring the payment of bribes to soldiers, police, and other officials on the main roads from cities to the hinterland. For products or services that can only be produced or offered locally, for example because of high transport costs, using a generator can be an option. Products that can be easily imported from towns that are connected to the grid are simply more expensive if a generator is used. Here, the situation changes if grid electricity becomes available.

32) While one might suspect potentials for a projection bias in such self-judgments, the fact that only 30 out of 104 firms that were created after electrification declared a direct relation to electricity backs the credibility of this variable. In addition, the field supervisor, who is one of the authors, individually confirmed the appropriateness of each judgment.

4. Economic Conditions in the Survey Regions

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. Around 40 % of households earn incomes from additional activities outside of agriculture – with men mostly working in manufacturing firms and women doing commerce activities.

To provide for a stylised example, we describe a typical medium-size village (1,000 households) as surveyed for this study: it has around 12 tailors, 10 carpenters, 8 mechanics, 8 hairdressers, 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 (refrigeration) and typically one sawmill are established in the village. Bars use electricity to offer cold drinks and sometimes use entertainment devices. A main road traverses the centre of the villages. Larger villages are connected to the next bigger towns by asphalt roads and the smaller ones by dirt roads. The dirt roads are bulldozed and are also drivable during the rainy season. All villages are accessible by cars and trucks, although not equally easily. The distance to the closest city varies between 20-50 km and the distance to the economic capital Cotonou ranges between 400 and 600 km. Although fix telephone lines exist in some villages, the lines, phone cabins and phones are in very bad condition and therefore rarely used. None of the non-electrified villages are covered by a cell phone network, which tends to be extended to villages that get connected to the electricity grid.

In rural areas of Benin grid electricity is virtually non-existent. The surveyed electrified region is one of the few grid-covered rural areas and was connected 3-8 years prior to the survey. Tariffs for private consumption varied in 2008 between 56 FCFA/kWh – the social tariff for the first 25 kWh consumed – and up to 95 FCFA/KWh for large consumers. Commercial users paid a fixed price of 88 FCFA/kWh.[33] Costs of an official connection – including the official fees and the in-house installation costs – varied between 50,000-200,000 FCFA depending on the distance to the grid and on accorded subsidies. Informal connections, also called secondary connections, account for more than half of all connections. Such connections are tolerated by the utility as the informal clients pay for the consumed electricity via the bill of the primary connection. These self-made 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).

The most important economic institution in the surveyed villages are the **weekly markets**. Villages without an institutionalised market are less developed with fewer permanent enterprises and less economic activity. Usually, in medium size-villages, there are 8 market days a month, mostly used to trade agricultural products. The firms that are examined in this study sell their manufactured products or services in permanent structures. Even if these enterprises do not directly profit from the markets, they enjoy indirect benefits from the influx of cash and associated increase in local purchasing power. Apart from the 8 market days, there is very little trade and exchange with other villages.

4.2. Micro-Finance and BDS

Theoretically, all firms in the survey regions have access to **micro-finance**. The usage of credits, however, is very low. No firm applied for a credit to finance the electricity connection. In total, less than 7 % of firms ever requested a credit – equally distributed across sectors. These few firms perform much better than the majority which has never received a loan. The low take-up rate of credits is even more astonishing given that all firms that ever applied for a credit eventually received one. As *Table 12* shows, procedural difficulties such as business plan requirements are perceived to be the most important hurdle. Interest rates and collateral demands, on the other hand, are not regarded major barriers. Another reason for the low take-up rate of credits might be that many of the surveyed firms believe that they do not dispose of adequate collateral for a credit

33) The local currency is the West Africa Franc (FCFA). It is pegged to the Euro at an exchange rate of 1 to 656. The FCFA/US $ exchange rate in May 2013 is 509.

(not depicted in *Table 12*). Taking into account that all firms that have applied for a credit also received one, this displays a somewhat puzzling result. One interpretation can be that firms overestimate procedural and collateral requirements. It might, however, as well be that only few firms are both technically and financially capable to fulfill the requirements. The data we have at hand does not elucidate this question.

Table 12: Subjective Reasons for Not Applying for Credits

	Region	Application procedure too difficult	Interest too high	Too many guaranties requested	The amount of credit is too small	Reimburse-ment might be difficult	No chance to get credit
Manufacturing	No access	68 %	4 %	7 %	3 %	27 %	70 %
	Access	67 %	7 %	8 %	8 %	9 %	10 %
Service	No access	75 %	2 %	15 %	4 %	25 %	10 %
	Access	70 %	5 %	5 %	8 %	14 %	2 %
Multiple answers possible							

It is sometimes argued that informal credits, most notably loans from family and friends, are a sufficient substitute to formal credit markets (see Little 1987). The surveyed regions do not support this, as only around 25 % of the firms have ever received a credit from such informal sources. Altogether, external capital seems to be hardly available.

In both the access and the non-access region some sort of BDS is or was available during the last 5 years. It is difficult, though, to compare the various BDS that were received because duration, quality and content show a large variation.

Table 13: Association Membership, Cooperation and BDS

		Enterprises that...			
		... are part of a business associati-on	... cooperate with other enterprises sharing services	... cooperate with other enterprises sharing knowledge	... received external business training
Manu-facturing	No access	47 %	25 %	4 %	5 %
	Access	48 %	31 %	27 %	23 %
Service	No access	65 %	39 %	2 %	2 %
	Access	68 %	15 %	13 %	25 %

All firms that used some sort of BDS declare that it had positive effects on their performance. As *Table 14* depicts, around 80 % of firms say that they would like to receive technical or management training. One might suspect a bias in these responses because interviewees might expect support for free if they answer positively. Yet, only very few entrepreneurs wish to receive computer training, which might indicate a correct tendency of the answers, as respondents seem to weigh up the importance of the respective training measure to their enterprise. In addition, the quantitative data cannot confirm a positive relation between firm performance and BDS usage: both in the service and the manufacturing sector the correlation coefficient between BDS usage and profits is slightly negative.

Table 14: Entrepreneurs Perception of BDS

		Enterprises that ...				
		... say the business training had a positive effect for their businesses (out of those that used BDS)	... wish to receive BDS in form of technical training	... wish to receive BDS in form of management training	... wish to receive BDS in form of computer training	... do not see any need of BDS
Manufacturing	No access	100 %	75 %	85 %	0 %	2 %
	Access	100 %	86 %	81 %	1 %	5 %
Service	No access	100 %	86 %	75 %	8 %	2 %
	Access	100 %	88 %	63 %	11 %	11 %

When asked more openly, that is without directly relating to BDS, only few entrepreneurs state that lack of training possibilities is a major problem. It is ranked far behind other bottlenecks: access to equipment and machines, credits and, in the non-access villages, electricity (*Table 15*). The perception of lacking access to credits as major problem raises questions since, as mentioned above, only few firms have ever applied for a loan – even though the probability of receiving one seems to be rather high. Only around 25 % of the firms say that lacking demand is a major problem.

Table 15: Major Problems as Mentioned by the Entrepreneurs (multiple answers possible)

Problem is the ...	Access	No access
Access to equipment 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 %

4.3. Market Access

It comes as a surprise that less than 25 % of the surveyed firms believe that lacking 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. Market access is clearly a decisive issue for the prospects of micro-enterprise in rural areas. Even firms with superior production technologies or product ideas have no chance to expand production if local demand is not sufficient and other clients cannot be reached.

In the survey regions, only few enterprises like bars and mechanics, fish shops or sawmills 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 seen in

Table 16, electrified and non-electrified firms do not differ in this regard – including the electricity-reliant firms. 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 16: Location of Product Selling – Manufacturing Firms (multiple answers possible)[34]

Products are sold ...	Non-reliant manufacturing firms		Reliant manufacturing firms
	Access	No access	Access
– directly at the enterprise (clients are coming to the production site)	100 % (146)	100 % (130)	100 % (32)
– on a market in the village (local market)	5 %	6 %	5 %
– on a market in a town close by (regional market)	1 %	2 %	5 %
– on a market in the capital (national market)	0 %	0 %	0 %
– on the international market	0 %	0 %	0 %

Comparing reliant and non-reliant manufacturing firms shows that among reliant firms, 14 % sell products to enterprises outside the village, compared with 7 % for non-reliant firms. This is due to the fact that for the new products – such as iron doors or large wooden boards – an elevated demand not only exists in the village but also in the non-electrified surroundings. Notably welders and sawmills fabricate competitive products that are sometimes bought by intermediary traders and sold in towns. Since non-reliant manufacturing firms produce predominantly hand made products that exist in every village, the number of those selling outside their own village is much smaller. Again more striking is the observation that reliant manufacturers frequently sell their products to other enterprises in the village (41 % of reliant firms compared to 18 % among non-reliant firms, see *Table 17*). Enterprises that use electric machines in some cases specialise in semi-finished goods, selling them to other manufacturing enterprises. For example, the most popular products sold by sawmills are wide boards and wooden beams. These semi-finished goods are needed by carpenters and were formerly either imported from electrified regions or were hand sawn by the carpenters.

Table 17: Destination of Products – Manufacturing Firms

		To local private individuals	To local enterprises	To enterprises from outside the village	To exporters	To public institutions
Non-reliant manufacturing firms	No access	100 %	16 %	7 %	0 %	2 %
	Access	100 %	18 %	4 %	0 %	1 %
Reliant manufacturing firms	Access	100 %	41 %	14 %	0 %	9 %
Service	No access	100 %	8 %	0 %	0 %	0 %
	Access	100 %	35 %	10 %	0 %	0 %

A comparable observation can in principle be made within the service sector. Some service enterprises in the access region sell their service to customers from outside the village. In fact, enterprises offering new services that are not available in non-electrified areas attract clients from the surrounding villages. Examples from the survey region are photocopies or frozen fish. Furthermore, people in transit are more inclined to stop for a break in a village if shops and bars are illuminated and electricity-based services such as cold drinks or fresh food are available.

34) Service firms are not included here, since services are by nature non-tradable and can only be offered on the firm site.

5. Intermediate Outcomes: Electrification Impacts on Inputs

5.1. Energy Usage

As could be already seen in *Table 10*, in the access region the connection rates are 38 % in the manufacturing sector and 83 % in the service sector. In general, most manufacturing enterprises do not use any non-human energy source, except for lighting. The reason is that they employ manual labour instead of any machinery.

As depicted in *Table 18*, some sort of artificial lighting – be it electric or not – is used in roughly 50 % of non-reliant firms. Since manufacturing firms mostly work during daytime, non-reliant manufacturing firms in the access and the non-access region do not differ very much in terms of lighting usage. Service firms, in contrast, frequently open in the evening hours or at night as well, and hence, use more artificial lighting as soon as electricity is available. Those non-reliant manufacturing firms, however, that get a connection – both in the service and manufacturing sector – mostly use some form of lighting. Also among reliant manufacturing firms there are many firms that do not use lighting (35 %), whereas only one reliant service firm does not use it. Those enterprises that use electric lighting rarely have more than two lighting points; one inside and one outside for security reasons. While the outside light remains illuminated the whole night (10-12 hours), the inside light is used only during operation hours in the evening (1-5 hours). Only very few firms use electricity and keep on using traditional lighting sources.

Table 18: Artificial Lighting Usage Among Electricity Non-Reliant Firms

	Total	Access	No access
Manufacturing	46 % (119)	52 % (66)	41 % (53)
Service	49 % (40)	77 % (25)	29 % (15)

It is widely expected that access to improved lighting services 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. Manufacturing firms in the access as well as in the non-access region generally end their work a little before sunset at around 6:30 pm, which does not come as a surprise since only few manufacturing firms are connected. Even connected manufacturing firms close on average only slightly after sunset at 7 pm. As described above, most connected manufacturing firms use electric lighting – but obviously not in order to prolong their working hours but to illuminate their workshops on hazy days. In contrast, service enterprises open until 8 pm on average, connected service firms even until 10 pm, indicating that electricity usage prolongs the opening hours.

With regards to total opening hours, service firms open around 12.5 hours per day, manufacturing firms less than 11 hours. Connected service firms work more than 14 hours per day, while manufacturing firms hardly extend their working time when they are connected. In terms of opening hours there is no difference between electricity reliant and non-reliant firms.

In general, the majority of firms in the surveyed regions does not use appliances that require some sort of non-human energy. Only around 48 % of manufacturing and less than 30 % of service firms use any energy using appliance. Among connected firms, this share is slightly higher (see *Table 19*). What is striking is that 77 out of 133 energy using appliances in manufacturing firms are charcoal irons, mostly used by tailors. Obviously, irons are not replaced when electricity becomes available as all connected firms that use an iron still run it with charcoal. Electric appliances used in service enterprises are most importantly refrigerators and radios, in manufacturing enterprises welding equipment and radios. In the non-access region some cereal mills are run with diesel motors and only few dry-cell radios are used.

Table 19: Energy Using Appliance Usage (electric and other)

	Number of firms using appliances	Number of connected firms using appliances	Number of non-connected firms using appliances
Manufacturing	133 (276)	38 (55)	95 (221)
Service	29 (91)	19 (33)	10 (85)

In order to shed light on the low take-up rates among manufacturing firms – both in terms of the connection rate and electric appliance usage – we can look at qualitative statements given by entrepreneurs as responses to multiple choice perception questions. This, however, does not reveal a clear picture. Most firms say that they cannot afford the connection. Against the background of average connection costs of around 90,000 FCFA for an official connection (including in-house installation), this seems to be plausible. Half of the connected firms, however, are connected unofficially to their neighbour's connection and faced connection costs of 20,000 FCFA only. While this is still a considerable amount for many rural enterprises, average monthly electricity expenditures of connected firms (see *Table 20*) put this amount into perspective. Rather, many non-connected respondents might have answered this question strategically, knowing that the survey was conducted within an electrification project, which potentially subsidises connection. Other reasons are for non-connecting are hardly named. Only 20 % explicitly state that electricity would generally not help their business and no firm named the lacking reliability of the grid as a reason.

The simple reason behind the low manufacturing take-up rates seems to be rather the operation time of most firms, which dominantly work during daytime. One might argue that it is electricity that could remove the daylight barrier and enables firms to extend opening hours. Yet, incentives to work longer are low, as the potentials to expand production are extremely limited in most cases (see *Section 7*). The reason why electric appliances are hardly used is that the production of demanded goods in rural areas – such as clothes or chairs – does not require electric machinery. Hence, even connected firms only rarely use some sort of electric non-lighting appliance. The few diesel generators, by contrast, are replaced as soon as grid electricity is avail-

Table 20: Connection Rates and Electricity Consumption

	Connection rate	Number of firms in total	Monthly expenditure in FCFA	Consumption in kWh per month
Non-reliant manufacturers	0.31	39	6,142	70
- Carpenter	0.15	4	1,325	15
- Welder	1.00	7	20,000	227
- Tailor	0.49	19	2,303	26
- Car-related	0.17	8	5,938	67
- Blacksmith	0.20	1	3,000	34
Reliant manufacturing firms		20	26,600	302
Non-reliant service firms	0.77	23	8,352	95
- Commerce	1.00	2	1,750	20
- Bars	1.00	8	19,313	219
- Hairdresser	0.72	13	2,623	30
Reliant service		10	5,250	60

able, which reflects the higher operating costs of generators. The higher connection rate among service firms seems to be due to a higher demand for lighting, as they frequently work after sunset.

The take-up rates in the electrified region can provide an indication for the scope of electricity consumption and connection rates to be expected in the target region of the GIZ project. *Table 20* shows connection rates and electricity consumption in the access region for service and manufacturing firms and, again, disaggregated for firm types. Among non-reliant manufacturing firms welders have the highest connection rate with 100 % and by far the highest consumption per month. The 227 kWh consumed by an average welder exceeds the consumption of tailors or carpenters by tenfold, reflecting that the latter only use lighting devices, while the former run also welding appliances. The electricity consumption of reliant manufacturing firms even exceeds the usage of those welders that already existed before electrification. The two sawmills among the reliant manufacturing firms consume 570 and 1,140 kWh, respectively.

Among service firms, bars exhibit the highest consumption level, which is due to their widespread use of refrigerators. Hairdressers and commerce firms in most cases only use lighting and have only moderate consumption levels.

5.2. Employment

Generally, as depicted in *Table 21*, most firms in the surveyed regions hire workers beyond the firm owner, in most cases on an informal basis. As most of these hired workers are unpaid apprentices without any written contract, however, many enterprises are effectively one-man businesses. In the manufacturing sector, firms in the access region have more workers, in particular if they are connected to the grid. Service firms, in general, more frequently hire no worker at all. The reason is that apprentices in the service sector hardly exist, since running services like bars, mills, shops or phone cabins require less skilled work and no apprenticeship is necessary.

If firms in both sectors hire workers at all, they employ about two workers. Only connected manufacturing firms almost reach three employees on average.[35] In order to capture seasonality, the questionnaire also accounts for employment variation in different months of the year revealing that the number of employed workers does not vary substantially over the year.

Table 21: Employment and Wages

	Share of firms that hire workers	Number of workers if workers are hired	... of which paid workers	Weekly wage per worker if paid
Manufacturing	0.84	2.2	33.1 %	3,192
Non-access	0.85	1.9	32.8 %	2,254
Access	0.83	2.4	33.2 %	3,800
- if connected	0.93	2.7	34.8 %	7,260
- if not connected	0.77	2.1	32.5 %	1,170
Service	0.66	2.0	56.4 %	6,790
Non-access	0.57	1.8	58.1 %	7,190
Access	0.78	2.2	56.0 %	6,590
- if connected	0.82	2.0	56.6 %	6,940
- if not connected*	0.50	3.0	46.5 %	1,200

Following economic theory, the wage per worker can be taken as indication for the productivity of the firms. In addition, it suggests how large the non-farm income in the households is. The interpretation of wages, however, is difficult in light of many unpaid workers, mostly apprentices but also family members. Therefore,

35) The estimation for non-connected service firms is, again, based on very few observations.

we exclude unpaid workers and investigate the average wage of paid workers only as an indicator both for productivity and income generation. Here, we find large differences between the groups. Workers in the manufacturing sector earn around 3,000 FCFA per week, while those in service firms receive some 6,800 FCFA on average. In the service sector, paid workers in the access and non-access region earn relatively comparable wages with the non-access region exhibiting slightly higher remuneration.

Among manufacturing firms, however, firms in the access region pay considerably higher wages, which is mainly due to the connected firms that pay around 7,300 FCFA on average. A wage of around 1,200 FCFA in non-connected manufacturing firms in the access region is the lowest in the whole sample. Interpreting this difference between connected and non-connected firms, however, has to be done carefully. First, a closer look into the data shows that the magnitude of the wages paid in connected manufacturing firms is mainly driven by the electricity-reliant enterprises, which pay as much as 28,000 FCFA per week (not depicted in *Table 21*). Second, selection processes are quite likely to be responsible for parts of the difference: those firms that already paid higher wages before electrification are more likely to get connected. Also the connected non-reliant enterprises still pay 4,300 FCFA per week.

5.3. 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.

At the first glance the capital endowment among service firms is substantially higher in the access region. Yet, it has to be noted that the magnitude is drastically dominated by transport capital like cars, trucks or motorcycles. Among service firms in the access region this accounts for more than 80 %. While 30 % of the service firms own a motorcycle with an average value of 260,000 FCFA, transport capital goods depicted in *Table 22* are dominated by only three firms that own expensive cars and trucks with an average value of 2.5 million FCFA.

But also apart from transport capital the capital stock in the access region is considerably higher. It seems that enterprises in the access region and notably those using electricity invest in electric appliances as well as in furniture and accessories they use for their service. Hence, their capital stock – also net of transport – is much higher.

Although only one service firm in the non-access region declares to own a generator, 32 enterprises use some sort of electric appliance explaining the relatively large amount of electricity-based capital in the non-access region. These appliances are widely dominated by radios and mobile phones that can, as a matter of course, also be run without a direct electricity connection. Yet, also some color television sets and electric fridges are used, which might come as a surprise. In fact, as non-questionnaire information from the field shows, some firms already acquired such smaller appliances because they wait to be connected soon. Some also have appliances that are broken and intend to repair them in case of electricity access.

Table 22: Average Capital Stock per Firm in the Service Sector (in FCFA)

	Access			Non-Access
	Total Access	Connected	Non-Connected	
Energy but not electricity-using appliances	6,125	7,424	2,069	2,353
Electric appliances	183,525	222,000	2,143	61,529
Transport	2,032,000	2,463,030	0	90,451
Tools and furniture used for service	205,138	214,333	161,785	76,705
Total	2,426,788	2,906,787	165,997	231,038

No such clear picture emerges in the manufacturing sector: the access and the non-access region do not differ significantly from each other with respect to the total capital stock. This might be a consequence of the low take up rate of manufacturing enterprises and hence the small number of electricity-using enterprises within the sample. The composition of the capital stock, however, is different in the access and the non-access groups (see *Table 22*). 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 electricity-using and non-using enterprises, where a significantly higher capital stock among enterprises connected to the grid can be discerned. At the first glance, firms in the non-access region employ non-electric appliances with an average value of 25,000 FCFA. When looking into the data, however, it can be found that this value is dominated by five welders using diesel mills with an average value of 410,000 FCFA, so that the remaining firms have virtually no non-electric energy-using capital at all (average value of 360 FCFA). These welders use mills that were converted to generators to generate electricity, which also explains the vast majority of the electricity-using capital in the non-access region. In the access region generators or diesel mills that had existed before electrification were replaced by a grid connection and electric mills.

Table 23: Capital Usage in the Manufacturing Sector

	Access			Non-Access
Capital in form of...	**Total Access**	**Connected**	**Non-Connected**	
Energy but not electricity-using machines	171,000	0	274,000	360,000
Electric appliances	70,250	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

6. Impacts on Firm Performance

The goal of this study is to investigate the impacts of electrification on the performance of firms and, ultimately, on income. Potential productivity gains induced by electrification might either translate into higher wages and employment and, hence, on worker's income. Or they might translate into higher profits that accrue to the firm owner. As the research focus of this study is on micro-enterprises rather than households, we examine the impacts of electrification on profits.

Starting with a simple comparison of monthly profit mean values in the service sector, we continue with a more detailed analysis of profits in the manufacturing sector. There, we employ regression analysis and matching techniques in order to identify the causal relationship between electrification and profits. Data collected in the service sector does not allow applying those techniques. The reason is mainly the smaller sample size compared to the interviewed manufacturing firms leading to very small subgroups. In particular, only seven service firms in the access region are not connected.

The application of regression or matching techniques becomes necessary because the simple comparison of mean profits is presumably biased. The reason is that self-selection and simultaneity effects are expected to affect the decision to connect among non-reliant old firms. More profitable firms are more likely to get connected (simultaneity effect). Also, observable and unobservable characteristics like managerial skill or motivation certainly affect both the decision to get connected and firm profits (self-selection). While observable characteristics can be controlled for in simple multivariate regressions, dealing with unobservable characteristics and simultaneity effects requires further approaches. Under certain assumptions, matching methods, for example, can reduce or remove selection biases.[36]

36) See, for example, Caliendo and Kopeinig (2008) or Dehejia and Wahba (2002).

6.1. Profits in the Service Sector

At first blush, the profits of service enterprises in the access region, particularly the connected ones, are much higher than those in the non-access region. Much of this difference, however, is driven by one extreme outlier: a grid-connected shop declares profits of more than 3 million FCFA, while only 7 other firms have profits exceeding 500,000 FCFA, none of them reaches the 1,000,000 mark. Although qualitative information from the field suggests the rough accuracy of this figure, it appears reasonable to exclude this firm from the sample. First, because it does not seem to be representative for the typical firm in the region. A second reason is that the outlier firm exhibits an electricity consumption of less than 30 kWh per month indicating that the huge profit has not much to do with electricity usage.

Therefore, *Table 24* shows the mean profit values excluding the described outlier. Still, access firms perform better than non-access firms – with a considerable difference of more than 20,000 FCFA. Taking into account the standard error, however, the difference between access and non-access region is not statistically different from zero.

Table 24: Profits in the service sector, access and non-access region

	Access	Non-Access	Difference	Standard Error
Monthly profits (1,000 FCFA)	85.25	64.53	20.72	15.14
# firms	39	51		

Connected firms, again, outperform the non-connected ones and are clearly responsible for higher profits in the access region (*Table 25*). Non-connected firms even earn less than the firms in the non-access region. Nevertheless, the difference is statistically not significant. In addition, interpreting the positive difference as an impact of electrification is difficult, as poorly performing firms are certainly more likely to abstain from getting connected. In addition, it comes as a surprise that electricity-reliant service firms exhibit profits below those of the non-reliant service firms (82,300 FCFA). Apparently, in the service sector the newly-created firms are not necessarily the high-performers.

Table 25: Profits in the Service Sector, Connected and Non-Connected Firms

	Connected Firms	Non-Connected Firms	Difference	Standard Error
Monthly profits (1,000 FCFA)	92.64	51.48	41.16	33.87
# firms	32	7		

6.2. Profits in the Manufacturing Sector

Compared to the service sector, the data availability in the manufacturing sector allows a more intensive investigation of the profits of manufacturing firms and their relation to electrification. We first investigate the simple difference in means and look at the robustness of this result in the light of observable confounding effects. For this purpose, we use Ordinary Least Squares (OLS) regression analysis and a matching approach.

6.2.1. Difference in Means

As in the service sector, monthly profits of manufacturing firms are higher in the access than in the non-access region, with a difference of 13,540 FCFA, which again is statistically not significant (see *Table 25*).

Table 26: Mean Performance Indicators by Access and Non-Access Region

	Access	No Access	Difference	Standard Error
Monthly profits (1,000 FCFA)	87.10	73.56	13.54	11.54
# firms	146	130		

Turning to the figures for the access region only and comparing users and non-users in *Table 26*, the performance differences become starker. 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 FCFA, some 50,322 FCFA more than their non-connected counterparts with this difference now being statistically different from zero at the 1 % level.

Table 27: Mean Performance Indicators in the Access Region

	Connected Firms	Non-Connected Firms	Difference	Standard Error
Monthly profits (1,000 FCFA)	118.50	68.18	50.322	18.34
# firms	55	91		

In comparing *Table 27* with *Table 26*, it is of interest to note that the mean profit in the non-access region is nearly 17,000 FCFA higher than the mean of non-connected firms in the access region. This might undercut the notion that the latter benefit from positive spillovers associated with grid access, i.e. that firms benefit even if they are not connected directly. It rather suggests a self-selection process probably leading more promising firms into the connected group. In other words, it is likely that those firms who choose not to use electricity do so for reasons that negatively bear on profits, including risk aversion, limited education and access to credits and poor managerial skills. One might, for example, imagine that a firm owner who is less skilled in terms of mid-term decision-making abstains from getting connected in spite of its advantages and, at the same time, fails to take right decisions in other situations. Another example is the firm owner who is more risk-taking and for this reason might be more successful. The lower risk aversion makes him at the same time more inclined to get connected. In both cases one would ascribe the better performance to the grid connection, although other observable or unobservable factors cause the better performance.

As outlined in *Section 3.2*, a substantial difference between electricity-reliant and non-reliant manufacturing firms was detected during the field work. The welders and sawmills that target heretofore unoccupied niches and that do so using electricity for their operations seem to perform much better than their non-reliant counterparts.

In fact, 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, for example, more dynamic. Yet, as *Table 28* shows, not only firms that already existed before electrification, but also newly-created firms that declare to be non-reliant to electricity exhibit lower profits – be they connected or not. 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).

Table 28: Electricity Reliant and Non-Reliant Manufacturing Firms in the Access Region

	Total	Electricity Reliant Firms	Non-Reliant Firms			
			Newly Created Firms		Firms Existed Before Electrification	
			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

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 29* presents the share of the access region's total profits, turnover, employees and electricity consumption that is accounted for by the reliant 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.

Table 29: Contribution of Electricity-Reliant Firms to the Local Economy

	Profits	Turnover	Employees	Electricity Consumption	# of Firms	% of Firms
Electricity-reliant firms	0.20	0.25	0.15	0.47	20	0.14
Electricity non-reliant firms	0.80	0.75	0.85	0.53	126	0.86

Although these figures convey seemingly impressive impacts of electrification via new firm creation, it bears recognising 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 parts of local consumer purchasing power are diverted to the new electricity reliant manufacturers, existing non-reliant manufacturers are likely to suffer a drain on business (budget effect). Finally, we should recall that the categorisation into reliant and non-reliant firms was done based on a self-judgment of the respondents. Although qualitative information from the field supports the accuracy of answers doubts might remain that some of the reliant firms would have also been established had there been no electrification intervention.

While it is reasonable to include the electricity reliant firms in the assessment of impacts on the regional level, it is not so if one wants to determine the impact on firm level: here, it is unwarranted to compare electricity-reliant firms to firms that are not connected or do not have access to electricity. The reason is, as a matter of course, that there are no comparable firms among the untreated firms to these electricity-reliant ones, simply because they cannot exist in regions without electricity. Therefore, to explore the impact on the firm level, we consequently removed the 14% of electricity-reliant manufacturing enterprises established after electrification and recalculated the means.

As indicated by the figures in *Table 30*, this results in a markedly different picture from that presented above. The average profits of enterprises in the access region drop dramatically and are actually lower than the profits in the non-access region.

Table 30: Mean Performance Indicators by Region, Excluding Electricity-Reliant Firms

	Access	No Access	Difference	Standard Error
Monthly profits (1000 FCFA)	69.55	85.14	-15.590	11.93
# firms	126	130		

A similar pattern is revealed when comparing connected and non-connected firms in the access region. Profits decrease precipitously with the exclusion of electricity-reliant firms, by some 38%. Nevertheless, in this instance the connected firms still register profits that are 8% higher than those of the non-users (see *Table 31*).

Table 31: Mean Profits in the Access Region, Excluding Electricity-Reliant Firms

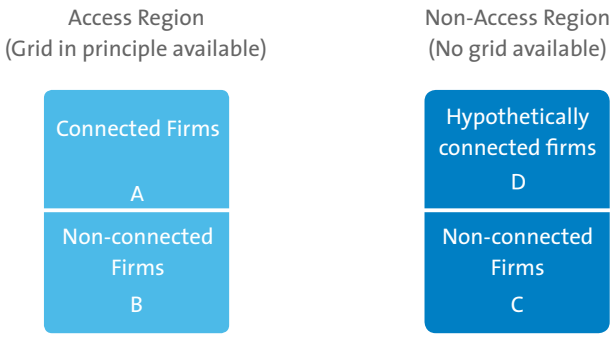
	Connected Firms	Non-Connected Firms	Difference	Standard Error
Monthly profits (1,000 FCFA)	73.18	67.93	5.251	11.85
# firms	39	87		

6.2.2. Matching Approaches

Even after removing the electricity-reliant firms from the sample, the results on the connection treatment depicted in *Table 31* can still be suspected to be substantially biased by simultaneity and selection biases described in *Section 6.2*.

One possibility to reduce such biases is to increase the comparability of treated and untreated firms via matching methods. For this purpose, determinants of the decision to connect are selected, referred to as covariates in the following. These covariates are used to identify non-treated firms that are similar to the treated firms in terms of these covariates. If one has to pick the treated and non-treated firms from the same region, one faces the problem that not many firms overlap with regards to the covariates, simply because the rather similar ones have selected themselves in the same group – either the treatment or the non-treatment group. In our case we can use matching methods to find firms in the non-access region that exhibit comparable covariates. The advantage is that it is more likely to find similar non-connected firms, as firms comparable to the connected firms had no possibility to select themselves into the treatment. As depicted in *Figure 6*, a fourth group emerges.

Figure 7: Matching of Hypothetically Connected Firms



Originally developed by Bensch, Kluve and Peters (2010), the intuition behind this approach is the identification of those firms in the non-access region that *would hypothetically* get connected if the grid was available. These hypothetically connected firms are than taken as comparison group to determine the impact of electrification on the effectively connected firms. For this purpose, we proceed in several steps (still excluding the electricity-reliant firms from the analysis):

Step one begins by estimating a probit model of the determinants of getting connected, only using firms from the access region (group A and B in *Figure 6*):

$$P(use = 1|\mathbf{x}) = \Phi\,(\mathbf{x}\beta)$$

Where Φ is the cumulative normal function, $\mathbf{x}$ is a vector of explanatory variables (covariates), and β is a vector of coefficient estimates. The explanatory variables have to be covariates of the decision to connect.

The selected covariates to be included in the probit model have to fulfil some conditions. First, matching builds on the so-called *conditional independence assumption* (CIA): the impact variables under research must be independent of treatment (in our case the household connection) conditional on the propensity score. This assumption requires that the covariates are *non-responsive* to the connection status (Rosenbaum 1984, Harding 2003). Furthermore, only covariates should be included that affect both the decision to connect and the outcome variable.[37]

In the optimal case one has pre-intervention observations at hand, for example firm profits at the time of the grid connection. Lacking these, we must resort to variables that we observe after the intervention but for which we can reasonably assume that they are not affected by the electrification intervention. Going into the

37) Caliendo and Kopeinig (2008) and Schmidt and Augurzky (2001)

data, the following variables meet the CIA and the requirements of affecting both the decision to connect and firm profits: 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 32: Mean Profits in the Access Region, Excluding Electricity-Reliant Firms

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 fairly high at 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.

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 behaviour 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. These propensity scores are now used to stratify the non-access firms into those that are likely to get connected and those that are likely to get not connected once electricity is available, so that a fourth group emerges, the *hypothetically connected* (Group D). We assume that those enterprises belong to this group that exhibit a propensity score larger than 0.5 and drop those 91 firms in the non-access region that show a propensity score smaller than 0.5. The new comparison group consists of the remaining 37 firms, while still 39 connected firms from the access region constitute the treatment group.

We use this stratification to obtain a more appropriate comparison of the connected firms. Comparing them to the hypothetically connected enterprises from the non-access region we see, as shown in *Table 33*, that the hypothetically connected firms perform much better than the connected firms in the access region. The difference in means, however, is not statistically significant different from zero.

Table 33: Mean Profits for Connected and Hypothetically Connected Firms

	Connected Firms	Non-Connected Firms	Difference	Standard Error
Monthly profits (1,000 FCFA)	73.18	98.84	-25.66	22.86
# firms	39	37		

This indicates that the connection treatment does not induce positive impacts among already existing firms. The descent of the calculated impact that can be observed starting with the results including the electricity-reliant firms (*Table 27*) via the unmatched difference in *Table 31* to the matched comparison in *Table 33* is in line with the expectations from a methodological point of view: by excluding the reliant firms and matching the treated to non-treated firms from the non-access region, we intended to increase comparability and thereby reduce the selection and simultaneity bias.

As robustness check, we applied conventional propensity score matching algorithms that match treated and untreated firms individually. Both nearest neighbour and Kernel matching confirm that hypothetically connected firms perform better – but still with this difference being insignificant.[38]

Recapitulating, we observe that the initial difference in monthly profits 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 tenfold to 5,664. 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. This result is confirmed by all matching techniques with the negative difference being insignificant in all cases, however. While the absence of positive effects of electrification on existing firms might come as a surprise, the next section provides for explanations based on theoretical considerations and qualitative findings from the field work.

7. Microeconomic Considerations of Firm Behavior

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, others may proceed on the premise that electricity is a prerequisite to modernise, neglecting the full implications for their business operations.[39]

In contrast to the electricity-reliant manufacturers, whose products typically fill a new market niche, the pre-existing manufacturers offer products that already exist, with limited, if any, access to external markets. Consequently, even if the variable costs of electrified capital initially fall as economies of scale are achieved, the firm may nevertheless not be able to reach the optimal scale of production for lack of sufficient demand.

This circumstance is illustrated in *Figure 8*, which shows the total revenue (TR) and total cost (TC) schedules corresponding to a labour-intensive and a capital-intensive production technology in the lower and upper panels, respectively. As in classical models, the TR curve passes straight through the origin because of constant prices at all levels of output (Koutsoyiannis 1979). The TC curve, by contrast, is non-linear. It initially becomes flatter as a result of economies of scale but subsequently rises at an increasing rate, reflecting the increased costs of expanding output with fixed stocks of labour and capital over the short-run. Shaded areas of the graph indicate production levels at which production costs are higher than revenues, meaning that the firm incurs losses. The optimal production point using the labour-intensive technology is point Y_L, where the difference between total revenue and total costs – profits – is maximised. By contrast, using the capital-intensive technology, production at point Y_L would result in losses. Profits using this technology are instead maximised at a higher production level corresponding to point Y_K^*.

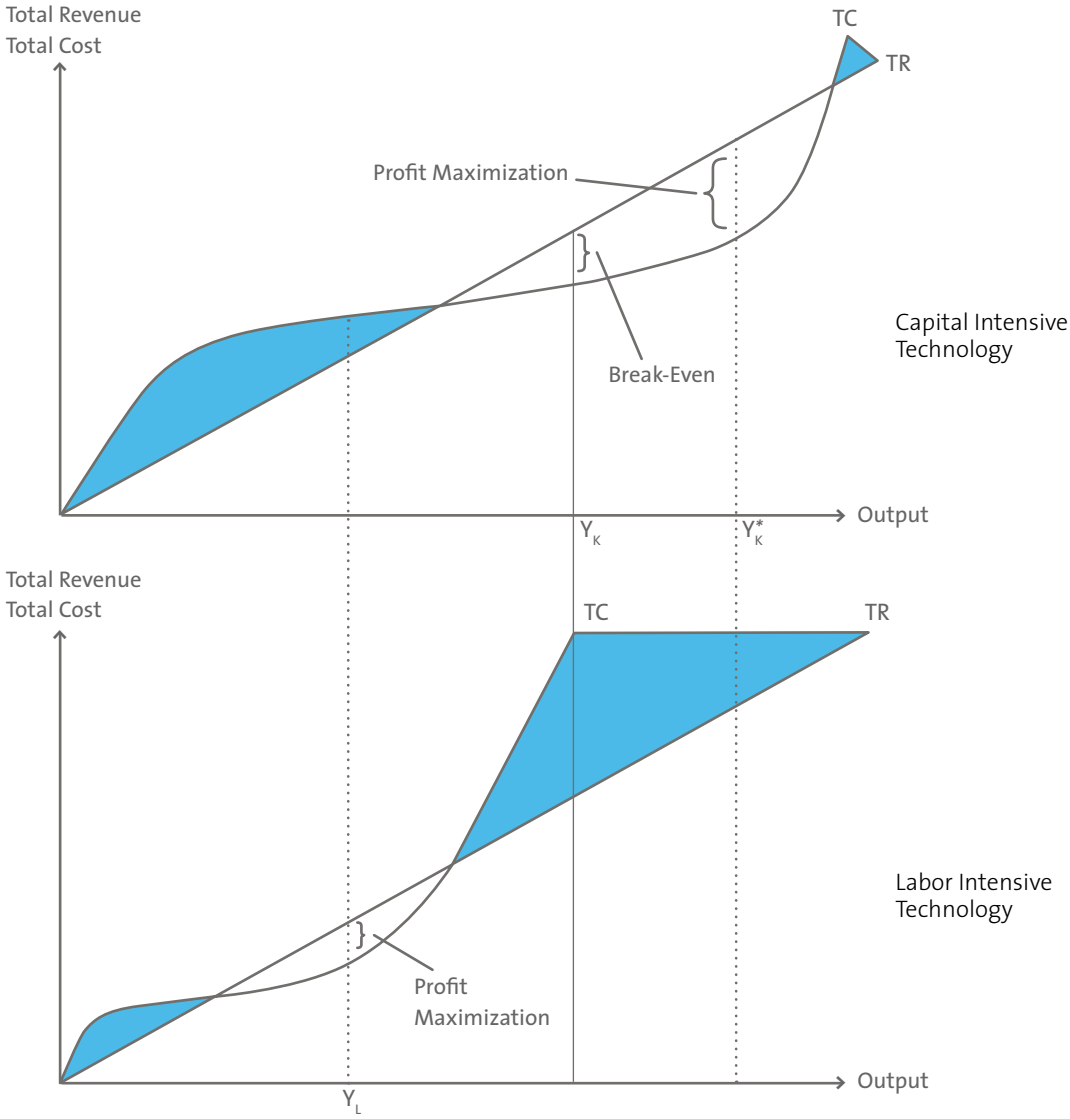
Whether the firm switches to the capital-intensive production technology made available by electricity depends fundamentally on whether the demand exists to sufficiently increase production beyond point YL. Although the attainable profits from this technology are higher than those with the labour-intensive technology, the firm may not be able to reach the corresponding level of production because of an inability to expand its customer base beyond that of the local market within which it is situated. In the stylised depiction of *Figure 7*, the labour-intensive firm must increase production by the amount given by the line segment $\overline{Y_L Y_K}$ in order to attain at least the profit level of its labour intensive production technology. Only if market potentials are sufficient to absorb at least Y_k should the firm decide to invest in an electricity connection and the respective machinery.

38) The procedure, the results as well as the balancing of matched subsamples are presented in Peters, Vance and Harsdorff (2011).

39) Thom (2000: 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.

Falling short of the Y_k level yields lower profits than in the initial labour-intensive production situation or may even create losses. Many of the surveyed firms undoubtedly find themselves in this circumstance – seeking to expand production to take advantage of the technologies afforded by electricity provision but unable to do so because of saturated local markets and limited access to external sources of demand from regional or national markets.

Figure 8: Optimal Production Level by Technology



This scenario would explain why over half the manufacturers in the grid access region decide not to connect, but it still would not account for why those that do connect have on average lower profits than in the non-access region.

Box 1: Grid-Connected Tailoring Business - A Stylised Example

An interviewed tailor in the village of Gourou invested 60,000 FCFA to buy an electric sewing machine after he received access to the grid. The electric machine enabled him to produce five instead of three pairs of trousers a day, whereby the monthly bill for electricity was about 12,000 FCFA. After five months he abandoned the electric machine and returned to the use of foot-powered sewing machines. He was not able to sell more clothes than before he obtained access to electricity, simply because the local market for trousers and clothes had been saturated already. It was also not possible to sell them at a higher price, as the quality remained the same. Since he was not able to expand the number of produced trousers due to market constraints, consequently he was not able to bring down unit costs and to amortise the sewing machine.

One explanation may be a lack of familiarity with electricity-using production technologies and an associated inability to assess the level of output needed to make profits using these technologies. Even when this level is known, the manufacturer may nevertheless overestimate the product's market potentials in relation to the total cost curve. The stylised but true example in *Box 1* underpins this consideration.

Compounding these difficulties could be an inherent inflexibility in optimally substituting factors of production. Contrasting with the enterprises established in response to electrification, the pre-existing manufacturers may have limited ability to optimise in scaling back the amount of labour after getting connected to the grid. As qualitative findings from the fieldwork suggest, this might be mainly due to contractual or familial commitments.

Another reason for the negative or at least non-positive effects of being connected to the grid shows up if the horizon is extended from the profit maximisation point of view: as evidenced by our own qualitative interviews as well as Kooijman-van Dijk (2008), 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. From the entrepreneur's non-business perspective, this is from a utility maximisation point of view, getting connected to the grid in spite of lacking potentials to increase sales can hence be rational.

8. Conclusions

A core question among development practitioners is the extent to which electrification leads to productive use and, in a next step, to improved firm performance. In order to contribute evidence to this discussion, we surveyed around 270 manufacturing and 90 service firms in two regions, one with and one without access to the electricity grid and examined the effects of electrification. As a first finding we can highlight that connection rates in electrified villages are higher among service than manufacturing firms. This is undoubtedly due to the fact that the latter can improve their services in many cases through electric appliances like entertainment devices, refrigerators or lighting. In fact, connected service firms substantially extend their working hours. Manufacturing firms, in contrast, hardly use non-human energy. Since they mostly work during the daytime, they widely abstain from getting a connection. Even among the roughly 38 % that are connected, lighting is the dominating application and take-up rates in terms of other electric equipment are low.

An important exception to this observation are manufacturing firms that are established after electrification and that require electricity for operation. These *electricity reliant firms* are by nature connected and use much more electric appliances. Market access seems to be better for such firms as they, first, offer new products to the local population and, second, sell semi-finished products to other enterprises in the region. As a consequence, the reliant firms perform much better and generate profits outpacing those of other connected and non-connected manufacturing firms. A clear positive impact for the electrified region can be observed, while potential crowding out effects on firms that had existed already before electrification potentially reduce the net effect on the local economy.

For the firms in the manufacturing sector established *prior* to electrification, we furthermore investigated firm profits as a performance indicator using a matching technique that identifies comparable firms in the non-access region, which we refer to as *hypothetically connected*. 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 suggest that the performance of the non-reliant firms is inferior to that of their counterparts in the non-access region. Although this negative difference is statistically non-significant, it might come as a surprise that no positive effect can be detected. One reason for this might be that firms decide to get connected without having properly developed the business plan for the investment in the connection or electric equipment. As our theoretical explanation underpins, this can easily lead to a situation that is less advantageous than the non-connected status, since higher operation costs as well as the investment have to be covered.

Two implications for programme design derive from this result. First, 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. Where this potential is deemed insufficient, additional measures may be required that facilitate participation in external markets. The design of these measures will depend on identifying where barriers to exchange exist but may include the improvement of marketing networks.

Second, the project should be accompanied by technical and possibly financial assistance to assess productive use potentials. In this regard, BDS 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. In the centre of any productive use promotion activity should be the establishment of proper business plans. Firms should be assisted in planning the investment into the connection or machinery. This assistance has to be open towards the result: productive use promotion activities might also consult local firms to abstain from investing in a connection or machinery – if the business plan shows that the investment is not beneficial. This is important to highlight, because many practitioners consider productive electricity use and machinery investment as a means to an end – and do not consider that it might be disadvantageous for some firms.

With regards to credit usage the findings are not straightforward. While the take-up rate is dramatically low, neither the quantitative nor the qualitative information can reveal why firms abstain from using credits. All firms that had applied for a credit also received one. At the same time, many firms that have never applied for a credit name procedural or collateral requirements as the main barrier. Accompanying measures in an electrification project could try to verify whether the gap between supply and demand of credits is a real one (i.e. for example due to a lack of credit supply) or one that might be closed simply by mutual information.

BDS are moderately used in the surveyed regions. Most participants claim a positive impact on their business, which can, however, not be confirmed in the data. In general, it has to be stated that the provided BDS are very heterogeneous in terms of quality, content and duration. Clearly, for both BDS and credit usage further research and focused study designs are required to gauge the relation between firm performance and these services.

One methodological lesson from this study is that the evaluation of the programme, 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 would also be good 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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