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Experimental impact study on a micro-grid project in Rural Madagascar: The Café Lumière project

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Experimental Impact Study on a Micro-Grid Project in Rural Madagascar: The Café Lumière Project

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Abstract

This paper evaluates the impact of the Café Lumière project launched by the NGO Électriciens sans frontières to address the lack of reliable electricity access in rural Madagascar. The project integrates solar-powered micro-grids and energy platforms to provide affordable electricity and basic electricity services for households, businesses, and public services. The study employs a randomized control design, with data collected through two waves of household surveys in 2017-2018 and 2023, complemented by locality data. The experimental dimension of the paper is based on a treatment implemented at the locality level. A dozen of comparable localities had been initially selected as suitable after a pre-feasibility study across the Vakinankaratra and Itasy highland regions, and the project has been randomly implemented in only half of them. Findings reveal notable improvements in household access to electricity, particularly in the use of modern energy services like lighting and phone charging. ... / ...

Keywords: electricity access; renewable energy; micro-grids; mini-grids; rural electrification; randomized controlled trial (RCT); impact evaluation; multiservice energy platforms.

.../... The project has also facilitated economic activities, especially secondary income-generating occupations, though the overall impact on household wealth and income remains limited. Social outcomes, including health, education, and public safety, have seen mixed results, with only minor improvements in health. The limited extension of all these impacts is compounded by their spatial narrowness. It is possible that a longer observation period would be necessary for the impacts of the project to fully materialize. However, more ambitious complementary initiatives foreshadowed in the project's theory of change but not fully implemented may be needed to achieve the broader economic and social transformation initially anticipated.

1 - Introduction

Madagascar's rural population faces significant challenges in accessing reliable electricity (rural electrification rate of 10,9% (2022, World Development Indicator), which limits its social and economic development in many dimensions.

The "Café Lumière" project by the NGO Électriciens sans frontières (ESF), implemented since 2018, proposes to address these multiple issues through an innovative solution combining a solar-energy powered micro-grid with an energy platform. The power plant feeding the micro-grid provides power available for income generating activities, part of households, collective services and the platform. The platform is essentially an electricity boutique producing basic electricity services with the objective of supplying these services at an affordable cost to the whole village population. Within the overall framework of sustainable development goals (SDGs), this project is designed to simultaneously fulfill the public policy objective of universal access to basic electricity services embedded in the SDG7, develop an economically sustainable business model for rural electrification that supports economic development objectives and improve collective services, thereby promoting social and human development progress. These three specific objectives are actually intertwined because the development of sustained electricity demand is necessary to ensure economic sustainability of the project and to deliver welfare improvements necessary to sustain engagement of all community actors involved. In the Café Lumière context, the interaction between social and economic objectives is reinforced by the introduction of a cross-subsidy mechanism, in which the electricity consumption of public services is subsidized by a local tax collected from private micro-grid customers and retroceded to the municipal authorities.

The Café Lumière solution has been first implemented by Électriciens sans frontières in Madagascar from 2018 under the FISONG (Facilité d'innovation sectorielle pour les organisations non gouvernementales) financed by AFD (Agence française de développement). This pilot case in Madagascar has been organized in a way facilitating its evaluation for the benefit of future replications. This evaluation has been implemented by FERDI independently of AFD and Électriciens sans frontières.

Evaluation of the impacts of micro-grid solutions is important because it has been poorly studied in the literature, in particular within a Randomized Control Trial (RCT) setting (Berthelemy and Millien, 2018). Most of the literature related to impacts of electricity access are based on grid network extension and usually covering Asian countries (Moore et al., 2020) and have typically relied on instrumentation strategy (Dinkelman, 2011). However this literature is poorly relevant to assess rural electrification through micro-grids as services offered to the population are quite different, as demonstrated by the Multi-Tier Framework (MTF) and the related literature (Nicolas et al., 2019).

Micro-grids are now seen as a robust alternative to bring electricity access in rural areas, in particular in Africa, but have been criticized to under-deliver in their expected impacts, in particular for driving economic activity, due to unsustainable business models over the long term, improper sizing, pricing or property ownership model (Duran and Sahinyazan, 2021; Duthie et al., 2024).

Most of the rural electrification impact literature using RCT designs has focused on standalone systems usually leading to quite limited impacts on topics such as health or education (Kudo et al., 2019a, 2019b). One similar study to our paper also based on an RCT design, which covered effects of microgrids installed in India, also found limited impacts, being able to conclude only on

significant effects on electricity access rate and kerosene expenditures, but did not find significant effects on households wealth or consumption, local economic development or other broader indicators of socioeconomic development (Aklin et al., 2017). Findings of limited outcomes related to economic and social topic are corroborated by another study focusing on rural electrification using on-grid randomized grid connections (Lee et al., 2020). Our study enriches the existing literature by providing rigorous RCT-based evidence on the impacts of a micro-grid project, the Café Lumière project, in rural Africa, specifically highlighting socio-economic outcomes in the under-researched context of rural Madagascar.

The Café Lumière concept has been initially implemented on a pilot project financed by Agence française de développement (AFD) in six villages located in the Vakinankaratra and Itasy regions of Madagascar. This pilot has served as a feasibility test and an evaluation strategy has been put in place from the beginning to study its impacts. This paper reports the conclusions of this impact evaluation, implemented by independent researchers with the collaboration of the project developer (Électriciens sans frontières) and the operator of the Café Lumière (Anka Madagascar) for data collection.

The core of the impact evaluation strategy presented in this paper is based on a two-wave household survey implemented in 2017-2018 and in 2023, covering six villages where the pilot has been implemented between 2018 and 2021 and six comparable control villages. These two sub-groups were randomly selected from an initial list of 12 villages identified by a preliminary study as suitable for the Café Lumière project. This random assignment of treatment at the village level is at the core of the RCT design, which has been put forward as the gold-standard design for impact evaluation and in particular in research in development economics aimed at poverty reduction (Banerjee et al., 2019). To facilitate the interpretation and validation of results obtained from this quantitative analysis, the household survey data were complemented by monthly implementation data provided by the project operator, as well as locality-level data collected concurrently with the household surveys.

Our findings highlight significant positive impacts of the Café Lumière project on household access to basic electricity services, particularly through increased use of electricity for lighting and mobile phone charging. Although broader socio-economic outcomes such as wealth and income improvements remain modest, the project demonstrates clear benefits for economic activities reliant on electricity, notably by promoting mechanized cereal processing and small-scale entrepreneurship. Furthermore, we document notable improvements in maternal and child healthcare services enabled by the electrification of health centers. This paper contributes to the existing literature by providing rigorous, RCT-based evidence on the effectiveness of integrated micro-grid solutions in rural Africa, filling a crucial gap by examining socio-economic impacts within the previously under-researched context of Madagascar.

The rest of this paper is structured as follows. In the first section we present the Café Lumière project and its theory of change and data related to its implementation phase. We then present data on the surveys and how they relate to the objective from the theory of change as well as the principal econometric method proposed to derive tests of impacts in this statistical context. Results of expected impacts observed on households and/or individuals' levels are reported in the next section. Then, we discuss these results by crosschecking statistical test results with alternative methods and by triangulating conclusions with locality data. The project has produced favorable outcomes, although with mixed results in several dimensions, which we discuss in conclusion.

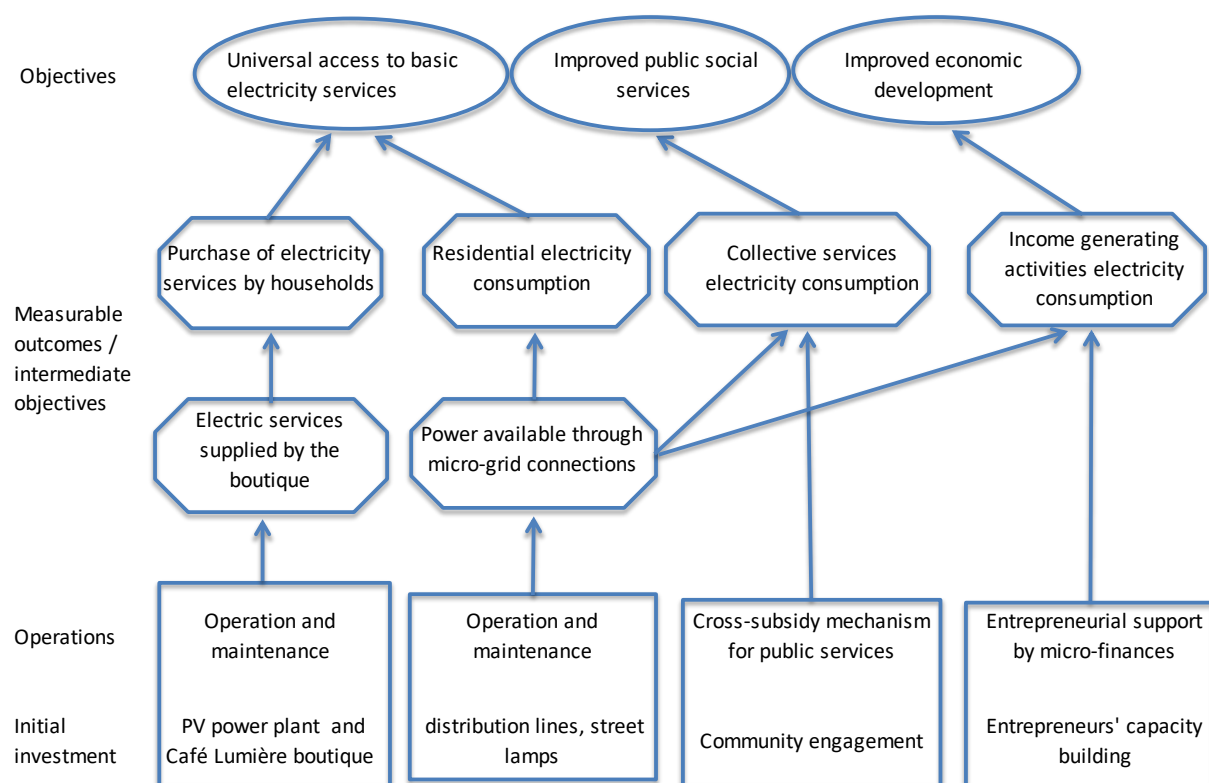
2 – The Café Lumière Project

2.1 Theory of Change

The *Café Lumière* project aims at promoting SDGs through 3 complementary specific objectives: universal access to basic electricity services, improved public social services and improved economic development. Figure 1 describes the theory of change of the project, designing the investments and operations implemented with a view to meet these specific objectives.

The technical solution of the *Café Lumière* does not differ from the majority of micro-grid projects implemented in developing countries. It consists in the production of electricity by solar panels, backed by batteries and an emergency diesel generator, distributed through a micro-grid. Based on previous experience, the project aims at promoting both social and economic development in villages of implementation.

Figure 1: Theory of change of the Café Lumière project



The social dimension of the project primarily rests on promoting universal access to basic electricity services. Universal access was considered by *Électriciens sans frontières* unattainable by the mere provision of electricity through the micro-grid, given that connection to this grid may entail fixed costs that are too high for the poor. For this reason, an electricity services provision is proposed in a boutique managed by the operator supplying notably recharges of cell phones as well as recharges and renting of solar lamps. Social development also rests on the development of social services, through the connection of health centers, schools and

streetlamps. A cross-subsidy mechanism reducing the cost of public services electricity bills has been introduced, initially through direct support by the operator and since 2023 through a local tax paid by the operator to the municipal authorities. The outcome of this financial support to collective services depends of course on the engagement of all community actors.

On the economic dimension, the micro-grid provides households and entrepreneurs, named henceforth very small size enterprises (VSEs) access to more reliable load, on a longer daily schedule and with potentially higher electric intensity than solar home systems, which were already used by some household and VSEs before the start of the project. A few VSEs used also diesel generators, but at a high operational cost. These immediate outcomes contribute to increased productivity of economic activities by enabling local businesses to operate for longer hours and offer a wider range of services. Over time, it is expected that these benefits will foster entrepreneurship and the creation of new businesses, leading to economic diversification. In order to promote this economic transformation, micro-finance interventions were planned to help VSEs to invest in electricity-powered equipment. Capacity building of VSEs, on technical and managerial skills, was also considered as an important factor of success of economic transformation.

Increased household wealth associated with the expected economic transformation is a key determinant of the economic sustainability of operations of the project and the ability to maintain equipment and invest, contributing to a virtuous cycle of economic growth. This economic growth, in turn, encourages further investment in education and health, creating a sustainable pathway to long-term socio-economic development. The sustainability of the project over time depends also on financial results of the operator, whose activity relies mostly on fixed costs, and therefore on electricity demand.

2.2 Project implementation

The Café Lumière project equipped 6 villages located in the southwest of Antananarivo, more precisely in the regions of Vakinankaratra and Itasy between 2018 and 2021¹. Figure 2 shows the location of the 12 villages.

The analysis in this section is based on the reporting done by Anka on its operations, available on a monthly basis from 2019 to 2023 in the 6 equipped villages. Such data document the actual implementation of the project. Table 1 lists the principal implementation data used in this section. These data are useful to understand the theory of change, by documenting in a single matrix action and expected outcomes. When it comes to tests the impact of the project, we also mobilize survey data collected in treated and non-treated villages. To illustrate the overall conceptual consistency of our statistical space, we list in the same matrix survey data, which will be analyzed in the following sections, to visualize how such data relate to the expected outcomes.

¹ Ambatonikolahy in 2018; Ambohimalaza in 2019; Antanamalaza, Antsampandrano and Dondona in 2020; Amparaky in 2021. **See Table S1 in supplementary material** for more details: <https://ferdi.fr/dl/df-s8p4qLcLC1uoUB6WX1gxdqpn/ferdi-wp354-supplementary-material.pdf>

Figure 2: Map of project and control villages

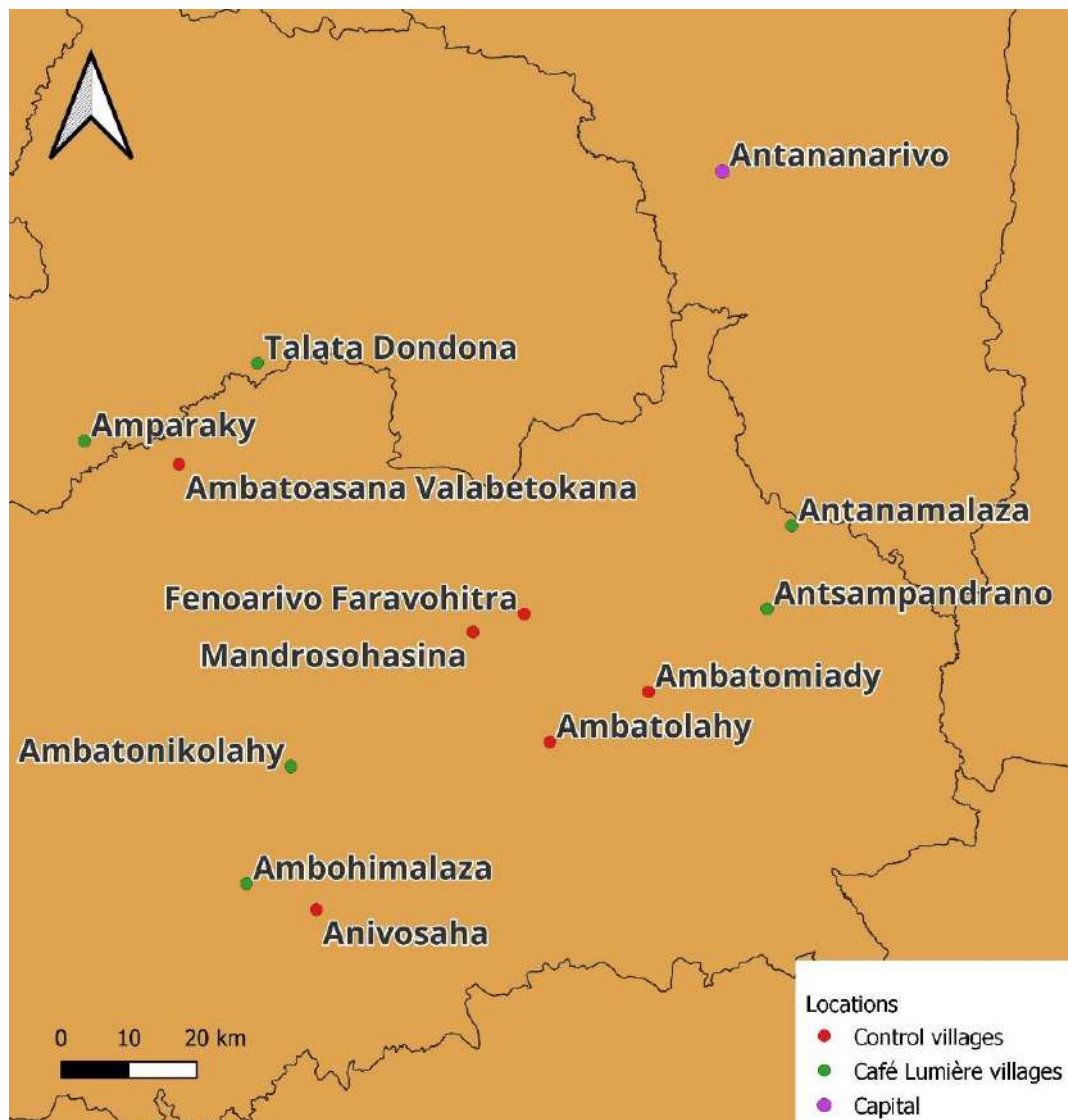


Table 1: mapping of data sources

| Observations Objectives | Outcomes reported by the operator | Tests of impacts using households' survey | Tests of impacts using individuals survey | Triangulation using locality survey data |
|---|--|--|---|---|
| Universal access to basic electricity services | | Private household elec- tricity access | | |
| | Phone & lamp re- charges by the Café Lumière boutiques | Light sources at home (electricity, solar lamps, kerosene lamps) | Mobile phones pos- session, recharging and usage | |
| | Electricity subscrip- tions by households | | | |
| Improved public social services | Electricity subscrip- tions by collective services | | | |
| | | Incidence of illnesses at household level | | Electrified primary health care center |
| | | Quality of water access and water treatment | | |
| | | | Birth delivery with electricity | |
| | | | Children vaccination | |
| | | | School attendance and completion | Electrified primary and secondary schools |
| | Electricity supplied for street lighting | Incidence of thefts | | |
| Improved economic development | Electric power con- sumption at the vil- lage level | Wealth index | Secondary incomes | |
| | Electricity subscrip- tions by VSEs | | | Number and electri- fication of services and commerce |
| | Electricity subscrip- tions by households | Possession of high- power appliances by households | | |
| | | Electricity used by households for eco- nomic purposes | Individual activities and their reliance on electricity | |
| | | Mechanized shelling of cereals | | |
| | Capacity building and microfinance | | Access to information | |

Universal access to basic electricity services:

The demand by households for direct electricity access through the micro-grid has grown rapidly in several villages, notably in the latest equipped villages (Figure 3). But this does not necessarily contribute a lot to the universal access objective, as it concerns only relatively few households (about 60 households per village at the end of 2023, which is about ten percent of the targeted population).

Compared to the planned design of the project, the weight given to the principal action foreseen to meet the universal access objective, namely supplying basic electricity services to household, has declined. While in the first equipped villages there have been noticeable numbers of recharges of cell-phones and solar lamps, this activity has decline rapidly and is absent in the last equipped villages (Figure 4).

It seems that the number of households potentially interested by this service had been overestimated, partly because the same services have been offered by private businesses and partly because the subscriptions of the households to the micro-grid has grown more rapidly than expected. In turn, this may have led the operator to reduce its implication on this activity becoming possibly less profitable than expected.

Figure 3: Micro-grid subscriptions (households)

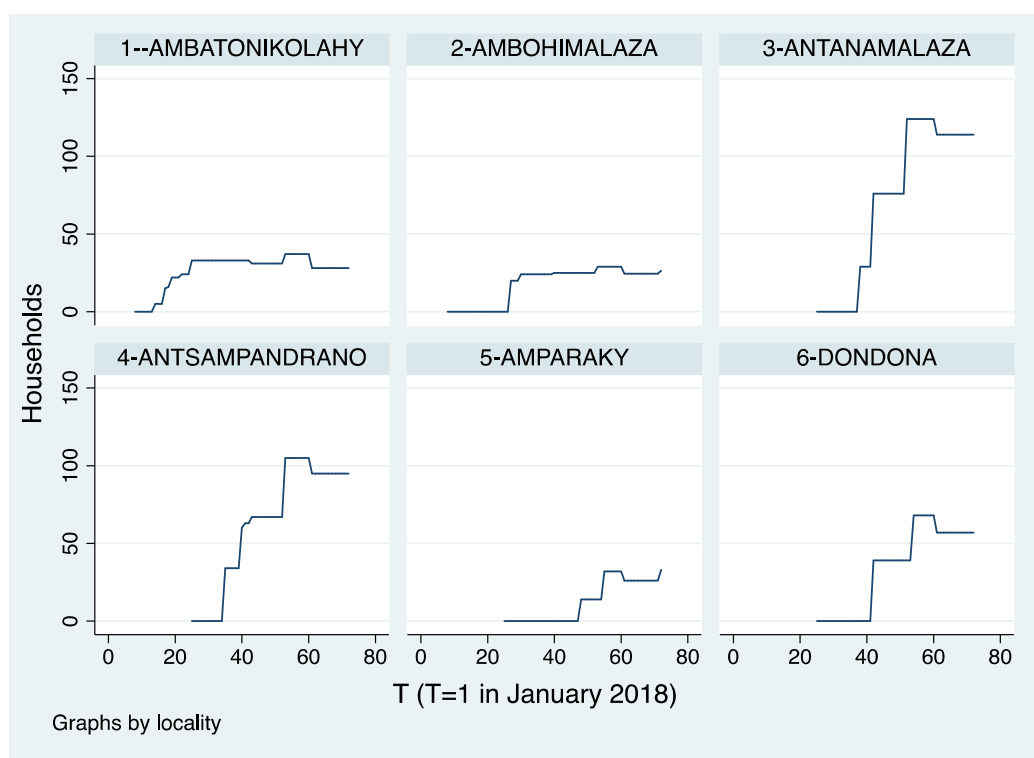
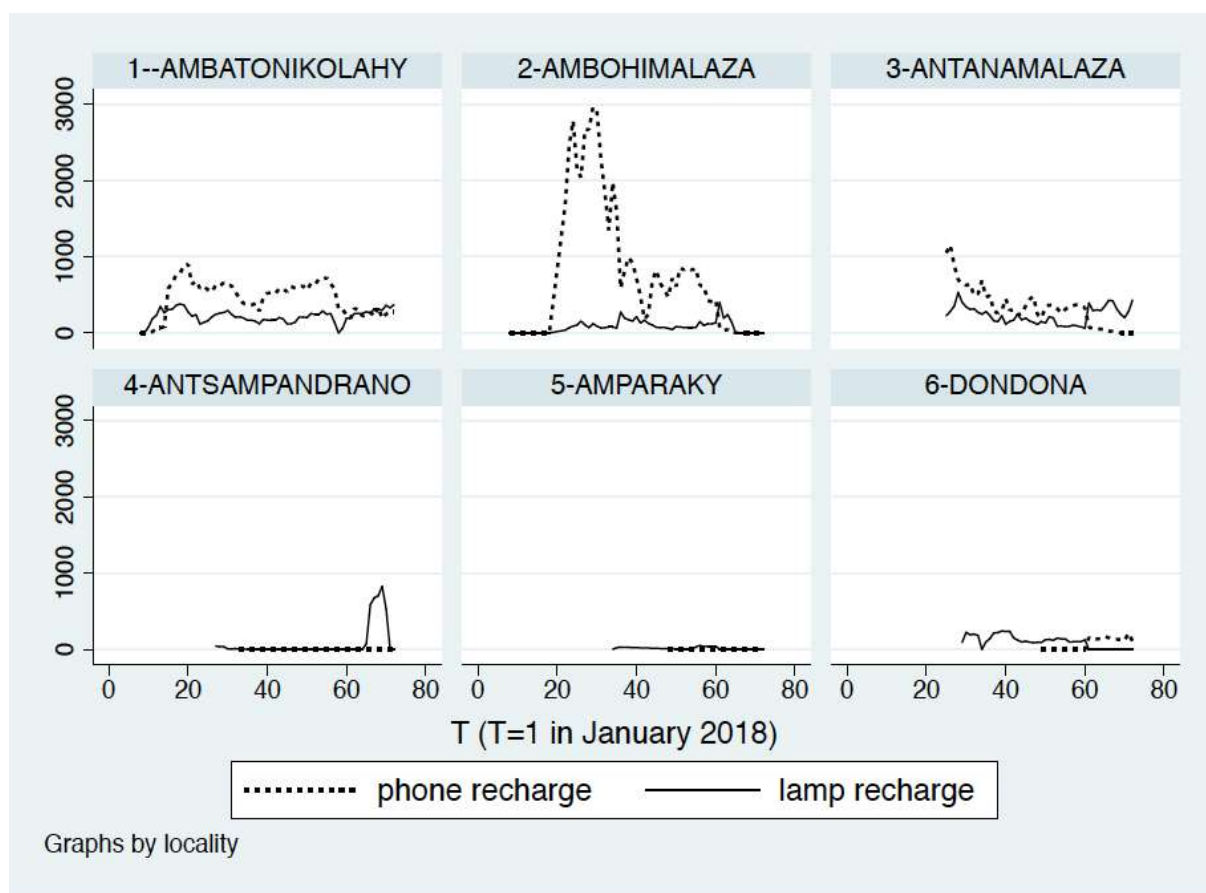


Figure 4: Phone & lamp recharges by the Café Lumière boutiques



Improved public social services:

Regarding electricity supplied to collective services, we obtained from the operator a detailed list of electricity subscriptions by collective services providers as of 2022. Most health centers have received a connection to the micro-grid (5 connected health centers in 6 villages). Schools have received much less access to the micro-grids, with 3 public primary schools electrified in 6 villages. Public street lighting has been installed in all villages, but only 2 out of 6 villages provide light all over the night, and one village has decided to stop using their street lamps, for cost-saving reasons. The most prevalent category of collective services connected to the micro-grid concerns churches, which are financed by their members (10 connected churches in 6 villages), suggesting that demand for electrified collective services exists but may be better served by civil society organizations than by public services.

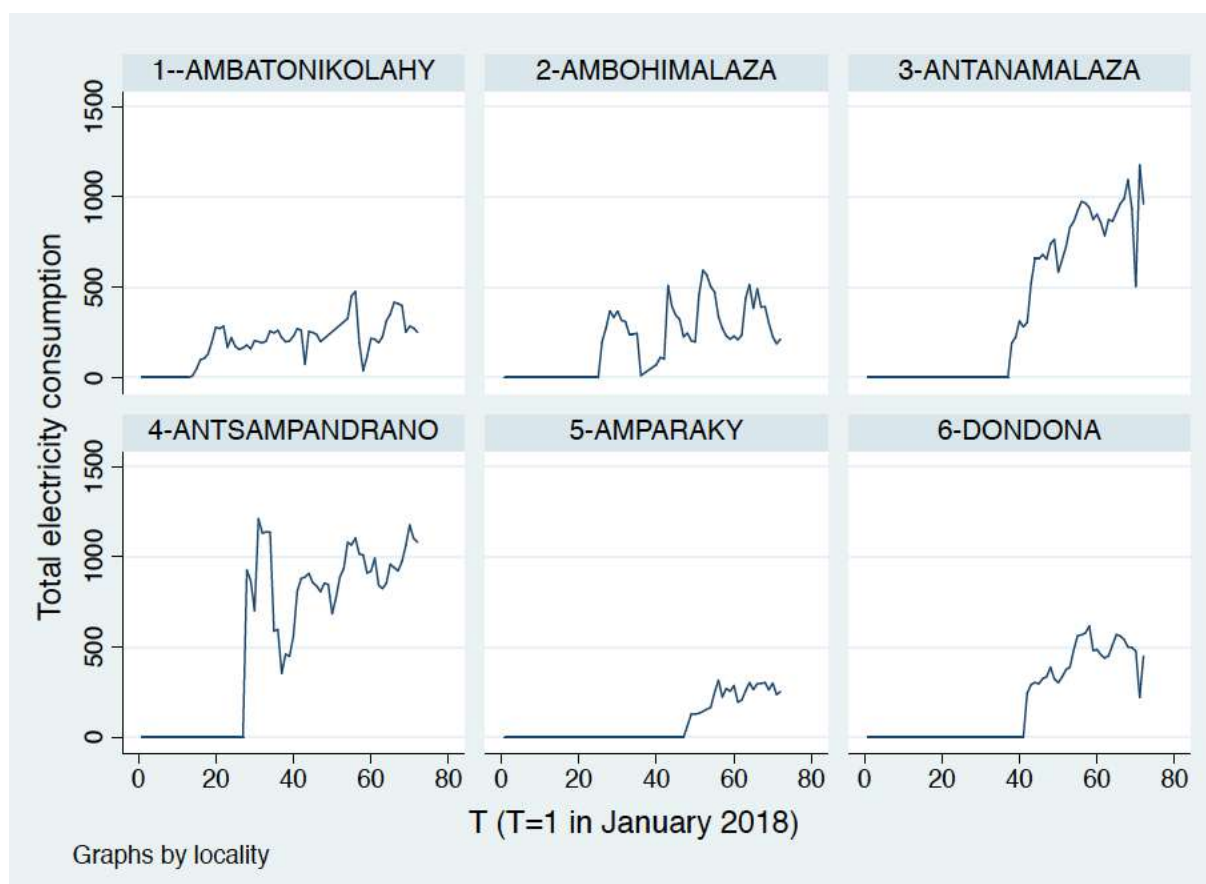
Improved economic development:

Regarding the economic development objective. Figure 5 reveals uneven results on total electricity consumption on the micro-grid showing only 2 villages with electricity consumption growing above 1000 kWh per month and a clear slowing down of the process.

There are both supply and demand possible explanations for this slowing down.

On the demand side, the principal aspect to consider is electricity demand by businesses, which corresponds by far to the highest share of electricity consumption. The project implementation has not triggered many creations of new businesses yet. Setbacks in relation to the project design reported in the project's theory of change may explain this slow dynamic. The micro-finance partner withdrew from the project and has not been replaced. In few instances, Anka has developed a few short-term credit initiatives to sell electric tools for shelling and crushing of cereals as well as for carpentry. On capacity building, efforts have been equally limited, beyond from training of Anka's staff by *Électriciens sans frontières*. Anka has provided some technical training to the clients of equipment that they sold, but training of potential new VSEs has not been significant. Initiatives in this direction have started only recently, in 2023, in the poultry feed milling sector.

Figure 5: Total electricity consumption (kWh per month)



According to Anka's information, there was only a dozen of VSEs using electricity in 2023 in total among the six Café Lumière villages. There were however twice as much households providing commercial electricity-based services (e.g. refrigeration, recharges of mobile phones, computer services). They consumed much less electricity than VSEs but their development suggests that the possibility to access quality electricity may trigger small-scale economic diversification. Scaling-up this process might have been facilitated in presence of micro-finance and more ambitious capacity building initiatives.

On the supply side, the micro-grid capacities are saturated in several villages, not necessarily for lack of power capacity but for lack of adaptability of the load curve to demand across the day, electricity use being highly concentrated at the end of daylight, after agricultural daily activities.

Overall, the implementation data provides evidence of clear evolutions of the theory of change of the project, illustrated by smaller emphasis given to the universal access objective in most recently equipped villages, unresolved issues in promoting public social services and insufficient initiatives aiming at promoting entrepreneurship among VSEs interested in investing in electricity-using activities.

3. Data and Methods

3.1 Survey data on project impacts

Original survey data were collected in May 2017 or May 2018, before implementation, and May 2023 (to respect the seasonality), after project implementation, from 50 households in each equipped village as well as in 6 comparable control villages. Data were collected at the household and/or individual levels, allowing computation of statistical significance level of the observed impacts, which define the main results of our evaluation study.

The survey sample is composed of 599 households for the first survey wave and 595 households for the second wave. From the first wave survey 133 households² were not found and were replaced by 129 new households³. Our tests of impact are implemented on the balanced panel of 466 households present in both survey waves. As mentioned previously in the project description, these households are scattered around a total of 12 villages (6 treated and 6 non-treated). Within each village the survey was implemented in two areas: the core area, which corresponds to the Fokontany center⁴, where the micro-grid infrastructure is built, and the periphery area, which corresponds to its catchment area (hamlets within a radius of 5 km around the Fokontany center). Our stratification strategy aimed at collecting about 60% of households in the core and 40% households in the periphery. In treated villages, the core is the area potentially positively impacted by the whole project, while the periphery is out of reach of the micro-grid itself but may be impacted by the other components of the project and by spill-over effects.

Our survey has multiple levels questions: localities, households and individuals (adults and children). In this paper we focus our main impact analysis on questions at the household and individual levels. Collected individual data are relatively scarce, except for adult males. We have 423 adult males (99.5% of which are household heads) and only 290 adult females (6.2% of which are household heads).

Universal access to basic electricity services:

Private household electricity access is used to test the net impact of the project on household direct electricity access; which encompasses access through the micro-grid or through standalone systems.

In absence of private access, the objective of universal access to basic electricity services may be met by the direct supply of such services. To evaluate achievements in this direction we consider first the sources of lighting in dwellings. The light sources in dwellings can take several modalities, and we focus specifically on electricity, solar lamps and kerosene lamps. We combine electricity and solar lamps into a single category since both represent electricity-based lighting solutions.

We also consider the development of mobile phones. Mobile phones are becoming increasingly important in rural areas as they can provide a wide array of services, such as modern banking

² 49 located in control villages and 84 in project villages.

³ 47 located in control villages and 82 in project villages.

⁴ A Fokontany is an administrative sub-division which usually groups small villages or hamlet in a common administrative entity.

solutions for instance. Given their extensive dissemination in rural areas, recharging phone batteries is more and more considered as a basic electricity service. We analyze the number of phones possessed, the frequency of their recharges and of their usage. Such data are reported at individual level.

Improved public social services:

We consider three major social development dimensions: health, education and security.

To assess the incidence of illnesses at household level, we utilize the declaration of symptoms of illness experienced by any household member over the past 30 days. The incidence of illnesses could be reduced in Café Lumière villages, notably through improved health care facilities accessing to electricity provided by the micro-grid, used for lighting and refrigeration. Additionally, we examine the quality of water access, as clean water is a key health determinant. Electricity can facilitate water-pumping solutions and boiling for disinfection. For this, we use variables about private access to water and water treatment, which indicate whether households have their own water source and whether they treat their water, either by boiling or using chemicals.

A topical health issue is child and maternal health. Health center electrification may have a positive impact in this respect because it facilitates childbirth in electrified healthcare facilities, providing safer delivery conditions than delivery at home. To test this impact, we consider the birth of children under five occurred in a room with electric lighting. We also consider childbirth at local health center to assess any potential changes in the utilization of local health centers.

To evaluate children vaccination, which could be facilitated by refrigeration availability in healthcare centers, we use the mandated vaccines status, which reflects the vaccination log status of children.

Indoor electrical lighting at school and at home could positively impact school attendance and completion. To test this impact, we rely on a set of three variables: missing school for at least a week, had to retake a school year, and completed the last school year. The first variable provides information on attendance and any significant events that might have hindered the child's school participation during the school year, while the second and third variables pertain to the child's performance and their ability to successfully complete and graduate from the school year.

Finally, street lighting could improve security. To analyze this, we examine variables related to burglaries experienced by households, including home burglary, home burglary at night, harvest stolen and livestock stolen. These variables indicate whether households suffered such events during the six months preceding the survey.

Improved economic development:

Household wealth is often used as a relevant synthetic indicator to assess the impact on economic development. We built a Wealth index for each household, following the methodology proposed by the Demographic and Health Surveys (DHS). The wealth index reflects the living conditions of the households as well as assets owned. We ran a Multiple Correspondence Analysis (MCA) on dwelling characteristics available in annexes table A1, as well as assets owned listed in table A2. Following DHS practices, we use as the Wealth Index the value of the projected scores on the principal axis from the MCA, which in our sample captures 51% of the inertia. This analysis on the wealth index is complemented by a partial analysis of individual

incomes, focusing on secondary incomes, given that the primary activity is predominantly in agriculture and is not directly impacted by electricity (no electricity used for irrigation).

We evaluate the possession of high-power appliances by households, defined by the number of appliances owned requiring a stable and high enough amperage electricity supply from the micro-grid. These appliances include refrigerators, cookers, televisions, DVD or VCR players. They can be used to improve households' living conditions but they can be used also for economic purposes. To assess the latter usage, we consider a variable available only in the second wave of the survey, which asks households whether they use electricity solely for personal use or also for economic activities.

To crosscheck this analysis, we use data available on individual adult activities, which inform us on the reliance on electricity of primary activities and the number of secondary activities relying on electricity.

To complement this analysis tracking the nexus of improved electricity supply – use of more electric equipment for economic purposes – we analyze the different methods of cereal shelling to which households' resort. Cereal shelling is a very important activity in highland Malagasy rural villages as this transformation is required to provide households with their staple food: shelling can be mechanized or done manually. Mechanized shelling provides significant productivity gains, as manual shelling is otherwise a time-intensive activity. To better understand the context, we also consider the location of shelling (in or outside the village) and the distance traveled to access a shelling machine.

Finally, we evaluate access to information through major media sources using TV use, which measures the frequency of TV usage per week, and information from TV, which tracks households reporting TV as a source of information, and "Radio use," which records the weekly frequency of radio usage.

3.2 Estimation strategy

With RCT designs, treatment effects could be theoretically tested through simple mean comparisons between treated and control units only after treatment. However, since we have both a baseline and a follow-up survey, we can mobilize baseline data to control for potential remaining discrepancies and shortfalls from the randomization. One common estimation method based on two round surveys is a difference-in-differences estimator but it has been demonstrated in the literature that this approach can be too restrictive to detect effects, in particular with a limited sample size (McKenzie, 2012). Indeed, ANCOVA can increase statistical power compared to difference-in-differences, while also controlling for baseline values which could be sources of bias due to randomization imperfections. Such approach is quite commonly used in RCT designs in rural electrification (Lee et al., 2020) or with solar lighting solutions (Chen et al., 2017; Kudo et al., 2019a), in particular with clustered treatment (Özler et al., 2018).

We therefore decided to apply the ANCOVA approach, which can be modeled as:

$$Y_{i,t} = \beta.Treated_{i,t} + \theta.Y_{i,t-1} + \varepsilon_{i,t} \quad (1)$$

Where, $Y_{i,t}$ is a variable of interest (continuous or categorical), β is the Average Treatment effect on the Treated (ATT), $Treated$ is a dummy variable denoting the treatment status, and $Y_{i,t-1}$ is the value of Y of household i (or individual i for questions at the individual level) before intervention (i.e., lagged dependent). We estimate this model at time $t = 1$, which is the post-treatment period. Standard errors of our estimations are all clustered at the randomization level, which is in our case the village level, according to Abadie clustering recommendations for RCT designs (Abadie et al., 2023). We also explore the impact of clustering at the village level by providing results without clustering in robustness checks.

Given the local distribution of a Café Lumière infrastructure, which is located in the central area of the Fokontany, we surveyed households living in this core area but also households living in nearby hamlets (called periphery area). Since households living in a periphery area cannot be considered as fully treated, we define a specific variable of treatment for them. This allows to investigate any heterogeneity in the results and potential spillover effect from the range of services offered by Café Lumière. Applying this estimation strategy to the ANCOVA model we then have:

$$Y_{i,t} = \beta_1 \cdot Treated_{core_{i,t}} + \beta_2 \cdot Treated_{periphery_{i,t}} + \theta \cdot Y_{i,t-1} + \varepsilon_{i,t} \quad (2)$$

Where “ $Treated_{core}$ ” denotes the treatment variable for households living in core areas, taking the value of 1 if the household is located in a Café Lumière village and 0 otherwise. Then, “ $Treated_{periphery}$ ” is defined as taking the value of 1 for people living in periphery areas of Café Lumière villages and 0 otherwise.

As robustness checks we estimate the same model without the “ $Treated_{periphery}$ ” variable to only compare households, or individuals, living in the core villages to all other units. This alternative simpler model represents a more classical approach with only one treated group against a control group and make no assumption of any spill-over effects. Given the fact that localities in the periphery areas can only benefit from a subset of the offered services and that our results don’t show any signs of spillover effects, we deem this hypothesis quite reasonable and it seems adequate to consider this second model without “ $Treated_{periphery}$ ” used as a second treatment variable. Considering this simpler model with only one treated group, we are also able to conduct robustness checks using another estimator, in particular the classical difference-in differences estimator. Although this estimator might not be the most optimal estimator for detecting any significant effects given the reasons mentioned previously, we are still able to use it as a robustness given our RCT design.

4 - Results

4.1 Universal access to basic electricity services

Table 2 provides information on the impact of the project on private household access to electricity (column 1) and on access to basic electricity services, observed through electricity-based and kerosene-based lighting (columns 2 and 3). We do not see a significant increase in private electricity access in Café Lumière villages compared to control villages due to a substitution effect reducing the use of solar panels as principal source of electricity when household subscribe a micro-grid connection in treated villages, while we saw a strong uptake of individual solar panels in control villages during the period.

Table 2: Private household electricity access and sources of lighting in dwellings

| VARIABLES | (1) Private access to electricity | (2) Light source: electricity or solar lamp | (3) Light source: kerosene lamp |
|---|---|--|---|
| Treated_core | 0.0996 (0.0594) | 0.107** (0.0480) | -0.0495 (0.0538) |
| Treated_periphery | -0.0850* (0.0408) | -0.0518 (0.0468) | 0.0588 (0.0589) |
| Lagged dependent | 0.411*** (0.0533) | 0.395*** (0.0457) | 0.277*** (0.0412) |
| Constant | 0.297*** (0.0229) | 0.323*** (0.0198) | 0.150*** (0.0441) |
| Observations | 466 | 466 | 466 |
| R-squared | 0.178 | 0.159 | 0.106 |
| Question level | Households | Households | Households |
| Standard errors clustered at the village level in parentheses | | | |
| *** p<0.01, ** p<0.05, *p<0.1 | | | |

There is however a positive impact of the Café Lumière on household access to basic electricity services measured by the energy solutions used for lighting, as households living in Café Lumière locations use significantly more electric means of lighting such as electricity supplied by the micro-grid or individual solar panels, or solar lamps. This impact is present in core areas but not in periphery areas of treated villages. Although the use of kerosene lamps is lower in Café Lumière locations, we do not find a significant difference in their use compared to control locations.

Mobile phone development indicators provide also informative insights on impacts on basic electricity services access (Table 3). The number of phones used by individuals is similar in Café Lumière villages and control villages (column 1). Individuals living in core areas of Café Lumière villages tend to charge their mobile phones more frequently, but this is not the case in periphery areas (column 2). They also use their mobile phone more frequently (columns 3). The impact is unfortunately only significant for male users, although the effect for women is higher than men, it is not significant due to more variation in use and a smaller sample size (columns 4 and 5).

Table 3: Mobile phones possession, recharging and usage

| VARIABLES | (1) Number of phones owned (men and women) | (2) Number of charges per week (men and women) | (3) Use of phone more than once a week (men and women) | (4) Use of phone more than once a week (men) | (5) Use of phone more than once a week (women) |
|-------------------|--|--|--|---|---|
| Treated_core | 0.0803 (0.0665) | 1.145** (0.383) | 0.188* (0.103) | 0.173* (0.0936) | 0.211 (0.157) |
| Treated_periphery | 0.0424 (0.0510) | 0.689 (0.602) | -0.0296 (0.0534) | -0.0357 (0.0509) | -0.0285 (0.0837) |
| Lagged dependent | 0.256*** (0.0602) | 0.170 (0.113) | 0.311*** (0.0568) | 0.281*** (0.0604) | 0.317*** (0.0855) |
| Constant | 0.228*** (0.0303) | 1.653*** (0.267) | 0.345*** (0.0309) | 0.422*** (0.0340) | 0.248*** (0.0409) |
| Observations | 697 | 110 | 465 | 278 | 187 |
| R-squared | 0.068 | 0.096 | 0.136 | 0.120 | 0.145 |
| Question level | Individuals | Individuals | Individuals | Individuals | Individuals |

Standard errors clustered at the village level in parentheses

*** p<0.01, ** p<0.05, *p<0.1

4.2 Improved public social services development

Table 4 provides results concerning health of the households and we found no evidence of less symptoms of illness in Café Lumière locations (column 1). We can however notice that during the baseline survey households living in Café Lumière location had significantly more symptoms of illness and they have recorded levels of symptoms similar to other villages during the second wave of the survey. One link usually mentioned in the literature between electricity and health is the use of electric solutions for cooking. However, we did not find any households using electricity as a mean of cooking during the second wave survey and all surveyed households are using charcoal or firewood. Electricity supplied by Café Lumière did not seem either to impact the quality of water access. The distribution of water access sources between private (wells or private taps) and public (springs or public fountains) sources has not changed (column 2). Treatment of the water, which concerns around 20% of households, is almost entirely done by boiling the water, but we do not see any difference in behavior between Café Lumière villages and others after project implementation (column 3).

We investigated the child vaccinations status and we did not find any difference between locations. In both locations we find that around 98% of under 5 children have their vaccination record up to date. This vaccination coverage rate was similar during the first and second survey waves.

Table 4: Incidence of illness and water access

| | (1) | (2) | (3) |
|-------------------|-----------------------|----------------------|----------------------|
| VARIABLES | Symptoms of illness | Private water access | Water is treated |
| Treated_core | 0.0545 (0.0491) | 0.157 (0.102) | -0.0833 (0.0544) |
| Treated_periphery | -0.0169 (0.0294) | 0.0900 (0.103) | 0.0297 (0.0803) |
| Lagged dependent | 0.0517 (0.0419) | 0.639*** (0.0872) | 0.125** (0.0551) |
| Constant | 0.0764*** (0.0155) | 0.0887* (0.0485) | 0.171*** (0.0329) |
| Observations | 466 | 466 | 466 |
| R-squared | 0.015 | 0.447 | 0.032 |
| Question level | Households | Households | Households |

Standard errors clustered at the village level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 5 presents results related to childbirth and in particular the impact of electricity on the conditions of childbirth. Since the questions are related to under 5 children, we do not have panel data and therefore do not take into account the levels of the outcome variable from the previous period. Although we find no difference in the number of childbirths at the local health center between Café Lumière and control locations (column 1), we found a significant difference with higher number of childbirths that benefited from electricity in the Café Lumière locations, but only in the core areas (column 2).

Table 5: Birth delivery with electricity

| | (1) | (2) |
|-------------------|-----------------------------------|--|
| VARIABLES | Childbirth at local health center | Childbirth at an electrified health center |
| Treated_core | 0.138 (0.189) | 0.517*** (0.151) |
| Treated_periphery | -0.162 (0.207) | 0.145 (0.169) |
| Constant | 0.612*** (0.149) | 0.400** (0.140) |
| Observations | 93 | 96 |
| R-squared | 0.044 | 0.184 |
| Question level | Individuals | Individuals |

Standard errors clustered at the village level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Concerning impact on education, table 6 reveals no significant differences between Café Lumière and control locations in children's school attendance (column 1), completion of school years (column 2), or completion of the previous schooling year (column 3).

Table 6: School attendance and completion

| VARIABLES | (1) Missing school for at least a week | (2) Had to retake a school year | (3) Completed the last school year |
|-------------------|---|--|---|
| Treated_core | -0.0190 (0.0362) | 0.0392 (0.0930) | 0.00699 (0.00662) |
| Treated_periphery | 0.0186 (0.0429) | 0.0536 (0.0808) | -0.0518 (0.0377) |
| Constant | 0.0800** (0.0266) | 0.327*** (0.0543) | 0.993*** (0.00662) |
| Observations | 303 | 303 | 291 |
| R-squared | 0.002 | 0.002 | 0.032 |
| Question level | Individuals | Individuals | Individuals |

Standard errors clustered at the village level in parentheses
 *** p<0.01, ** p<0.05, * p<0.1

Table 7: Incidence of thefts

| VARIABLES | (1) Home burglary | (2) Harvest stolen | (3) livestock stolen | (4) Home burglary at night |
|-------------------|-------------------------|--------------------------|----------------------------|-------------------------------------|
| Treated_core | 0.0477** (0.0208) | 0.0960 (0.0792) | 0.150 (0.0901) | -0.200 (0.155) |
| Treated_periphery | 0.0313* (0.0147) | 0.128 (0.102) | -0.231*** (0.0735) | -0.250 (0.179) |
| Lagged dependent | 0.0852 (0.0582) | 0.0119 (0.0614) | 0.107 (0.137) | |
| Constant | 0.00127 (0.00436) | 0.192*** (0.0513) | 0.433*** (0.0582) | 1*** (7.45e-09) |
| Observations | 466 | 464 | 465 | 15 |
| R-squared | 0.033 | 0.017 | 0.020 | 0.021 |
| Question level | Households | Households | Households | Households |

Standard errors clustered at the village level in parentheses
 *** p<0.01, ** p<0.05, * p<0.1

Table 7 does not reveal any relative improvement in security in Café Lumière locations, measured by occurrences of thefts. We even notice a higher occurrence of home burglary in Café Lumière locations (column1) but no difference in theft of harvest (column 2) or livestock

(column 3). If we look further in the cases of home burglary, we see that the few cases of burglary do not appear to have incurred more or less frequently at night in Café Lumière locations (column 4).

4.3 Improved economic development

Table 8 presents results related to the wealth of the households and individual secondary incomes. The wealth index shows an increase in wealth for households living in Café Lumière core area's locations. This increase in wealth seems however uncertain as it is only significant at the 10% level (column 1). We also investigate individual incomes; we find a slight increase of income from secondary activity in core areas of Café Lumière villages, (column 2) in particular for male individuals (column 3). It should be noted that results on income are based on a very limited sample of individuals due to the low number of respondents to this question. Regarding secondary activity only 119 males and 51 females declared to have a secondary activity out of respectively 407 males and 290 females, but few of them were able or willing to declare revenue generated from this secondary activity.

Table 8: Household wealth index and secondary individual income

| | (1) | (2) | (3) |
|-------------------|----------------------|--|---|
| VARIABLES | Wealth index | Income from secondary activity (male and female) | Income from secondary activity (male) |
| Treated_core | 0.221* (0.105) | 80,885* (40,344) | 99,153* (50,147) |
| Treated_periphery | -0.0897 (0.0840) | 58,810 (37,893) | 58,120 (39,941) |
| Lagged dependent | 0.786*** (0.0418) | 0.692*** (0.190) | 0.876*** (0.0581) |
| Constant | 0.110* (0.0542) | 55,409* (29,479) | 49,570* (23,053) |
| Observations | 466 | 43 | 31 |
| R-squared | 0.536 | 0.323 | 0.444 |
| Question level | Households | Individuals | Individuals |

Standard errors clustered at the village level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 9 displays results about electricity use for economic purposes at household level. Connection to the micro-grid allows household to own and use electric appliances requiring sustained electric high power, which could hardly be powered by individual solar panels. Those Lumière core area locations and not those living in the periphery areas (column 1). Correlatively, households living in the Café Lumière core area locations declare to have significantly more use of electricity for economic activity (column 2), and on the contrary households living in the periphery areas do not use electricity for an economic purpose.

Table 9: Households high-power appliances possession and economic uses of electricity

| | (1) | (2) |
|-------------------|---------------------------|-----------------------------|
| VARIABLES | Use high power appliances | Economic use of electricity |
| Treated_core | 0.219** (0.0941) | 0.111** (0.0432) |
| Treated_periphery | 0.0151 (0.0711) | -0.0778** (0.0324) |
| Lagged dependent | 0.482*** (0.108) | |
| Constant | 0.135*** (0.0392) | 0.102*** (0.0235) |
| Observations | 463 | 264 |
| R-squared | 0.211 | 0.041 |
| Question level | Households | Households |

Standard errors clustered at the village level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: column 2 does not control for lagged dependent, as this question was not in pre-treatment survey.

Regarding the use of electricity in economic activities of individuals (Table 10), the use of electricity seems slightly higher for the primary economic activity of individuals living in core areas of Café Lumière villages with a positive coefficient only significant at the 10% level (column 1). By contrast, although the sample size is quite limited, we found a more positive and significant effect for the use of electricity in secondary economic activity of men (column 2), but not of women (column 3).

Table 10: Individual activities and their electricity reliance

| | (1) | (2) | (3) |
|-------------------|--------------------------------------|--|--|
| VARIABLES | Electricity use for primary activity | Electricity use for men's secondary activity | Electricity use for women's secondary activity |
| Treated_core | 0.0880* (0.0490) | 0.238** (0.0884) | -0.273 (0.278) |
| Treated_periphery | -0.00102 (0.0261) | 0.0362 (0.134) | 0.121 (0.223) |
| Lagged dependent | 0.443** (0.144) | -0.167 (0.118) | 0.727*** (0.166) |
| Constant | 0.0240** (0.0103) | -2.203*** (0.244) | -0 (0.400) |
| Observations | 459 | 55 | 27 |
| R-squared | 0.095 | 0.073 | 0.173 |
| Question level | Individuals | Individuals | Individuals |

Standard errors clustered at the village level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

We also observe a positive impact in the processing and transformation of agricultural products (Table 11). We found that households living in Café Lumière locations are using significantly less manual shelling (column 1). Mechanized shelling done locally, which can be enabled by local electricity access is more frequent in core areas of treated villages (column 2). By contrast, mechanized shelling is done less frequently outside the village (column 3) and correlatively, the distance covered by a household to access a husker tend to be slightly shorter for households living in Café Lumière core area locations (column 4).

Table 11: Choices of cereal shelling by households

| | (1) | (2) | (3) | (4) |
|-------------------|----------------------|---------------------------------|---|------------------------------------|
| VARIABLES | Manual shelling | Local mechanized shelling | Outside village mechanized shelling | Distance to shelling machine |
| Treated_core | -0.211** (0.0929) | 0.318*** (0.0979) | -0.0870*** (0.0249) | -0.279* (0.136) |
| Treated_periphery | -0.141 (0.108) | 0.0281 (0.110) | 0.120 (0.0839) | 0.687 (0.587) |
| Lagged dependent | 0.442*** (0.0710) | 0.368*** (0.0847) | 0.0922 (0.0738) | 0.195*** (0.0484) |
| Constant | 0.334*** (0.101) | 0.238** (0.0791) | 0.0798*** (0.0239) | 0.494*** (0.118) |
| Observations | 445 | 445 | 445 | 217 |
| R-squared | 0.253 | 0.234 | 0.073 | 0.247 |
| Question level | Households | Households | Households | Households |

Standard errors clustered at the village level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 12 provides results concerning access to media and information, which can be an important driver for development. We can see individuals living in core areas of Café Lumière villages watch more frequently the television (column 1), while there is no difference in the frequency of radio use (column 2), which is low powered media carrier. If we investigate the type of media viewed on the television, we see that more people are getting information from television in core areas of Café Lumière (column 3).

Table 12: Access to information

| | (1) | (2) | (3) |
|-------------------|----------------------|----------------------|-----------------------|
| VARIABLES | TV use | Radio use | Information from TV |
| Treated_core | 0.122** (0.0503) | 0.0278 (0.0749) | 0.0688*** (0.0122) |
| Treated_periphery | -0.00464 (0.0434) | 0.00688 (0.0645) | -0.0126 (0.0104) |
| Lagged dependent | 0.293*** (0.0606) | 0.133** (0.0483) | 0.176* (0.0849) |
| Constant | 0.0549 (0.0307) | 0.345*** (0.0579) | 0.0161** (0.00726) |
| Observations | 697 | 697 | 697 |
| R-squared | 0.152 | 0.013 | 0.049 |
| Question level | Individuals | Individuals | Individuals |

Standard errors clustered at the village level in parentheses

*** p<0.01, ** p<0.05, * p<0.1

5 - Discussion

Universal access to basic electricity services:

Overall, we do not find positive impact on private electricity access, due to a substitution effect between standalone systems and micro-grid connections. There are however some indications of a positive impact of the project on access to basic electricity services, which can be procured through battery recharge services supplied in the Café Lumière boutique or in other shops. This is particularly relevant for the use of mobile phones, which has significantly increased in the core areas of treated villages. Robustness checks on private electricity access however show that if we consider a model without the “*Treated_periphery*” variable, the effect becomes significant at the 5% level for households living in the treated villages. Findings concerning use of modern lighting solutions and phone charges are confirmed by the robustness model, but not by the DiD estimator.

Improved social development:

On social development impacts we observe positive impact, particularly on maternal and child healthcare in core areas of treated villages., thanks to the electrification of health care centers, offering safer conditions for birth delivery. This is consistent with our locality survey data (Table 13), which show that the proportion of electrified primary health care centers (csb2) has increased much more in treated than in control villages, even though treated villages were disadvantaged initially. This is true both for the existence of indoor lighting and for the availability of refrigeration. These findings of improvement in conditions of childbirth are also confirmed by robustness checks on the alternative simple treatment model.

Table 13: Electrification of csb2 by locality and survey wave

| | Share of csb2 with electric lighting | | | Share of csb2 with refrigeration | | |
|------------------------------------|--------------------------------------|-----------------|----------------------|----------------------------------|-----------------|----------------------|
| | 1rst survey wave | 2nd survey wave | Difference over time | 1rst survey wave | 2nd survey wave | Difference over time |
| Treated | 33% | 100% | +67% | 17% | 83% | +67% |
| Non treated | 75% | 75% | 0% | 50% | 75% | +25% |
| Difference treated vs. non-treated | -42% | 25% | +67% | -33% | 8% | +42% |

By contrast, we do not observe impact on education, neither on security.

Improved economic development:

The limited changes in the household’s wealth index and income could be explained by the short period between surveys and potential impacts on wealth could take a long time to be fully measurable. Although this changes on measures of wealth and income are mellow in magnitude, they are quite consistent across several outcomes and other changes are more pronounced. We

can see for instance use of electricity for economic purposes are more prevalent in villages where the project Café Lumière has been implemented.

Although results on the increase of the Wealth index appear limited, they are confirmed in our robustness checks by both the alternative model using treated villages only and the DiD estimator, while results on secondary income are only confirmed by the DiD estimator. However, results regarding usage of high-power electric appliances, economic use of electricity, as well as its use in a secondary activity remain positive and significant with the alternative model or the DiD estimator, suggesting that although the effect is hard to measure quantitatively in terms of income, it is more robust qualitatively (Annex Tables A10 and A11).

Having the possibility to access distributed electricity helps individuals to conduct electrified non-agricultural activities. This could in turn help generating more revenue and increase wealth in a more significant manner in the longer term. Although the primary activity, which is farming for 90% of the people, is not directly impacted by electricity access, the ability of individuals to use electricity in secondary activities may be key for generating new incomes. This is visible in the positive impact on the household use of electricity for economic purposes, and correlatively of high-power appliances.

Although our survey is limited to the observation of impacts from the viewpoint of household data, we find similar results from the viewpoint of businesses in the subsector of cereal shelling, which is central in rural villages of the Malagasy highlands region: there is a positive impact on the local supply of mechanized shelling in Café Lumière locations.

Our locality survey provides complementary descriptive information on businesses impacts. We observe that shops and dinners' electrification progress during the period in treated villages (Table 14), but also that the number of such businesses declines. A similar observation is obtained from data on services activities, which encompasses all services but shops and dinners (e.g., shelling, carpentry, small mechanical reparation, tailor, hairdressing, video club) (Table 15). The reduction of the number of observed businesses in Café Lumière villages is likely the mere result of their higher economic efficiency compared to un-electrified businesses, in a sort of Schumpeterian process of creative destruction.

Table 14: Share of electrified shops and dinners and number of observations

| | Share of electrified shops and diners | | | Number of shops and diners | | |
|------------------------------------|---------------------------------------|-----------------|----------------------|----------------------------|-----------------|----------------------|
| | 1st survey wave | 2nd survey wave | Difference over time | 1st survey wave | 2nd survey wave | Difference over time |
| Treated | 12% | 83% | +71% | 197 | 140 | -57 |
| Non treated | 11% | 4% | -7% | 87 | 141 | 83 |
| Difference treated vs. non-treated | 1% | 79% | +78% | 110 | -1 | -140 |

Table15: Share of electrified services and number of observations

| | Share of electrified services providers | | | Number of services providers | | |
|------------------------------------|---|-----------------|----------------------|------------------------------|-----------------|----------------------|
| | 1st survey wave | 2nd survey wave | Difference over time | 1st survey wave | 2nd survey wave | Difference over time |
| Treated | 86% | 100% | +14% | 83,5 | 68 | -15,5 |
| Non-treated | 91% | 48% | -43% | 11 | 27 | +16 |
| Difference treated vs. non-treated | -5% | 52% | +57% | 72,5 | 41 | -31,5 |

Note: numbers are averages of dry and wet seasons

6 - Conclusion

The Café Lumière project has demonstrated clear improvements in specific areas of electricity access of off-grid rural communities, with positive economic and social consequences on treated villages compared to non-treated villages. More households gained access to basic electricity services in treated villages. More household and entrepreneurs accede to higher quality electricity services in terms of reliability and power availability, leading to greater penetration of electricity in craft and services. The economic transformation process that could result from this change is however still underway, as is the Schumpeterian creative destruction process under way in VSEs. More entrepreneurs use electricity, but the creation of new activities is lagging behind. This may be due to the failure of the project to deliver on micro-finance support, and also to insufficient capacity building in entrepreneurship, as these two dimensions were identified in the theory of change as integral parts of the project but were underperformed.

Social development indicators, such as education, health and public safety, show limited impact. The only noticeable exception concerns the impact of electrification of healthcare centers. Specifically, electrified healthcare centers have increased the proportion of childbirths benefiting from electricity, contributing directly to maternal and child health development.

Overall, the jury is out concerning the expected long-term dynamics of economic and social transformation, which is still uncertain at this point. Another evidence of the incompleteness of successes obtained so far is that these successes are limited to the core area of treated villages and we did not measure any positive spillover effects on locations at their periphery. This absence of spillover effect is consistent with our analysis of the limitations of the economic transformation process triggered by mere increased and improved electricity access.

That being said, although the time interval between our first and second waves of survey is long (7-8 years), the inception of the project has been slow, and retarded by the COVID-19 crisis. Consequently, we measure with this survey actually only 2-3 years of impact of the project, which is not long enough to derive final conclusions.

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Declaration of generative AI in scientific writing

During the preparation of this work the authors used chatGPT-4o in order to improve grammar and readability. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

Annexes

Table A1: Dwelling Characteristics

What is the nature of the roof?

What is the nature of the walls?

How many floors does the dwelling have?

How many rooms does the dwelling have (living rooms: bedroom, kitchen, living room)?

Is the kitchen located inside the dwelling?

What is the housing status of the dwelling?

What type of toilets does the household have?

What is the main source of water supply for the household?

Is the water of good quality (colorless, odorless, tasteless)?

Does the household have land to cultivate?

Does the household own the land it cultivates?

Table A2: Assets owned

| Table | Cart |
|-------------------------|------------------------------|
| Chair | Car/truck |
| Bed or mattress | Radio |
| Wardrobe/closet/trunk | Television |
| Watch/clock | VCR |
| Sewing machine | DVD player |
| Stove | Computer (desktop or laptop) |
| Refrigerator or freezer | Tablet |
| Fan | Landline phone |
| Bicycle | Mobile phone |
| Moped/motorcycle | |

Table A3: Robustness on private household electricity access and sources of lighting in dwellings

| VARIABLES | (1) | (2) | (3) Light source: electricity or solar lamp | (4) Light source: electricity or solar lamp | (5) Light source: kerosene lamp | (6) Light source: kerosene lamp |
|------------------|----------------------|----------------------|--|---|---|---|
| Treated_core | 0.122** (0.0554) | | 0.122** (0.0434) | | -0.0656 (0.0432) | |
| Lagged dependant | 0.406*** (0.0555) | | 0.390*** (0.0471) | | 0.272*** (0.0411) | |
| DID | | 0.0498 (0.0676) | | 0.0329 (0.0676) | | 0.0638 (0.0577) |
| Constant | 0.276*** (0.0244) | 0.308*** (0.0501) | 0.311*** (0.0208) | 0.278*** (0.0441) | 0.167*** (0.0356) | 0.488*** (0.0412) |
| Observations | 466 | 932 | 466 | 932 | 466 | 932 |
| R-squared | 0.174 | 0.032 | 0.157 | 0.047 | 0.104 | 0.051 |
| Method | ANCOVA | DiD | ANCOVA | DiD | ANCOVA | DiD |
| SE clustered | Yes | Yes | Yes | Yes | Yes | Yes |
| Question level | Households | Households | Households | Households | Households | Households |

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table A4: Robustness on mobile phones possession, recharging and usage

| VARIABLES | (1) Number of phones owned (men and women) | (2) Number of phones owned (men and women) | (3) Number of charges per week (men and women) | (4) Number of charges per week (men and women) |
|------------------|---|---|---|---|
| Treated_core | 0.0689 (0.0619) | | 0.945** (0.336) | |
| Lagged dependant | 0.254*** (0.0600) | | 0.180 (0.118) | |
| DID | | -0.00259 (0.0573) | | 2.430 (2.020) |
| Constant | 0.240*** (0.0217) | 0.292*** (0.0327) | 1.826*** (0.181) | 4.447** (2.008) |
| Observations | 697 | 1,394 | 110 | 446 |
| R-squared | 0.067 | 0.008 | 0.080 | 0.004 |
| Method | ANCOVA | DiD | ANCOVA | DiD |
| SE clustered | Yes | Yes | Yes | Yes |
| Question level | Individuals | Individuals | Individuals | Individuals |

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table A4 (continued): Robustness on mobile phones possession, recharging and usage

| VARIABLES | (5) Use of phone more than once a week (men and women) | (6) Use of phone more than once a week (men and women) | (7) Use of phone more than once a week (men) | (8) Use of phone more than once a week (men) | (9) Use of phone more than once a week (women) | (10) Use of phone more than once a week (women) |
|------------------|--|--|--|--|---|--|
| Treated_core | 0.196* (0.0939) | | 0.183* (0.0891) | | 0.218 (0.141) | |
| Lagged dependant | 0.310*** (0.0570) | | 0.280*** (0.0599) | | 0.318*** (0.0861) | |
| DID | | 0.0852 (0.0947) | | 0.0806 (0.108) | | 0.0970 (0.124) |
| Constant | 0.337*** (0.0262) | 0.320*** (0.0411) | 0.413*** (0.0265) | 0.379*** (0.0376) | 0.240*** (0.0347) | 0.243*** (0.0511) |
| Observations | 465 | 1,146 | 278 | 668 | 187 | 478 |
| R-squared | 0.135 | 0.053 | 0.119 | 0.055 | 0.145 | 0.053 |
| Method | ANCOVA | DiD | ANCOVA | DiD | ANCOVA | DiD |
| SE clustered | Yes | Yes | Yes | Yes | Yes | Yes |
| Question level | Individuals | Individuals | Individuals | Individuals | Individuals | Individuals |

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table A5: Robustness on incidence of illness and water access

| VARIABLES | (1) Symptoms of illness | (2) Symptoms of illness | (3) Private water access | (4) Private water access | (5) Water is treated | (6) Water is treated |
|------------------|-------------------------------|-------------------------------|-----------------------------------|-----------------------------------|----------------------------|----------------------------|
| Treated_core | 0.0590 (0.0446) | | 0.132 (0.0782) | | -0.0910* (0.0465) | |
| Lagged dependant | 0.0511 (0.0419) | | 0.645*** (0.0885) | | 0.125** (0.0559) | |
| DID | | -0.0953 (0.0643) | | 0.117* (0.0560) | | -0.0702 (0.0716) |
| Constant | 0.0721*** (0.0132) | 0.156*** (0.0292) | 0.110** (0.0388) | 0.305*** (0.0840) | 0.179*** (0.0354) | 0.251*** (0.0389) |
| Observations | 466 | 932 | 466 | 932 | 466 | 932 |
| R-squared | 0.015 | 0.045 | 0.443 | 0.034 | 0.031 | 0.011 |
| Method | ANCOVA | DiD | ANCOVA | DiD | ANCOVA | DiD |
| SE clustered | Yes | Yes | Yes | Yes | Yes | Yes |
| Question level | Households | Households | Households | Households | Households | Households |

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table A6: Robustness on birth delivery with electricity

| | (1) | (2) | (3) |
|---------------------------------------|---------------------------------------|---|--|
| VARIABLES | Child vaccination is up to date | Childbirth at local health center | Childbirth at an electrified health center |
| Treated_core | 0.0281 (0.0397) | 0.185 (0.146) | 0.472*** (0.120) |
| Constant | 1.015*** (0.0161) | 0.565*** (0.118) | 0.444*** (0.102) |
| Observations | 88 | 93 | 96 |
| R-squared | 0.007 | 0.028 | 0.170 |
| Method | ANCOVA | ANCOVA | ANCOVA |
| SE clustered | Yes | Yes | Yes |
| Question level | Individuals | Individuals | Individuals |
| Robust standard errors in parentheses | | | |
| *** p<0.01, ** p<0.05, * p<0.1 | | | |

Table A7: Robustness on school attendance and completion

| | (1) | (2) | (3) |
|---------------------------------------|--|-----------------------------------|--------------------------------------|
| VARIABLES | Missing school for at least a week | Had to retake a school year | Completed the last school year |
| Treated_core | -0.0250 (0.0375) | 0.0220 (0.0951) | 0.0237 (0.0152) |
| Constant | 0.0860*** (0.0210) | 0.344*** (0.0427) | 0.976*** (0.0152) |
| Observations | 303 | 303 | 291 |
| R-squared | 0.002 | 0.000 | 0.007 |
| Method | ANCOVA | ANCOVA | ANCOVA |
| SE clustered | Yes | Yes | Yes |
| Question level | Individuals | Individuals | Individuals |
| Robust standard errors in parentheses | | | |
| *** p<0.01, ** p<0.05, * p<0.1 | | | |

Table A8: Robustness on incidence of thefts

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|------------------|----------------------|----------------------|----------------------|----------------------|----------------------|-----------------------|-------------------------|
| VARIABLES | Stolen at home | Stolen at home | Harvest stolen | Harvest stolen | Animals stolen | Animals stolen | Stolen at home at night |
| Treated_core | 0.0397* (0.0197) | | 0.0630 (0.0567) | | 0.210** (0.0898) | | |
| Lagged dependant | 0.0841 (0.0596) | | 0.0309 (0.0520) | | 0.116 (0.137) | | |
| DID | | 0.0223 (0.0240) | | 0.0306 (0.0683) | | 0.167* (0.0763) | |
| Constant | 0.00937 (0.00592) | 0.0329** (0.0119) | 0.222*** (0.0466) | 0.126*** (0.0279) | 0.373*** (0.0512) | 0.0719*** (0.0204) | 0.800*** (0.155) |
| Observations | 466 | 932 | 464 | 930 | 465 | 931 | 15 |
| R-squared | 0.027 | 0.009 | 0.005 | 0.022 | 0.012 | 0.067 | 0.000 |
| Method | ANCOVA | DiD | ANCOVA | DiD | ANCOVA | DiD | ANCOVA |
| SE clustered | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Question level | Households | Households | Households | Households | Households | Households | Households |

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, *

p<0.1

Table A9: Robustness on household wealth index and secondary individual income

| | (1) | (2) | (3) | (4) | (5) | (6) |
|------------------|----------------------|---------------------|--|--|---------------------------------------|---------------------------------------|
| VARIABLES | Wealth index | Wealth index | Income from secondary activity (male and female) | Income from secondary activity (male and female) | Income from secondary activity (male) | Income from secondary activity (male) |
| Treated_core | 0.244** (0.106) | | 53,198 (46,551) | | 67,553 (54,021) | |
| Lagged dependant | 0.786*** (0.0421) | | 0.646*** (0.189) | | 0.842*** (0.0566) | |
| DID | | 0.236* (0.110) | | 108,712** (45,376) | | 133,636* (66,136) |
| Constant | 0.0867* (0.0448) | -0.0923 (0.0831) | 85,459** (32,204) | 129,716*** (23,644) | 82,794** (28,210) | 136,502*** (25,800) |
| Observations | 466 | 932 | 43 | 306 | 31 | 225 |
| R-squared | 0.535 | 0.031 | 0.300 | 0.033 | 0.425 | 0.041 |
| Method | ANCOVA | DiD | ANCOVA | DiD | ANCOVA | DiD |
| SE clustered | Yes | Yes | Yes | Yes | Yes | Yes |
| Question level | Households | Households | Individuals | Individuals | Individuals | Individuals |

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table A10: Robustness on household's high-power appliances possession and economic uses of electricity

| VARIABLES | (1) Use high power appliances | (2) Use high power appliances | (3) Economic use of electricity |
|------------------|--|--|--|
| Treated_core | 0.215** (0.0843) | | 0.130** (0.0445) |
| Lagged dependant | 0.482*** (0.108) | | |
| DID | | 0.125* (0.0691) | |
| Constant | 0.139*** (0.0317) | 0.153*** (0.0281) | 0.0824*** (0.0212) |
| Observations | 463 | 929 | 264 |
| R-squared | 0.211 | 0.035 | 0.035 |
| Method | ANCOVA | DiD | ANCOVA |
| SE clustered | Yes | Yes | Yes |
| Question level | Households | Households | Households |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table A11: Robustness on individual activities and their electricity reliance

| VARIABLES | (1) Electricity use for primary activity | (2) Electricity use for primary activity | (3) Electricity use for men's secondary activity | (4) Electricity use for men's secondary activity | (5) Electricity use for women's secondary activity | (6) Electricity use for women's secondary activity |
|------------------|--|--|---|---|---|---|
| Treated_core | 0.0883 (0.0506) | | 0.234** (0.0918) | | -0.299 (0.236) | |
| Lagged dependant | 0.443** (0.143) | | 0.0147 (0.0519) | | 0.727*** (0.163) | |
| DID | | 0.0849 (0.0476) | | 0.550* (0.299) | | 0.230 (0.242) |
| Constant | 0.0237** (0.00996) | 0.0129* (0.00607) | -1.841*** (0.0879) | -1.307*** (0.292) | 0.0260 (0.369) | -1.882*** (0.132) |
| Observations | 459 | 1,137 | 55 | 272 | 27 | 116 |
| R-squared | 0.095 | 0.036 | 0.071 | 0.097 | 0.168 | 0.080 |
| Method | ANCOVA | DiD | ANCOVA | DiD | ANCOVA | DiD |
| SE clustered | Yes | Yes | Yes | Yes | Yes | Yes |
| Question level | Individuals | Individuals | Individuals | Individuals | Individuals | Individuals |

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

“ Sur quoi la fondera-t-il l'économie du monde qu'il veut gouverner ? Sera-ce sur le caprice de chaque particulier ? Quelle confusion ! Sera-ce sur la justice ? Il l'ignore. ”

Pascal



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