Rural electrification and women's empowerment in the Côte d'Ivoire.

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Abstract

In 2013, in order to improve the living conditions of the rural population, the Ivorian government launched the *Programme National d'Électrification Rurale* (PRONER) to electrify all localities with more than 500 inhabitants. This paper assesses the impact of this programme on the empowerment of rural women using data from the *Enquête sur le Niveau de Vie* (ENV) of households in 2015. To achieve this, we employ an Inverse Probability Weighted Regression Adjustment (IPWRA) model, corrected for selection bias. The results show that PRONER, while reducing the time allocated to performing household chores, increases women's empowerment through the reallocation of time to full-time paid work in the agricultural and non-agricultural sectors. We also find that the allocation of men's time is not affected by this programme. This implies that PRONER reduces gender inequalities in terms of paid hours worked in the Ivory Coast.

Keywords: Rural electrification, empowerment, gender economic analysis, IPWRA, Ivory Coast, rural employment.

JEL Classification: O18, J16, N57, E24, C12

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I. Introduction

Investment in rural electrification is one of the preferred means of structural change and methods for improving the living standards of vulnerable households (Khandker et al., 2014, Avadikyan and Mainguy, 2016; Gould and Urpelainen, 2018, Samad and Zhang, 2019, Chhay and Yamazaki, 2020, Nock, et al., 2020). Economic infrastructures are catalysts for the reduction of poverty by allowing vulnerable households access to basic social and economic services.

Such interventions have been shown to be particularly beneficial in enabling the empowerment of women (Govindan et al., 2020; Samad and Zhang, 2019; Basu, 2019; Dowie et al, 2018; Burney et al. 2017; Saing 2017; Da Silveira Bezerra et al. 2017; Mohun and Biswas 2016; Standal and Winther 2016; Koolwal and Van de Walle 2013; Khandker et al. 2009; Winther 2008; Kanagawa and Nakata 2008). Nevertheless, there is little existing information concerning the role of rural electrification on the empowerment of women in sub-Saharan Africa, where poverty rates are high and women's empowerment low (World Bank, 2020).

In a social context of gender disparity, access to electricity can be a powerful lever for improving women's well-being through (i) new employment opportunities in the labour market (Dinkelman, 2011; Rud, 2012; Samad and Zhang, 2019), (ii) increased agricultural productivity (Chakravorty, Emerick and Ravago, 2016), (iii) improved family finances (Rao, 2013; Thomas et al 2020), (iv) reduced fertility (Grimm et al, 2015; Fujii and Shonchoy, 2020), (v) greater involvement in decision-making (Sedai et al, 2020, Samad and Zhang, 2019), (vi) improved education (Lipscomb, Mobarak and Barham, 2013, Samad and Zhang, 2019), and (vii) less time spent on fuel collection (Khandker et al. , 2014; Gould and Urpelainen, 2018; Barron and Torero, 2016).

According to the above authors, the time saved on doing unpaid household chores as a result of improved economic infrastructure is reused to generate income. Not only do women use these infrastructures in their daily activities, but they also participate in their provision as employees. All of these elements contribute to the improvement, not only of their incomes, but most importantly of their self-esteem, which changes the perceptions of their community towards them, regarding their traditional roles.

Despite all these benefits, access to electricity remains very low in developing countries (Peters and Vance, 2011; Bernard, 2012; Nock, et al., 2020, Chhay and Yamazaki, 2020). Conscious of the key role of electrification in social and economic development, the Ivorian government, with support from the African Development Bank, has since 2013, launched the *Programme National d'Électrification Rurale* (PRONER).

This programme, which aims to electrify all villages with more than 500 inhabitants, made it possible to provide electricity to 4,537 of the 8,500 eligible localities in 2016, an increase of 57.7% compared to those covered in 2011. Several departments in the north and west have greatly benefited from this programme, some having recorded an acceleration in the rate of electrification of up to 300% compared to the year 2011 (CI-Energies, 2019).

Nevertheless, the positive impact of electrification on women's autonomy does not receive unanimous support. Other studies report more mixed results. They argue that it depends on the cost of access, the type or form of infrastructure and the time frame involved (Béguerie et al., 2016; Peters and Sievert, 2016; Béguerie and Pallière, 2016; Attigah and Mayer-Tasch, 2013; Shanker, 2012; Pinstrup-Andersen and Shimokawa, 2007).

This is because the availability of electricity does not necessarily guarantee that poor households will have access to it due to the subscription fees. For example, Gupta and Pelli (2020) in India show that electrification creates a financial burden on poor households and leads to an increase in the likelihood of a shift towards the use of biomass fuels and a decrease in the use of modern cooking fuels.

Van de Walle et al (2013) found only moderate effects in India resulting from the increase in informal female work, but not from regular paid work. Standal and Winther, (2016), and Agénor and Agénor, (2014) highlight mostly long-term negative effects on household welfare as women reduce the amount of time they spend on childcare with the economic opportunities created by electrification. Peters and Vance (2011) find a positive association between electricity and fertility for urban households, as opposed to a negative one for rural households in the Ivory Coast.

An evaluation of the socio-economic impact of PRONER in the Ivory Coast using effective econometric tools is therefore necessary to provide guidance on how to improve it. This paper addresses the following questions: Has PRONER really contributed to the

improvement of household welfare in the target areas? More specifically, what is the impact of the programme on women's empowerment? Such questions are particularly relevant in the context of the Ivory Coast, where average incomes of women are only 51% of that made by men (NSI, 2015), confirming strong gender inequalities in the country. The situation is more alarming in rural areas, where the poverty rate for women is 67.4% compared with 45.5% for men (AfDB, 2015).

The main objective of this paper is to assess the impact of PRONER on the empowerment of rural women by focusing on the participation rate of women in the labour market. To do so, we use data from the 2015 *Enquête sur le Niveau de Vie* (ENV 2015).

From an empirical point of view, there are two major problems in estimating the impact of electrification. Firstly, the selection of localities for the implementation of PRONER is not done randomly. Therefore, women benefiting from PRONER could have different observable and unobservable characteristics than those who did not benefit from it, potentially biasing the estimation results. In order to correct this bias, some authors generally use instrumental variables methods (Dinkelman, 2011), fixed-effect models (Sedai et al., 2020), matching methods (Bensch, et al., 2011; Rhati and Vermaak, 2018, Samad and Zhang, 2019.), and the inverse probability weighted regression adjustment method (Chhay and Yamazaki, 2020). However, it remains a challenge to select a good tool.

More recently, Bensch et al (2020) and Lee et al (2020) have expressed reservations about using geographical variation in experimental studies to isolate the effect of electrification from other infrastructural variables and concurrent factors. Criticising Dinkelman's (2011) identification strategy, Bensch et al. (2020) argue that additional assumptions on confounding factors are needed to truly measure the impact of electrification. We adopt this option in our study, as other investments were made at the same time as PRONER for the promotion of women's empowerment (see section 2.1). It should be noted, however, that these investments were made independently, with no direct link to the electrification status of the localities.

In light of these considerations, and in order to obtain an unbiased estimate of the programme's impact on women's empowerment, our identification strategy consists of using the Inverse Probability Weighted Regression Adjustment (IPWRA) method. The eligibility

criteria for a locality to be included in the PRONER programme - i.e. having a population of more than 500 and being located within 20 km of the national network - were used to estimate these probabilities. The IPWRA method takes into account endogeneity biases resulting from the non-random nature of the assignment of women to treatment.

As noted by Morgan and Winship (2014) and Chhay and Yamazaki, (2020), the IPWRA technique offers a double robustness in assessing the impact of a programme, because the estimators remain convergent even in the case of misspecification. Furthermore, in order to take into account the other investments made, we introduce into all our econometric specifications, an access index to road infrastructures to assess their impact on the empowerment of women.[1]

Secondly, the decision to participate in a segment of the labour market is potentially endogenous (Killingsworth, and Heckman, 1986; Dawson et al, 2009; Semykina, 2018). This may lead to a selection bias in the results if not corrected. In order to strengthen our results, we add the Heckman selection bias correction (1979) to our IPWRA-weighted estimates to take into account the fact that women in a given activity may have particular characteristics that may lead to biased estimates.

The results show that PRONER integrates the gender dimension well insofar as it only impacts women's activities. Indeed, it has a positive impact on the empowerment of rural women through the reallocation of time to full-time paid work in the agricultural and non-agricultural sectors, and by reducing the amount of time allocated to performing household chores. We also find that the allocation of men's time is not impacted by this programme. We can therefore deduce that PRONER reduces gender inequalities in terms of paid hours worked.

This paper contributes to the literature on the impact of electrification on women's empowerment through their participation in the labour market (Sedai et al., 2020; Samad and Zhang, 2019; Rathi and Vermaak, 2018). To our knowledge, it is the first study to combine the Inverse Probability Weighted Regression Adjustment Method and selection-bias correction in programme evaluation in sub-Saharan Africa.

[1] As discussed in section 2.1, investment in road infrastructure accounted for the biggest share of total spending on new infrastructure during the period 2012-2014 (Ministry of Planning and Development, 2015).

Contextually, although several studies have been carried out to assess the effect of electricity on the empowerment of women (Sedai et al., 2020; Samad and Zhang, 2019; Rathi and Vermaak, 2018), to the best of our knowledge, none have focused on sub-Saharan French-speaking countries where social structures are somewhat different.

The paper is organised as follows: Section 2 describes the background, variables and study data. Section 3 presents the identification strategy and Section 4 analyses the results, before the conclusion and policy recommendations.

II. Context, definition of variables and data

2.1 Context

The PRONER programme is being carried out in a setting of poverty and gender inequality in the Ivory Coast. In fact, poverty reached 46.3% of the population in 2015 compared to 49% in 2008 (NSI, 2015). The human development index was 0.474 in 2015 compared to an African average of 0.54 (UNDP, 2017). The majority of the poor are women, who face real difficulties in accessing education, health, employment and positions of responsibility.

In the labour market, the combined unemployment/underemployment rate related to working time and the potential labour force is much higher for women (37.6%) than for men (20.2%) (ENSESI, 2016). Thus, the rate of vulnerable employment is 78.9% for women compared to 64% for men (UNDP, 2017). This is partly explained by a lower literacy rate for women with 36.3% being literate, compared to 53.3% of men (NSI, 2015).

With regard to representation in decision-making authorities, women are under-represented holding only 11.8% and 19.2% of seats in the National Assembly and the Senate

respectively. They are equally less represented in regional councils and town halls, holding only 3.2% and 4.6% of seats respectively (Ministry of Planning and Development, 2019).

The government is convinced of the need for economic infrastructure to reduce poverty and inequality and has put in place a programme called the Government Social Programme (PSgouv). The PSgouv aims to strengthen and accelerate the population's access to quality public services. The priority sectors are health, roads and especially water and electricity. Indeed, since the end of the post-electoral crisis in 2011, a number of investments in economic infrastructures have been made in both urban and rural areas. These include road infrastructures (asphalting and rehabilitation of roads), health, education and drinking water supply.

According to the Ministry of Planning and Development (2015), over the 2012-2014 period, more than 557 billion CFA francs were invested in infrastructure and transport. Over the same period, education and health sectors received investments of 198 billion CFA francs and 140 billion CFA francs respectively. As for actions relating to the promotion of gender and equality, specific expenditure for women amounted to 1.7 billion CFA francs. Infrastructure and transport expenditure accounts for 23.66% of total investment, followed by energy, mining and hydrocarbons with 15.26%, which includes investment in the electrification programme (PRONER). The agricultural sector comes in third place with 8.49% of the total budget. Several other sub-sectors of production share the remaining funds (Ministry of Planning and Development, 2015).

However, it should be noted that these investments are not linked to the rural electrification programme. In fact, infrastructures are created independently of the electrification programme because they are part of a post-crisis framework whose objective is to provide the country with quality economic infrastructures and to support the growth-generating sectors. The social aspect, which includes PRONER, came later in late 2013. Therefore, these investments are made in both beneficiary and non-beneficiary areas of PRONER.

2.2 Description of the *Programme National d'Électrification Rurale* (PRONER)

In terms of electrification, the key tool of the PSgouv is the *Programme National d'Électrification Rurale* (PRONER) adopted by the Council of Ministers on the 2nd of July 2013 in Korhogo. This programme aims to achieve a more evenly balanced access to electricity across the different departments and regions. The objective is to correct regional disparities in terms of coverage by aiming for 100% coverage for all localities with more than 500 inhabitants by 2020, and for all localities in the country by the year 2025.

The aim of the programme is to reduce poverty in rural areas by providing electricity to the populations, in order to enable them to diversify their sources of income. Indeed, the availability of electricity is essential for the provision of essential services such as lighting in schools and homes, food safety through refrigeration, access to communication technologies and the enhancement of productivity in economic sectors, including agriculture.

The purpose of this roll-out of electrification is to improve living conditions in rural areas by opening up the local economies. This programme has been awarded to the *Société des Energies de Côte d'Ivoire* (CI-Energies), which is in charge of the project. This state structure, which was created in 2011 following a reform of the electricity sector, is under the leadership of the Ministry of Petroleum and Energy.

The eligibility criteria to be considered for PRONER can be summarised in two points. The locality must have a population of more than 500 people and must be located within 20 km of the national electrical grid. In line with these criteria, CI-Energies based its analysis on the 2014 General Population and Housing Census data (RGPH) conducted by the National Institute of Statistics, and identified 8,518 eligible localities across the Ivory Coast. Field deployment is carried out by means of major projects subject to public consultation (technical ministries and decentralised administrative authorities) and is subjected to environmental and social impact studies.

Local SMEs are prioritised for the execution of the works. With an estimated overall cost of US$1.4 billion, the programme is strongly supported by the government and several donors in the form of loans and grants. As a result of these efforts, the number of electrified localities has risen from 2,800 in 2011 to 4,500 in 2017 and to 5,859 localities at the end of

2019, bringing the coverage rate to 69% compared to 33% in 2011, as reported by CI-Energies. The overall progression rate was 109% between 2011 and 2019. This rate of progress in terms of electrical coverage varies from region to region and has reached 200% in the Folon region, 322% in the Kabadougou region and even 400% in the Boukani region. This dynamic has brought the national coverage rate[2] to 53% in 2016, up from 34% in 2012 and the access rate to electricity, to more than 80%, up from 74% in 2011. As a result, 69% of approximately 8,518 localities were electrified in 2019 under PRONER.

However, even if progress in implementation can be considered to be satisfactory, it should be noted that the programme still faces difficulties, particularly due to the low level of resources allocated to it and the exclusion of certain localities, considered ineligible due to their size (localities with less than 500 inhabitants). Indeed, the programme, which is essentially based on the national electricity grid, requires substantial financial and technical resources to be made available for the electrification of certain remote rural areas, particularly the camps.

After several years of implementation, it is important to know whether the National Rural Electrification Programme has contributed to improving the living conditions of households through the empowerment of women.

2.3 Data, description of performance indicators

This study uses the database from the "Standard of Living of Households" survey conducted in 2015. The General Population and Housing Census (RGPH 2014) was used as the sampling frame for this study. A sample of 12,900 households was drawn in two stages: in the first stage, by proportional allocation of Census Areas (CAs) or Enumeration Areas (EAs) within the study strata; and in the second stage, by systematically drawing 12 households per EA.

[2] Coverage rate: The total number of electrified localities out of the total number of localities.

The advantage of this survey (ENV 2015) for our study is that it provides baseline data on household living standards and conditions (health, education, housing, expenditure, activities, transport etc.) in a post-PRONER context. In addition, it is the most recent survey available to date (data from the 2018 ENV survey is not yet available). Furthermore, this survey includes the variables that allow to perceive the empowerment of women and to identify a number of PRONER-eligible localities.

To analyse the impact of PRONER on the empowerment of rural women, we focus on the indicators presented in Table A1 in the appendices. The indicators include variables relating to both women's participation in the labour market (paid employment, full-time employment) and the allocation of the time, spent by women on performing different tasks (time for household activities, time for non-agricultural activities and time for agricultural activities). Although income is the variable that best captures the economic empowerment of women, its unavailability in our database leads us to resort to other indicators presented in this table.

In fact, empowerment is a difficult concept to measure because of its multidimensionality, so that the proxies used, vary from one author to another and depend on the context. According to Laszlo et al (2017), the indicators used to measure women's empowerment can be classified into three groups: direct measures, indirect measures and constraints. In the absence of direct measures such as income, we have an indirect measure, namely women's participation in paid employment or income-generating activities, which has been used by Mahmud and Tasneem (2014), Ganle et al. (2015) and Orso and Fabrizi (2016) respectively. In reality, the amount of income obtained from the participation of a woman in an economic activity outside the household is closely linked with the degree of empowerment (Anderson and Eswaran, 2009), especially in a rural setting where the woman is often working on the family farm without pay. In addition, time allocation is used by some authors (Garikipati, 2008) as a direct and objective measure even though it is considered to be the outcome of the empowerment process rather than a measure in itself (Laszlo et al., 2017).

The value of these indicators is that they are objective measures (Laszlo et al., 2017; Quisumbing et al., 2016). Therefore, the favoured indicators for measuring women's empowerment, based on our database, are participation in non-agricultural employment,

participation in paid employment, participation in full-time employment, and time spent on household, agricultural and non-agricultural activities. Information on women's income could not be used due to the fact that income variables observed in developing country surveys are prone to large measurement errors and their value depends essentially on the season in which the survey took place (Deaton and Zaidi, 2002).

It is therefore difficult for the analyst to identify the share of income generated by each individual, especially in the case of family-related activities in the agricultural sector and in rural areas. Additionally, when it comes to household chores, there is no standard wage associated with women's work. This is why the type of employment and hours worked per sector were chosen as indicators of women's empowerment.

One of the potential effects of rural electrification is the development of value chains and non-farm activities that can generate income for rural women. Thus, through the diversification of the sources of income and the resulting increase in their revenues, women will be better equipped to ensure their economic empowerment and to provide for the needs of their families. The latter effect is due to the fact that the literature shows that, compared to men, women spend a large share of their incomes on the basic needs of their families. Therefore, the empowerment of women through access to quality jobs, will ensure regular and higher incomes, which is key to achieving social well-being.

2.4 Construction of the study sample and descriptive statistics

The initial step in drawing up the study sample was to select the post-PRONER rural household survey database, i.e. after 2013. Due to the unavailability of a more recent household database, we have used the NSI[3] ENV 2015 database. Using this data, we undertook a rigorous mapping of the localities that have benefited from PRONER and of those

[3] Unfortunately, the 2008 ENV database (collected before the implementation of the PRONER reform) could not be used in this study because it does not contain the same localities as observed in the 2015 ENV database.

that have not. To achieve this, it was necessary to identify among the localities of the 2015 ENV, those that are on the list of non-electrified localities eligible for PRONER, which was produced by the NSI, following the 2014 General Population and Housing Census (RGPH).

This research was completed with information from *Côte d'Ivoire Energies* on the electrification status of localities with more than 500 inhabitants since the implementation of PRONER. Following this cross-tabulation, the localities identified, were grouped according to their electrification status in 2015. Those that are electrified are part of the treatment group and those that are not, but are eligible, make up the comparison or control group. At the end of this process, we counted 314 eligible localities, of which 244 were non-electrified (comparison group) and 70 electrified, PRONER beneficiaries (treatment group). The table A2 in the appendices shows that our sample is representative, as it covers 93.5% of the national territory.

The characteristics of all the variables in the study are presented in Tables 1 and 2. Table 1 presents the descriptive statistics for all the dependent variables used. These variables are presented according to the treatment status (group of treated localities and group of control localities) and by gender. The values in Table A1 in the appendices as well as Table 1 show the domination of men in terms of the number of hours they spend on different activities with the exception being on household chores. Indeed, men spend more time than women on both agricultural and non-agricultural activities. On average, men spend 37 hours per week on agricultural activities, while women spend only 30 hours. This finding remains the same when taking into account the status of electrification. Indeed, in electrified areas, men spend 38 hours per week on agricultural activities, while women spend only 31 hours.

In terms of time allocated to non-agricultural activities, men spend an average of 41 hours per week on these activities, while women spend an average of only 31 hours. This trend is consistent regardless of the status of electrification, with men spending an average of 42 hours per week on these activities, compared to 35 hours per week for women in areas with electricity.

Regarding the time spent doing household activities, it is not surprising to find that women spend more time than men doing them, thereby confirming the assumption that African cultural practices attribute this task exclusively to women. Indeed, while women tend

to spend an average of 84 hours a week on household activities, men spend only 25 hours. This result is confirmed, if we take into account the status of electrification, because in the electrified areas, for example, women spend an average of 71 hours a week on household activities compared to only 26 hours for men.

Full-time employment is predominantly held by men, with a rate of 57%, compared to 34% for women. This trend is confirmed regardless of the status of electrification of the localities. In areas with electricity, the proportion of men (58%) is higher than that of women (38%) in full-time employment. Similarly, a higher percentage of men were in paid employment. The results of the difference-in-means tests between the treatment and control groups (Table 1) show that income-generating employment opportunities and time spent on household activities are significant for women.

Table 1: Description of the dependent variables

Variables	Description	MEN			WOMEN		
		Treated	Controls	Mean diff.	Treated	Controls	Mean diff.
Time for household activities	Number of hours spent on household chores per week by individuals aged between 17 and 64 years old in the home.	23.18	21.04	-2.40**	62.33	79.11	16.78***
Time for non-agricultural activities	Number of hours per week spent on non-agricultural activities by individuals aged between 17 and 64 in the household	42.10	41.16	-0.94	34.91	30.23	-4.68
Time for agricultural activities	Number of hours per week spent on agricultural activities by individuals aged between 17 and 64 in the household	38.77	36.74	-2.03**	30.87	29.63	-1.24
Paid employment opportunity	Indicator equal to 1 if the individual is in paid employment and 0 otherwise	0.31	0.32	0.01	0.18	0.22	-0.04**
Full-time employment opportunity	Indicator equal to 1 if the individual is in full-time employment and 0 otherwise.	0.58	0.57	-0.01	0.38	0.33	-0.048
Total number of observations	-	996	3051	-	921	2974	-

NB: ***Significance threshold at 1%. **Significance threshold at 5%. *Significance threshold at10%.
Source: Authors' calculations based on data from the 2015 ENV

The characteristics of the other variables in the study, notably the explanatory variables, are presented in Table 2, whose results show that, on average, households in electrified and non-electrified areas display different characteristics. Nevertheless, the difference-in-means

test finds similarity between the two groups in terms of age and rate of school enrolment. In fact, the average age of the household is 40 years in both electrified and non-electrified areas.

Also, only 41% of people are in schooling, regardless of the treatment status of the area. In line with the eligibility criteria for the National Rural Electrification Programme, the population size of the electrified areas is higher than that of the control areas. In contrast, the average distance of the localities from the national grid before treatment is higher in the treated areas than in the control areas. The average distance is 8 km and 6 km respectively. The "population size" criterion seems to be predominant in enrolment to the programme.

Table 2 : Descriptive statistics

Variables	Obs	Av	Std. Dev.	Min	Max	Av (TREATED)	Av (CONTROLS)	Avg. diff.
Household characteristics								
Proportion of people with primary education	6853	0.20	0.40	0	1	0.23	0.19	-0.04***
Average age in the household	7942	40.56	10.58	18	64	40.74	40.50	-0.23
Number of women in the household	3895	3.69	2.85	0	21	3.54	3.74	0.20**
Number of men in the household	4047	3.21	2.38	0	20	2.91	3.31	0.39***
Household size	7942	6.19	4.73	1	34	5.66	6.36	0.70***
Proportion of people in rural areas	7942	0.90	0.30	0	1	0.83	0.92	0.09***
Proportion of people attending school	7942	0.41	0.49	0	1	0.42	0.41	-0.01
Proportion of households using modern toilets	7942	0.56	0.50	0	1	0.62	0.54	-0.08***
Number of children under 5 years old	8808	1.57	1.70	0	10	2.13	6.68	-4.55***
Explanatory variables for the treatment								
Population of localities	8815	18157.4	18172.45	0	92805.26	19245.81	17828.64	-417.17***
Distance of the localities from the national rural grid (in Km)	7915	6.66	7.18	0.1	45	7.85	6.29	-1.56***

NB: **, *** Significance threshold at 5 and1% respectively.
Obs.: number of observations in terms of number of individuals
Source: Authors' calculations based on data from the 2015 ENV

III. Identification strategy

The following model describing the relationship between having benefited from electrification in one's locality and the analysed employment variable, allows us to estimate the causal impact of electrification on women's employment:

$$Y_i = \beta_0 + \beta_1 T_i + \delta X_i + \epsilon_i \qquad (1)$$

Where Y_i represents one of the employment variables to be analysed for an individual *i*. These variables are agricultural hours worked, non-agricultural hours worked, hours worked in the household, the probability of working full-time and the probability of having a paid job. T_i is the binary treatment variable having a value of 1, if the individual resides in an eligible locality that has benefited from electrification through the programme (treated population) and 0 if the individual resides in an eligible locality that has not been electrified (untreated population). X_i is the vector of confounding factors.

Among these factors, in order to assess the impact of other infrastructural investments taking place at the same time as PRONER, we have included an access index to road infrastructures. This index is a binary variable which has a value of 1 if the individual has access to an asphalt road within 5 km of their dwelling and a value of 0 if they do not. The β_1 represents the impact of the programme on the employment variable.

If the electrification of localities was carried out randomly, all individuals living in eligible localities would have the same probability of receiving electricity and therefore the model (1) could be derived by the ordinary least squares approach. However, it is reasonable to assume that the electrification of localities is not conducted randomly and that the two eligibility criteria of population size and distance from the electricity grid are the factors that can affect the probability of a locality being selected for the electrification scheme. In this context, the treatment variable T_i is endogenous and a method that takes endogeneity into account must be adopted in order to obtain a robust estimator of the impact of electrification.

We therefore adopt the Inverse Probability Weighted Regression Adjustment method to correct for treatment endogeneity (Cattaneo, 2010; Chhay and Yamazaki, 2020). The treatment equation is defined as:

$$T_i = \alpha_0 + \alpha_1 X_i + \alpha_2 V_i + \mu_i \qquad (2)$$

V_i is the vector representing the two eligibility criteria for the programme, namely the population of the locality and the distance from the electricity grid. The other variables are identical to those in equation (1). The inverse probability weighted regression adjustment (IPWRA) estimation procedure consists of four steps.

The first step is to estimate, from equation 2, the weighting score of each individual to have the treatment. In the second step, we predict the conditional probability of each individual being treated. In the third step, we assign the inverse of the probability of being treated for treated individuals and the inverse of the probability of not being treated for the control individuals. The last step is to estimate the main equation (equation 1) using these inverse probabilities as weights in the regression. The weights calculated and assigned to each individual in the sample allow for the amplification of the treatment of individuals who would otherwise have a lower tendency to be treated and the lessening of the weight of individuals who would otherwise have a higher probability of being treated.

The estimator obtained from the weighting is a convergent and doubly robust estimator of the causal impact of electrification on the dependent variable if the employment decisions were observed for all women (Chhay and Yamazaki, 2020). However, the IPWRA estimator is potentially biased, because in reality, employment is observed only among women participating in that employment. In order to take this selection bias into account, we therefore combine the IPWRA method with the Heckman estimation strategy (1979). The selection equation is as follows:

$$S_i = a_0 + a_1 X_i + a_2 Z_i + \eta_i \qquad (3)$$

S_i is a dichotomous variable equal to 1, if the woman participates in the labour market and 0 if not. Z_i is the exclusion variable represented by the number of children under the age of five in the household. Following the strategy of Heckman (1979), the inverse Mills ratio, calculated from equation (3) is included in equation (1) to correct for selection bias.

IV. Results

The findings presented below relate mainly to indicators of women's economic empowerment in terms of the allocation of their time and the quality of their employment.

4.1 Results regarding the allocation of women's time

Several indicators of women's empowerment, relating to the allocation of their time, were tested. These are time spent on non-agricultural activities, agricultural activities, and household chores. Table 3 presents the results for both women and men. The results show that PRONER did not have a significant impact on the allocation of men's time. It does however have a significant impact on women's time allocation regardless of the activities considered. PRONER therefore has a gender effect that is proactive towards women.

Table 3: The impact of PRONER on the time allocation of women and men

	Women			Men		
	OLS	**IPWRA ESTIMATE (ATE)**	**IPWRA with correction for selection bias (ATE)**	**OLS**	**IPWRA ESTIMATE (ATE)**	**IPWRA with correction for selection bias (ATE)**
Time for agricultural activities	2.818* (1.44)	4.227*** (1.41) [14.28]	4.126*** (1.34) [13.93]	1.426 (1.09)	0.952 (0.99) [2.56]	0.876 (0.99) [2.35]
Time for non-agricultural activities	4.206 (3.70)	7.001** (3.59) [22.84]	7.053** (3.58) [23.01]	-3.546 (3.37)	-3.835 (3.14) [-8.93]	-3.863 (3.14) [-8.99]
Time for household activities	-4.147 (6.86)	-12.79** (6.70) [-12.58]	-12.82*** (6.18) [-12.63]	8.414 (8.79)	6.922 (9.56) [15.15]	5.570 (9.07) [12.12]

Source: Authors' estimates based on the 2015 ENV.
Note: (...) represents standard errors; [....] represents results obtained from: 100*coefficient/mean of control group; and *, **, *** indicate the degree of significance at 10%, 5% and 1% levels respectively. For each of these estimates the following control variables were included: educational level, age, marital status, religion, number of women in the household, household size, presence of modern toilets in the household, proportion of the working population in the locality, employment rate, access index to road infrastructures, total population in the locality, and distance of the locality from the electricity grid.

The results show that PRONER significantly increases the amount of time women spend on non-agricultural activities at the 5% level of significance. Indeed, women in the areas electrified under PRONER, devote significantly more time to non-agricultural activities. This represents an increase of about 23% of the average time spent by women in the control areas. This result seems to reflect a catch-up effect, as men spend on average 41 hours per week on non-agricultural activities compared to 31 hours for women (see Table A1).

These activities are likely to be among the economic opportunities created by electrification. This result is in line with the findings of some authors who argue that access to electricity leads to the emergence of non-agricultural activities in beneficiary localities (Barron and Torero, 2014; Dasso and Fernandez, 2015, Vernet et al., 2019). These new activities increase the opportunity cost of household chores, which become less attractive, resulting in a sharp decline in the time spent on housework. This decline represents about 12.6% of the average time spent on housework by the comparison group. In fact, as a result of the reduction in household chores due to the availability of electricity, women have more time to devote to income-generating activities.

This increase in income is likely to increase their bargaining power within the household (World Bank, 2003). These results confirm those of several authors who argue that access to economic infrastructures in general, and to electricity in particular, leads to a decrease in time spent on household chores (Dikelman, 2011; Barron and Torero, 2014; Burlig and Preonas, 2016 and Tenezakis and Tritah, 2020).

This time gain is also partly allocated to agricultural activities. Although the time spent on agricultural activities increases significantly at the 1% threshold, the effect is weaker. In fact, the reallocation of women's time is higher (23%) in favour of non-agricultural activities than towards agricultural activities (13.9%). This result could reveal both the existence of disguised unemployment and the wait-and-see attitude of women linked to the recent development of economic infrastructure (electricity) in their area. In the latter case, the ratchet effect would come into play.

Even if women reallocate their time to non-agricultural work, it is worthwhile knowing more about the quality of this employment, since household empowerment and household welfare are directly linked to it. The following section addresses this issue.

4.2 Results relating to the quality of women's employment

The results of the impact of PRONER on job quality through paid employment and full-time employment for both women and men are presented in Table 4. As with time allocation, PRONER has a gender-differentiated effect on job quality. While it does not affect the quality of men's jobs, it has a significant impact on women's. PRONER is found to significantly increase, at the 10% and 1% thresholds respectively, employment opportunities in both paid and full-time employment for women.

Indeed, being in an area with electricity increases the probability of women having a full-time paid job. This likelihood of having a full-time job is 56.9% higher than that of women not benefiting from the programme. However, concerning paid employment, it is only about 4.3% higher. PRONER has an elevating effect in terms of gender equality insofar as one in three women had the opportunity to have a full-time job compared to about two in three men.

Table 4: The impact of PRONER on women's and men's employment opportunities

	Women			Men		
	OLS	**IPWRA ESTIMATE (ATE)**	**IPWRA with correction for selection bias (ATE)**	**OLS**	**IPWRA ESTIMATE (ATE)**	**IPWRA with correction for selection bias (ATE)**
Paid employment opportunity	0.029 (0.018)	0.033* (0.017) [4.23]	0.033* (0.017) [4.26]	-0.014 (0.02)	0.012 (0.02) [7.76]	0.012 (0.02) [1.70]
Full-time employment opportunity	0.133*** (0.047)	0.191*** (0.044) [57.17]	0.190*** (0.044) [56.86]	-0.028 (0.034)	-0.070* (0.035) [-11.88]	-0.07 (0.35) [-11.88]

Source: Authors' estimates based on the 2015 ENV.
Note: (...) represents standard errors; [....] represents results obtained from: 100*coefficient/mean of control group; and *, **, *** indicate the degree of significance at 10%, 5% and 1% levels respectively. For each of these estimates the following control variables were included: educational level, age, marital status, religion, number of women in the household, household size, presence of modern toilets in the household, proportion of the working population in the locality, employment rate, access index to road infrastructures, total population in the locality, and distance of the locality from the electricity grid.

These high-quality (paid and full-time) employment opportunities would further justify the strong reallocation of women's time towards non-agricultural jobs. This result is consistent with the finding of Thomas et al (2020) which suggests that electricity is used primarily to

boost potential household earnings. More importantly, electrification substantially increases income from paid employment as highlighted by Rathi and Vermaak (2018) in a study of India and South Africa.

Consequently, employment is a powerful channel for the empowerment of women as recently revealed by Samad and Zhang (2019). Subsequently, such empowerment would lead to improved household welfare as women spend up to 45% of their earnings on the needs of the household (Reardon et al., 1994; Haggblade et al., 2002).

V. Conclusion and recommendations

Employment is increasingly recognised as an indicator of women's social status and autonomy. Investment in infrastructure is particularly beneficial to women's well-being. Thus, promoting women's empowerment and reducing gender inequalities requires the provision of infrastructures which increase employment opportunities in rural areas. The Ivorian government understood this when it set up the *Programme National d'Électrification Rurale* (PRONER) in 2013 to improve the well-being of rural households, particularly that of women, who are generally relegated to performing household tasks.

This paper aimed to assess the impact of this programme on the empowerment of rural women in the Ivory Coast using data from the 2015 *Enquête sur le Niveau de Vie* (ENV). We used an econometric strategy combining the Inverse Probability Weighted Regression Adjustment (IPWRA) method with the Heckman selection bias correction method (1979). This robust strategy takes into account endogeneity biases, resulting from the non-random nature of the allocation to the treatment, together with the self-selection of women into the labour market segments.

The results show that PRONER has a positive and significant impact on the empowerment of rural women through the redeployment of their time from preforming household chores to non-agricultural activities. Indeed, electrification reduces the time spent performing domestic activities through two mechanisms. The first is related to the time saved through the lightening of domestic workloads. As for the second mechanism, it is the result of the creation of income-generating activities due to electrification that leads to an increase in the opportunity cost of household tasks causing them to be abandoned.

The combined effect is a sharp decline in the time spent performing domestic chores, which is about 12.6% less than the comparison group average. In addition, the improvement in the quality of employment provided by PRONER provides further encouragement in terms of women's economic empowerment by guaranteeing them a stable income. In contrast, PRONER has no effect on men's time allocation. Furthermore, we can infer from our results that major infrastructural investment, reduces gender inequalities in paid work and full-time employment opportunities.

Using a robust econometric method, our results are consistent with the findings in the literature (Dinkelman, 2011; Rud, 2012; Samad and Zhang, 2019) which suggest that rural electrification functions as a social ladder for women and reduces gender inequalities. This paper demonstrates the effectiveness of PRONER in addressing inequalities. Furthermore, considering the impact of women's empowerment on household welfare and the education of children (Namoro and Roushdy, 2009, Das and Mukherjee, 2007; Folaranmi, 2013), there is evidence in our results to suggest that PRONER could have a long-term impact on the construction of human capital and meeting the Millennium Development Goals in the Ivory Coast.

In terms of policy recommendations, the study recommends the continuation and extension of the *Programme National d'Électrification Rurale* (PRONER) to other localities with less than 500 inhabitants. The implementation of support and cost reduction programmes is also recommended in order to sustain effectiveness.

One of the limitations of the study is related to the quality of the data and information on the localities benefiting from the programme. In fact, for the period prior to implementation of the programme, we do not have follow-up data on a cohort of households

residing in the same localities identified in the 2015 ENV database. Therefore, it would have been interesting to analyse the impact of PRONER after a relatively longer period of time after its implementation. However at the time of writing this paper, the 2018 ENV database was not yet available.

It is important to note, nevertheless, that these results were obtained in the specific context of PRONER in the Ivory Coast and are not necessarily applicable to rural electrification programmes in other contexts. Furthermore, the choice of other indicators to measure women's empowerment is limited by the quality of the data available. With a view to future work, it would be interesting to extend this analysis to include other aspects of women's empowerment and household welfare.

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Appendices

Table A1: The description of the variables of interest by gender type

Variables	Description	MEN	WOMEN
Time for household activities	Number of hours per week spent on housework by individuals over the age of 17 years old in the household	21.6	75.01
Time for non-agricultural activities	Number of hours per week spent on non-agricultural activities by individuals over the age of 17 years old in the household	41.52	31.54
Time for agricultural activities	Number of hours per week spent on agricultural activities by individuals over the age of 17 in the household	37.19	29.85
Opportunity for paid employment	Indicator equal to 1 if the individual is in paid employment and 0 if he/she is not	0.32	0.21
Opportunity for full-time employment	Indicator equal to 1 if the individual is in full-time employment and 0 if he/she is not.	0.57	0.34
Total number of observations	-	4469	4339

Source: Authors' estimates based on the 2015 ENV.

Table A2: Distribution of localities from the 2015 ENV by administrative region

REGIONS	Number of localities
HAUT-SASSANDRA	9
PORO	19
GBEKE	7
INDENIE-DJUABLIN	3
TONKPI	16
YAMOUSSOUKRO	2
GONTOUGO	12
SAN-PEDRO	15
KABADOUGOU	6
N'ZI	9
MARAHOUE	4
SUD-COMOE	4
WORODOUGOU	16
LOH-DJIBOUA	13
AGNEBY-TIASSA	4
GOH	1
CAVALLY	2
BAFING	20
BAGOUE	15
BELIER	10
BERE	9
BOUNKANI	44
FOLON	6
GBOKLE	9
GRANDS-PONTS	6
GUEMON	4
HAMBOL	17
IFFOU	7
ME	2
NAWA	10
TCHOLOGO	10
MORONOU	3
TOTAL : 33	**TOTAL : 314**

Source: Authors based on data from the Ministry of the Interior