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

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Abstract

Purpose – This paper assesses the impact of this program on the rural women's employment opportunities using data from the 2015 round of the household's living standard survey (HLSS) of Côte d'Ivoire.

Design/methodology/approach – In 2013, in order to improve the living conditions of the rural population, the Ivorian government launched the National Program for rural electrification (PRONER) to electrify all localities with more than 500 inhabitants.

Findings – The results show that PRONER, while reducing the time allocated to performing household chores, increases women's employment through the reallocation of time to full-time paid work in the agricultural and non-agricultural sectors. The authors also find that the allocation of men's time is not affected by this programme. A possible mechanism that would explain such a pro-women effect is the labour-saving technology introduced to home production as an effect of the reform.

Research limitations/implications – As a limitation, it is important to note that these results were obtained in the specific context of PRONER in Côte d'Ivoire 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. It would be interesting for future research to extend this analysis to include other aspects of women's empowerment and household welfare.

Originality/value – This paper is the first to the author's knowledge to apply a robust econometric method by combining an inverse probability weighted regression adjustment model with Heckman sample selection method to access a robust causal effect of the PRONER in Côte d'Ivoire.

Keywords Rural electrification, Empowerment, Gender economic analysis, IPWRA, Côte d'Ivoire, Rural employment

Paper type Research paper

1. Introduction

Investment in rural electrification is one of the most important means of structural change and methods for improving the living standards of vulnerable households (Chhay and

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Ethical statement: No ethical approval was needed from the authors as Household's Living Standard Survey data are publicly available https://microdata.worldbank.org/

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Yamazaki, 2021; Nock *et al.*, 2020; Osunmuyiwa and Ahlborg, 2019; Samad and Zhang, 2019; Gould and Urpelainen, 2018; Avadikyan and Mainguy, 2016; Khandker *et al.*, 2014). 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 and de Haan, 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 is 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 (1) new employment opportunities in the labour market (Samad and Zhang, 2019; Rud, 2012; Dinkelman, 2011), (2) increased agricultural productivity (Chakravorty *et al.*, 2016), (3) improved family finances (Thomas *et al.*, 2020; Rao, 2013), (4) reduced fertility (Fujii and Shonchoy, 2020; Grimm *et al.*, 2015), (5) greater involvement in decision-making (Sedai *et al.*, 2020; Samad and Zhang, 2019), (6) improved education (Samad and Zhang, 2019; Lipscomb *et al.*, 2013) and (7) less time spent on fuel collection (Gould and Urpelainen, 2018; Khandker *et al.*, 2014).

According to the above mentioned papers, 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 (Nock *et al.*, 2020; Chhay and Yamazaki, 2021; Bernard, 2012; Peters and Vance, 2011). 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 National *Program for rural electrification* (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 with 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 (Diallo and Moussa, 2020; Peters and Sievert, 2016; Attigah and Mayer-Tasch, 2013; 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 that 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 Côte d'Ivoire.

An evaluation of the socio-economic impact of PRONER in Côte d'Ivoire using effective econometric tools is therefore necessary to assess its impact on employment opportunities and any gender differentiated effects. This paper seeks to assess whether PRONER has contributed to the improvement of women's employment opportunities in remunerated activities that, in turn, is expected to increase women's empowerment within the household and in their communities. In order to do so, we use data from the 2015 Household's Living Standard Survey (HLSS) of Côte d'Ivoire, combined with a mapping of the localities that have benefited from PRONER and of those that have not. This research question is particularly relevant in the context of Côte d'Ivoire, where average incomes of women are only 51% of that made by men (INS, 2015), confirming strong gender inequalities in the country.

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 (Samad and Zhang, 2019; Rathi and Vermaak, 2018; Bensch *et al.*, 2011) and the inverse probability weighted regression adjustment method (Chhay and Yamazaki, 2021). 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. 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. While we cannot rule out that other investments made at the same time as PRONER may have affected the promotion of women's empowerment, these investments were made independently, with no direct link to the electrification status of the localities.

As noted by Morgan and Winship (2014) and Chhay and Yamazaki (2021), 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 combined the Heckman selection bias correction (1979) with the IPWRA model to take into account the fact that working women may have particular characteristics that may lead to biased estimates.

The results show that PRONER has a pro-women employment effect 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.

Although the electrification programme does not specifically target women, this gendered effect of electrification has been documented in previous studies in developing countries (Emmanuel and Japhet, 2020; Osunmuyiwa and Ahlborg, 2019; Winther *et al.*, 2017; Grogan and Sadanand, 2013; Sovacool, 2012). For example, Grogan and Sadanand (2013) found that access to electricity increased the propensity of rural women to work outside the home by about 23%, but had no impact on male employment in Nicaragua. Estimating the impact of South Africa's national electrification program, Dinkelman (2011) found that women's employment increases in electrified areas at both the extensive and intensive margins while there are no significant male effects. One plausible channel is discussed in Dinkelman (2011): the electricity-induced labour saving change in home production would affect women's time allocation more than men. In such a context, women can transition from domestic (unpaid) work to paid work more quickly than men (Emmanuel and Japhet, 2020; Osunmuyiwa and Ahlborg, 2019). Sovacool (2012) also highlights that, in developing countries, women are by large the most vulnerable to energy scarcity and modern energy technologies helps improve women empowerment. This pathway would result in a higher impact of the reform on women's employment than on men's. For instance, PRONER reduces time spent on household chores activities that are mainly for women, creating therefore opportunities for formal paid employments.

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.

2. Context, definition of variables and data

2.1 Context

The PRONER is being carried out in a setting of poverty and gender inequality in Côte d'Ivoire. In fact, poverty reached 46.3% of the population in 2015 compared to 49% in 2008 (INS, 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%). 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 (INS, 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 period 2012–2014, more than 557 billion CFA (African Financial Community) 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 National Program for rural electrification *(PRONER)*

In terms of electrification, the key tool of the government is the PRONER adopted by the Council of Ministers on the 2nd of July 2013 in Korhogo. The first wave of PRONER began in 2013, but subsequent waves have continued later on. When the government's first social programme was presented in 2019, PRONER was officially introduced as one of the main programs with a focus on increasing the electrification of PRONER targeted localities. It 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. PRONER has seen acceleration under the PSgouv from 265 electrified localities over the period 2013–2018, to 919 localities electrified between 2019 and 2020 under the PSgouv.

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 conducted by the National Institute of Statistics (INS) and identified 8,518 eligible localities across Côte d'Ivoire. 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. It should be noted that, even if there are households with solar energy, they are negligible, especially in rural areas (the focus of our empirical analysis). According to the INS (2015), only 6.7% of rural households use solar energy or a generator. Indeed, the cost of accessing solar equipment is high for these mostly poor households. It is estimated at 195,000 FCFA (about 300 euros) for stand-alone solar kits (ECREEE, 2019) [2].

Local small- and medium-sized enterprises (SMEs) are prioritised for the execution of the works. With an estimated overall cost of US$1.4bn, 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 [3] 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 PRONER 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 HLSS conducted in 2015. The General Population and Housing Census 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 or enumeration areas (EAs) within the study strata; and in the second stage, by systematically drawing 12 households per EA.

The advantage of this survey 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 HLSS was not yet available at the time when the research was carried out). Furthermore, this survey includes the variables that allow to perceive the empowerment of women and to identify a number of PRONER-eligible localities. Another advantage of using the 2015 survey is that, given that the effective rolling out of electrification was at the end of 2013, we do not expect significant differences in terms of access to electricity by the sampled households in the targeted areas, thereby minimising the risk of heterogeneous exposure to the reform across individuals.

The supply of electricity is a state monopoly in Côte d'Ivoire. All the electrified localities identified in this study were electrified under the PRONER. The list was provided by the ministry in charge of energy in Cote d'Ivoire. Conversely, some households could have access to alternative sources of electricity such as solar energy. However, solar energy is very rare in Cote d'Ivoire and is not very accessible to rural households due to the high fixed costs of installation.

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 individual 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). 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 2015 round of HLSS [4], a national representative data set. Using this data, we undertook a rigorous mapping of the localities that have benefited from PRONER and of those that have not. To achieve this, it was necessary to identify among the localities of the 2015 HLSS, 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.

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). Table A2 in the appendices shows the distribution of localities from the 2015 ENV by administrative region.

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 h per week on agricultural activities, while women spend only 30 h. This finding remains the same when taking into account the status of electrification. Indeed, in electrified areas, men spend 38 h per week on agricultural activities, while women spend only 31 h.

In terms of time allocated to non-agricultural activities, men spend an average of 41 h per week on these activities, while women spend an average of only 31 h. This trend is consistent regardless of the status of electrification, with men spending an average of 42 h per week on these activities, compared to 35 h 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 h a week on household activities, men spend only 25 h. 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 h a week on household activities compared to only 26 h 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

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	3,051	–	921	2,974	–

Note(s): NB: ***Significance threshold at 1%. **Significance threshold at 5%. *Significance threshold at 10%
Source(s): Authors' calculations based on data from the 2015 HLSS

Table 1.
Description of the dependent variables

Variables	Obs	Av	Std. Dev	Min	Max	Av (treated)	Av (controls)	Avg. diff
Household characteristics								
Proportion of people with primary education	6,853	0.20	0.40	0	1	0.23	0.19	−0.04***
Average age in the household	7,942	40.56	10.58	18	64	40.74	40.50	−0.23
Number of women in the household	3,895	3.69	2.85	0	21	3.54	3.74	0.20**
Number of men in the household	4,047	3.21	2.38	0	20	2.91	3.31	0.39***
Household size	7,942	6.19	4.73	1	34	5.66	6.36	0.70***
Proportion of people in rural areas	7,942	0.90	0.30	0	1	0.83	0.92	0.09***
Proportion of people attending school	7,942	0.41	0.49	0	1	0.42	0.41	−0.01
Proportion of households using modern toilets	7,942	0.56	0.50	0	1	0.62	0.54	−0.08***
Number of children under five years old	8,808	1.57	1.70	0	10	2.13	6.68	−4.55***
Explanatory variables for the treatment								
Population of localities	8,815	18157.4	18172.45	0	92805.26	19245.81	17828.64	−417.17***
Distance of the localities from the national rural grid (in Km)	7,915	6.66	7.18	0.1	45	7.85	6.29	−1.56***

Note(s): NB: **, *** Significance threshold at 5 and 1% respectively
Obs.: Number of observations in terms of number of individuals
Source(s): Authors' calculations based on data from the 2015 HLSS

Table 2.
Descriptive statistics

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.

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 PRONER, 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.

3. Identification strategy

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

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

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). As such, our treatment variable captures both the direct (on individuals who have direct access to electricity) and indirect (on individuals who have not direct access to electricity, but who can nonetheless get benefit from higher opportunities created by electrifying a target community) effects. For this reason, β_1 identifies an intent-to-treat effect. 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 [5]. 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 IPWRA method to correct for treatment endogeneity (Chhay and Yamazaki, 2021). The treatment equation is defined as:

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

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 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, 2021). 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:

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

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.

4. 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.

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 h per week on non-agricultural activities compared to 31 h 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

	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]

Note(s): (...) 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
Source(s): Authors' estimates based on the 2015 HLSS

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

access to electricity leads to the emergence of non-agricultural activities in beneficiary localities (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 (Doss, 2013). 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 (Dinkelman, 2011; Burlig and Preonas, 2016; 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.

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

	Women			Men		
	OLS	IPWRA estimates (ATE)	IPWRA with correction for selection bias (ATE)	OLS	IPWRA estimates (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]

Note(s): (. . .) 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

Source(s): Authors' estimates based on the 2015 HLSS

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.

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.*, 2010).

5. 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 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 Côte d'Ivoire using data from the 2015 HLSS. We used an econometric strategy combining the 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 lightning 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 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 HLSS 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 this study, the 2018 HLSS database was not yet available.

As a limitation, it is important to note that these results were obtained in the specific context of PRONER in Côte d'Ivoire 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.

Notes

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).
2. Nonetheless, as a robustness check, we re-ran all the regressions by excluding the observations with access to solar panels and the results (available upon request) are qualitatively unchanged.
3. Coverage rate: The total number of electrified localities out of the total number of localities.
4. Unfortunately, the 2008 HLSS 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 HLSS database.
5. We cannot not rule out that the distance to a paved road may capture other investments or projects in the locality, including activities of non-governmental organisations or local actors. Unfortunately, data on the other projects in each locality were not available. However, it is important to note that PRONER is by far the most important government project in terms of budget invested in the beneficiary localities. In addition, discussions with PRONER actors also indicated that, for technical reasons, distance to the nearest paved road was one of the main criteria for the program implementation.

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Appendix

Table A1.
The description of the variables of interest by gender

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	–	4,469	4,339

Source(s): Authors' estimates based on the 2015 ENV

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(s): Authors based on data from the Ministry of the Interior

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

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