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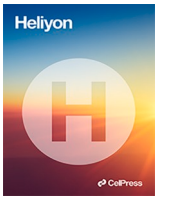

Research article

Does solar home system promote entrepreneurship in off-grid areas?

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ABSTRACT

In Côte d'Ivoire, only 31.3% of peoples living in rural areas have access to the grid electricity. With the potential of solar energy of the country, the solar home system provides a crucial alternative that is being exploited by households. This paper analyses the effect of the adoption of solar home system on entrepreneurship in off-grid areas using the data from the 2015's Living Standard Measurement Survey of Côte d'Ivoire. The estimates show that access to solar home system increases by 6.5% points the probability of engaging in entrepreneurial activities. This result holds for the trade, industry, and service sectors, while there is no evidence for the agricultural sector. Hence, the expansion of solar home system – as alternative to electricity grid in off-grid areas – has benefits for alleviating poverty via the promotion of entrepreneurship.

1. Introduction

The literature has highlighted the important role of access to electricity on poverty reduction and improvement of the quality of life [1–3]. Similar results have been found when analysing the use of solar home systems in off grid areas [4,5]. Several channels have been explored to explain those results, among which income plays an important role. In fact, access to electricity improves productivity at household level [2] and the lack of access to electricity makes it difficult to carry out any activity that requires the use of an electric device or equipment [3]. First, having access to electricity offers better income opportunities by allowing the development of new businesses and the extension of working hours [1]. Second, the use of electricity for business purposes can also promote entrepreneurship by shifting from agricultural to non-agricultural activities [6] especially in rural areas.

Although entrepreneurship is one channel through which access to electricity affects welfare, the relationship between electricity and entrepreneurship is not well studied in the literature.

Entrepreneurship is defined by Wennekers and Thurik [7] as "the manifest ability and willingness of individuals, on their own, in teams, within and outside existing organizations to perceive and create new economic opportunities (new products, new production methods, new organizational schemes, and new product–market combinations), and to introduce their ideas to the market in the face of uncertainty and other obstacles by making decisions on location, form and the use of resources and institutions". This definition points out two types of entrepreneurs: (i) the replicative and (ii) the innovative entrepreneur [8]. The replicative entrepreneurs are those who organise new business, without introducing a new product or process, nor a new organizational scheme; that constitutes the difference with the innovative entrepreneurs. Thus, an entrepreneur is an innovator who perceives profit opportunity and assumes the risk associated with uncertainty.

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Regardless the type of entrepreneur, entrepreneurial activities are important for economic growth. An increase in entrepreneurial activities prevalence rate is positively associated with an increase in economic growth [9]. Entrepreneurship has an impact on economic growth through innovation, profit opportunity perception and risk. Entrepreneurship mainly affect economic growth by introducing newness. Carree and Thurik [10] discuss the linkage between entrepreneurship and economic growth at the regional, industry, and country levels by putting emphasis on the fact that the decision for engaging in entrepreneurship is a result of (i) the search for reward to the efforts for innovation and risk taking, and (ii) the choice of entrepreneurship instead of employment. At the regional level, the literature highlights that the size of villages are the result of entrepreneurial decisions of key economic agents including property owners, farmers, and artisans [11]. The same holds for the location of the market town for a group of villages. Furthermore, entrepreneurship is key to explain the socioeconomic state [12] and the evolution of villages [13].

Access to electricity is key for launching entrepreneurial activities and for entrepreneurship development. As a production factor, electricity in general and rural electrification in particular is associated with an increase in working hours for entrepreneurs, especially for businesses located within households [14] and is associated with an increase in production in peak seasons. However, the effect of electricity can be lessened due to its quality [15]. For example, Moyo [16] shows that energy power outage has negative impact on firms' productivity, especially for small ones. Furthermore, the low energy power in some rural electrification settings constraints to the basic use, i.e., lighting, and thus can limit the gain from productive use of electricity [17]. The lack of access to electricity can also act as a barrier to entrepreneurship. In fact, not having access to electricity will constrain potential entrepreneurs from engaging in entrepreneurial activities that require electricity as production factor. As a result, rural electrification can promote entrepreneurship. For example, Peter et al. [18] show that rural electrification increases firm creation.

Rural electrification, through the extension of the electric grid is a challenging task [19] especially in the African context due to (i) its high cost, (ii) the limited production of electricity, and (iii) the low electricity transportation capacities. In sub-Saharan African countries, the electrification rate is very low (45.8% in 2018, far below the worldwide average that is 89.4%) and outages and unreliable connection characterise those households with access to electricity [20]. The situation in Côte d'Ivoire is quite similar, with an electrification rate of 68.6%. In rural areas in Côte d'Ivoire, only 31.3% of the population has access to electricity [4]. Therefore, the solar home systems offer a great alternative for rural electrification [21]. Javadi et al. [22] show that renewable energy sources are the best choice for rural electrification in sub-Saharan African countries. Furthermore, Grimm et al. [23] show that solar home system is the best approach for mass rural electrification.

The adoption of solar home system as alternative energy source to electricity grid has experienced a rapid growth in sub-Saharan Africa [20,21]. This rapid extension is due to several policies put in place to afford the financial cost of the solar technologies. In fact, the adoption and installation costs of solar home systems are high, and even if household in rural areas are willing to pay for electricity, their willingness to pay does not cover entry cost [23]. The policy measures implemented around the African continent include tax reduction on solar home systems equipment as well as the setting of business models for alleviating the financing barriers to the extension of solar home systems. Among these business models, fees for services and microcredits [24,25], tontines [26], and pay-as-you-go schemes [27] have been experienced and have proved their efficiency.

The analysis of the effects of the expansion of solar home systems on welfare has pointed out the income channel through which solar home systems affect welfare. One of the main arguments behind this channel is the implicit assumption that access to electricity has the same effect on entrepreneurship development whether it is through ordinary grid electricity or solar home systems. However, services level for solar home systems are low in comparison to the conventional grid connection [23]; even if the solar home system is moved to a solar mini-grid system [28]. Solar home systems are suited for lighting and basic home appliances that usually consume low power [29]; thus, few research papers find that solar home system and the conventional grid electricity result in a similar service level only for lighting and small appliances like television [30]. In addition, Stojanovski et al. [31] highlight that only few of solar home systems adopters use their solar home system for business purpose. These findings highlight that the transposition of the effect of grid electricity on entrepreneurship to that of the solar home system in off-grid areas should be questioned. Do access to solar home systems increases firm creation in off-grid areas?

This paper aims at shedding light on the effects of solar home systems on entrepreneurship in off-grid areas in Côte d'Ivoire. The paper uses the data from the national Living Standard Measurement Survey (LSMS 2015) of Côte d'Ivoire. It shows that access to solar home system increases by 6.5 points of percentage the probability to engage in entrepreneurial activities. Furthermore, a positive and significant effect is found when considering trade, industry, and service sectors while for the agricultural sector, there is no significant effect of access to solar home system on entrepreneurship. This is an important advocacy to implement policy for promoting solar home systems in off grid areas, and by this way, contributing to poverty alleviation.

The contribution of this paper is twofold. It provides a theoretical model that explains how solar home systems could affect entrepreneurship development in off-grid areas by accounting for both environmental and individual level variables and tests it empirically. Furthermore, an analysis of the extent to which the adoption of solar home system affects the engagement in entrepreneurship in each sector of activity.

The rest of the paper is organised as follows. Section 2 reviews the literature and Section 3 presents the theoretical model. Section 4 describes the empirical strategies and the data, while Section 5 presents the results. Section 6 concludes and provides the policy recommendations.

2. Literature review

The determinants of entrepreneurship can be divided into two main categories: the (i) individual determinants and (ii) business environment. Even if the literature was mainly focused on the individual determinants, Cuervo [32] argues that a better understanding

of the entrepreneurial activities must account simultaneously for both individual and environmental determinants.

At the individual level, the literature highlights the role of demographic variables including gender and age [33] with female being negatively associated with entrepreneurship. The effect of age on entrepreneurship can be negative [33] as well as positive [34]. Moreover, Reynolds et al. [35] establish an inverted U-shaped relationship between age and entrepreneurship, with the higher probability of being entrepreneur reaches between 25 and 34 years old. This inverted U-shaped relationship is due to the experience that increases the probability of being entrepreneur at the first time and the opportunity costs that decrease the probability to engaging in entrepreneurial activities above a certain age [9].

The effect of education is also controversial. Tunali and Sener [33] find that an increase in education is negatively associated with entrepreneurship. The rationale behind this result is that individuals with low education have lower skills and are thus less likely to get a salaried job. This negative association is especially pronounced for women and in poor countries [36]. Grilo and Thurik [34] show that individuals with low education levels are more likely to engage in entrepreneurship than those with medium education levels; however, in comparison to individuals with medium education level, those with high education might have higher or quite similar probability of engaging in entrepreneurship. This result is in line with the theoretical and empirical findings that state that higher education level is associated with an increased probability of engaging in entrepreneurial activities [9,37]. The rationale is that higher education is associated with a refinement of entrepreneurial judgment and can provide historical awareness about entrepreneurship.

Other important determinants of entrepreneurship at the individual level are income, access to finance, risk, and social interaction. Income and banking access are positively associated with the probability of being entrepreneur [33,38] since income might help lifting the barriers related to access to credit or financial support [9]. Others individual level determinants are related to risk aversion, perception on entrepreneurship, and knowing entrepreneurs [9,33].

Regarding business environment, the determinants of entrepreneurship include economic stability measured by inflation, tax rate and others administrative complexities, unemployment rate, size of the economy as well as economic growth, quality of infrastructures. Inflation rate is negatively associated with entrepreneurship [39] due to the high-risk environment it creates. The effect of taxation and more generally the fiscal system can be of two types. The fiscal system can be used as an incentive policy tool to promote entrepreneurship by reducing the taxes on capital gains, profits, and transfers [32]. However, tax rate appears to have a negative effect on entrepreneurship, since tax increases production cost [39]. Administrative complexities include institutional requirements to create business. These required procedures generate entry costs related to bureaucracy, intellectual property rights, low economic freedom, and even to corruption. As a result, in accordance with the theory of institution, the administrative complexities negatively affect the probability to engage in entrepreneurial activities [34,39,40]).

The effect of unemployment on entrepreneurship is nonlinear [40] and the explanation to this result is twofold. First, unemployment is positively associated with entrepreneurship since the lack of salaried job can constrain individuals to entrepreneurship (self-employment). Second, an increase in unemployment negatively affects entrepreneurship by causing a drop in markets, i.e., by reducing the demand faced by entrepreneurs. In addition, the stringency of the labour market law reduces the probability of entrepreneurship [38]. The complete analysis of this latter effect needs to consider the size of the economy and economic growth. In fact, the level of development can affect both the demand and supply sizes of the market. For poor economies, entrepreneurship offers an alternative to salaried jobs that are scarce [39]. However, economic growth is associated with increased wages that can move individuals into salaried jobs that become more attractive [41]. Economic development is also associated with the growth of the demand side of the market that can positively affect entrepreneurship.

Another important environmental determinant of entrepreneurship is the quality of infrastructures. The quality of infrastructures acts as a positive externality that promotes entrepreneurship [38]. Infrastructures include roads and transport for provisioning and getting access to markets, equipment for production, and energy or electricity particularly as production factor.

Access to electricity is required to any entrepreneurship development [42] and is shown to be positively correlated with entrepreneurship [43]. Especially in rural areas, Vernet et al. [44] show that rural electrification increases the rate of creation of micro-business, confirming the findings by Bastakoti [45]. Two main channels can be invoked: the first is related to the use of electricity as production factor, while the second is related to the business opportunity in the energy sector in off grid areas. On the first hand, electricity is combined, as production factor, with labour and capital in the production system at firm level [2,3,43]. Thus, the lack of access to electricity can prevent engaging in some entrepreneurial activities, particularly those that require electricity as a complementary production factor. On the second hand, the need for procurement of solar home systems in off grid areas is likely to promote entrepreneurship in the industry sector [46]. Furthermore, the installation of solar home systems is key in creating a large photovoltaic service market [47].

3. Theoretical model

Let e denotes the entrepreneurship decision and let us consider an individual who have to choose between being an entrepreneur ($e = 1$) or a salaried worker ($e = 0$). A salaried worker received a wage ω_t per unit time worked at period t while the entrepreneur generates a profit by combining production factors and its entrepreneurial abilities γ_t at period t to produce a good. Let assume that the good is produced using the production function F and has a price that is equal to 1 and let π_t denotes the profit. Then, if c_t denotes the cost function at period t, the profit π_t is given by:

$$\pi_t = F(\gamma_t, l_t, E) - c_t \tag{1}$$

where E is the dummy variable for the adoption of solar home system that is equal to 1 if the individual has access to solar home system

and 0 otherwise, l_t is the working time. The rationale for the inclusion of access to solar home system (E) as factor of production is that energy can be used in a productive manner by households since several production processes are related to it [3].

The revenue from job status at period t is then given by

$$e\pi_t + (1-e)\omega_t l_t \tag{2}$$

Let x denotes the aggregate consumption at the individual level and r the interest rate, the dynamics of the individual wealth is given by:

$$I_{t+1} = (1+r_t)(I_t + e(F(\gamma_t, l_t, E) - c_t) + (1-e)\omega_t l_t - x_t) \tag{3}$$

The decision to be entrepreneur is taken in a multi-stage decision making scheme where each individual account for the future flows of utility generated by his current decision. Let u denotes the individual utility function, a Cobb-Douglas utility function, that depends on the aggregate consumption and the leisure time $1 - l_t$ considering that the total time, i.e., leisure plus work sums to one.

$$u(x_t, l_t) = \frac{1}{\eta} x_t^{\eta} \frac{1}{\mu} (1-l_t)^{\mu} \tag{4}$$

The lifetime utility of the representative individual is given by:

$$\begin{cases} \max\limits_{x_t, l_t} \left\{ U = \sum\limits_{t=0}^{\infty} \theta^t u(x_t, l_t) \right\} \\ s.t. \quad I_{t+1} = (1+r_t)(I_t + e(F(\gamma_t, l_t, E) - c_t) + (1-e)\omega_t l_t - x_t) \geq 0 \end{cases} \tag{5}$$

Where $\theta \varepsilon]0;1[$ is the discount factor. The Lagrangian of this problem is given by:

$$\mathscr{L} = \sum_{t=0}^{\infty} \theta^t [u(x_t, l_t) + \lambda_t \{(1+r_t)(I_t + e(F(\gamma_t, l_t, E) - c_t) + (1-e)\omega_t l_t - x_t) - I_{t+1}\}] \tag{6}$$

The first order conditions of this problem are given by:

$$\begin{cases} \dfrac{\partial \mathscr{L}}{\partial x_t} = x_t^{\eta-1} \dfrac{1}{\mu} (1-l_t)^{\mu} - \lambda_t (1+r_t) = 0 \\ \dfrac{\partial \mathscr{L}}{\partial l_t} = -\dfrac{1}{\eta} x_t^{\eta} (1-l_t)^{\mu-1} + \lambda_t (1+r_t) \left[e \dfrac{\partial F}{\partial l} (\gamma_t, l_t, E) + (1-e)\omega_t \right] = 0 \end{cases} \tag{7}$$

From these first order conditions, it follows that:

$$x_t = \frac{\eta}{\mu} (1-l_t) \left(\omega_t + e \left[\frac{\partial F}{\partial l} (\gamma_t, l_t, E) - \omega_t \right] \right) \tag{8}$$

Therefore, by reintroducing this equation in the constraint equation, the optimal control functions at a period t are the given by: $\widehat{x}_t = x_t(e, I_t, \gamma_t, \omega_t, E)$ and $\widehat{l}_t = l_t(e, I_t, \gamma_t, \omega_t, E)$. Then, the lifetime utility function is given by $U = \widehat{U}(e, I_0, \gamma_0, \omega_0, E)$.

The decision to enter in entrepreneurship is the one that maximises the lifetime utility function for a given E and I_0. Thus,

$$\widehat{e}(I_0, \gamma_0, E) = \underset{e}{\text{Argmax}} \{ \widehat{U}(e, I_0, \gamma_0, \omega_0, E) \} \tag{9}$$

This decision depends on the access to solar home system, the entrepreneurial abilities, and the average wage. In fact, if it is used in a productive manner, access to solar home system (E) is expected to increase the probability of engaging in entrepreneurship. The current wage rate (ω_0) is expected to decrease the probability of engaging in entrepreneurship by shifting individuals to salaried job. The entrepreneurial abilities, i.e., γ_0 are expected to be positively associated with the probability of being entrepreneur.

In this paper, I aim at testing the main relationships discussed in the literature review. Due to data availability, only few of these relationships are tested. At the individual level, the hypothesis of an inverted U-shaped relationship between age as well as education and entrepreneurship will be tested. Education is used as the main proxy for entrepreneurial abilities [9,37]. Another proxy for abilities can be the individual's age since it could help capturing the experience [9]. I also test the gender-entrepreneurship nexus.

In terms of business environment variables, the hypothesis of non-linearity of the effects of unemployment on entrepreneurship will be tested by including an interaction term to capture a U-shaped relationship, i.e., the inclusion of unemployment rate and its square in the model. In fact, high unemployment rate can constrain individual to engage in entrepreneurial activities while to some extent, unemployment can cause market drop at the demand side that could negatively affect entrepreneurial activities [40]. In addition, the hypothesis of a negative effect of inflation on entrepreneurship will also be tested. In fact, a high inflation rate creates a risky business environment that can prevent from engaging in entrepreneurial activities [39].

4. Empirical strategies

4.1. Data

The dataset used in this paper is a subset of the National Living Standard Measurement Survey (LSMS-2015) of Côte d'Ivoire. The LSMS is a nationally representative survey, with 12,899 households surveyed, that consists of a two-stage stratified random survey in which the stratification variable is the administrative regions. At the first level 1075 enumeration blocks are randomly selected in each stratum; the number of enumeration block is proportional to the population size of each stratum. At the second level, 12 households are randomly selected in each enumeration block drawn at the first level.

Since I am interested in the off grid rural areas, I extract the subsample of households surveyed in those areas. Then, the subsample consists of 128 villages that are off grid from which 2747 households were surveyed. At the individual level, the sample of interest consists of 3181 individuals aged between 15 and 64 and are employees or entrepreneurs.

The survey provides information on entrepreneurial activities including the ownership, the age of the firm, and other characteristics. It also includes sociodemographic variables measured at the individual level, namely age, gender, year of education, as well as some characteristics measured at household's level.

It is important to notice that the dataset used herein is a cross sectional data, i.e., it does not include a time dimension (time series or panel data). Therefore, it does not allow to analyse the dynamic of the relationship between access to solar home systems and entrepreneurship. Furthermore, access to SHS is observed from the sample as a one-point situation since the dataset used is a cross sectional data. This implies that the analysis conducted herein cannot account for the price of the setup of the solar home system and the extent to which individuals can alleviate the constraints to adoption of the solar home system.

4.2. Definition of variables

The outcome of interest of this paper is the status of entrepreneur. It is a dummy variable that takes the value 1 if the individual is engaged an entrepreneurial activity, i.e., an individual who is self-employed and owns a firm that is managed and organised by himself. Entrepreneurial activities considered herein include non-farming activities that consists of production or sale of goods or services that provides regular income to its owner. Another categorical variable is the sector of activity to which the entrepreneur belongs. The sector of activity includes agriculture, industry, trade, and service.

The main determinant is the dummy variable for access to solar home system. Since I consider off grid areas, this dummy variable takes the value 1 if the individual has access to solar home system and 0 for other sources of lighting, including battery torch, oil lamps, and others basic lighting sources. Individual characteristics included as controls in this paper are the following. There are two gender categories considered, 1 for female and 0 for male. Age is measured in years as a continuous variable. Education level is measured in terms of number of education years completed as a continuous variable. The linkage with the household's head is a categorical variable that takes three possible values, including head of household, spouse, and other related.

Business environment variables like the unemployment rate and the regional average wage are computed using the data from the LSMS. The unemployment rate is computed using the definition of unemployment by the International Labour Organisation (ILO). From this definition, the unemployed are all persons of working age who were: (i) without work during the reference period, (ii) currently available for work, and (iii) seeking work. The regional average wage is the weighted average wage regardless of the sector of activity, the education level, and the job seniority. The last business environment variable considered in this paper is the regional inflation rate that is provided by the national statistics office. This regional inflation rate is expressed in percentage of the inflation rate of the capital of the country, i.e., Abidjan. All the business environment variables are measured as continuous variables.

4.3. Econometric settings

I point out in Section 3 that the decision to enter in entrepreneurship depends on individual abilities, the adoption of solar home system and income level at the period the choice should be made. Following this theoretical result, I specify the equation below.

$$\begin{cases} e_i^* = \beta_0 + \beta_1 E_i + X_i\beta + \varepsilon_{1i} \\ e_i = \mathbb{I}_{e_i^*>0} \end{cases} \tag{10}$$

where e_i takes 1 if the individual is an entrepreneur and 0 otherwise, E_i is 1 if the individual is a solar home system adopter and 0 otherwise. The vector X_i includes variables two types of variables namely the individual characteristics and the business environment variables. The individual characteristics included in the regression are age, gender, education level, and the link with the household's head. The business environment variables are the regional unemployment rate, the regional average wage, and the regional inflation rate measured in percentage of the inflation rate in the capital of the country.

However, individual abilities that account for entering entrepreneurship are also determinant for the adoption of solar home system. In such a context, the adoption of solar home system might be endogenous in this model. For this purpose, I specify a system of equations.

The model is specified as follows:

$$\begin{cases} e_i^* = \beta_0 + \beta_1 E_i + X_i\beta + \varepsilon_{1i} \\ E_i^* = \alpha_0 + Z_i\alpha + \varepsilon_{2i} \\ e_i = \mathbb{I}_{e_i^*>0}; E_i = \mathbb{I}_{E_i^*>0} \end{cases} \tag{11}$$

Where the vector of error terms are:

$$\begin{pmatrix} \varepsilon_{1i} \\ \varepsilon_{2i} \end{pmatrix} \sim \mathcal{N}\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}; \begin{pmatrix} 1 & \rho \\ \rho & 1 \end{pmatrix}\right) \tag{12}$$

Since the decision of adoption of the solar home system is a household's level decision, the vector of explanatory variables Z_i includes, in addition to the individual characteristics, the traditional determinants of solar home system adoption that are related to household and its head characteristics, namely household's head age, gender, years of education, the possession of agricultural land, and the type of roof used by the household.

To ensure the identifiability of the equations, some exclusion restrictions are needed. These are variables that are used as instrumental variables in each equation. As Diallo and Moussa [4]; I use the proportion of households with access to the conventional electricity grid in the region is used as exclusion restriction variable in the equation of the adoption of solar home system.

A test of exogeneity is conducted following the procedure by Lollivier [48,49] in which the null hypothesis of $\rho = 0$ implies exogeneity. If the hypothesis of exogeneity is not rejected, then the entrepreneurship equation can be estimated separately, and the results are not subject to bias due to endogeneity. Then, since the aim of the paper is the effects of solar home system on entrepreneurship, in such a situation, the equation of entrepreneurship is estimated. This equation corresponds to:

$$\begin{cases} e_i^* = \beta_0 + \beta_1 E_i + X_i\beta + \varepsilon_{1i} \\ e_i = \mathbb{I}_{e_i^*>0} \end{cases} \tag{13}$$

The specified model is estimated using a full information maximum likelihood procedure and the test for exogeneity are conducted within this framework. As for robustness check, the results obtained using the limited information maximum likelihood approach are also provided.

5. Results

This section provides the description of the sample with respect to the entrepreneurship status and the solar home system adopter status. It also provides the differences between entrepreneurs and non-entrepreneurs according to the key characteristics identified from the literature. The section ends with an analysis of the determinants of the entrepreneurship.

5.1. Characteristics of the sample

Table 1 provides the distribution of the sample by entrepreneurship status and sector of activity for entrepreneurs. I consider four sectors of activity that are agriculture, trade, industry, and service following the International Standard Industrial Classification of All Economic Activities (ISIC). It appears that only 15.6% of the sample are entrepreneurs. The entrepreneurs are mainly (8.9% on the sample) engaged in trade activities while only few of them are engaged in the sector of services (1.4%).

Table 2 below provides comparison tests between solar home system adopters and those who do not adopt its according to their characteristics and their entrepreneurship status. There is a weakly significant difference between the proportion of entrepreneurs among SHS adopters (19.65%) and non-adopters (15.02%). Also, the SHS adopters are younger (aged 34.9 in average) than non-adopters (aged 36.3 in average) and the proportion of female among SHS adopters (30.9%) is lower than that observed among non-adopters (36.9%). However, no significant difference is observed between SHS adopters and non-adopters in terms of education and other characteristics included.

Table 6 in appendices provides statistics on individual characteristics by entrepreneurship status as well as comparison tests between entrepreneurs and non-entrepreneurs.

Table 1
Type of entrepreneurial activity.

Type of activity	Proportion (se)
Not entrepreneur	0.8440 (0.0079)
Entrepreneur	0.1560 (0.0079)
Agriculture related	0.0268 (0.0034)
Trade	0.0893 (0.0065)
Industry	0.0259 (0.0033)
Service	0.0140 (0.0026)

Cluster robust standard errors are in parenthesis.
Source: Author' calculation using data from LSMS 2015.

Table 2
Comparison tests between SHS users and non SHS users.

Variables	Access to SHS	No access to SHS	Difference
Entrepreneurs	0.1965 (0.0228)	0.1502 (0.0084)	0.0463* (0.0243)
Age	34.91 (0.64)	36.27 (0.36)	−1.36* (0.73)
Gender (female)	0.3092 (0.0256)	0.3690 (0.0096)	−0.0598** (0.0273)
Years of education	1.8494 (0.2219)	1.4683 (0.0794)	0.3811 (0.2357)
Not educated	0.7379 (0.0304)	0.7698 (0.0107)	−0.0319 (0.0323)
Head of household	0.6141 (0.0270)	0.6298 (0.0097)	−0.0157 (0.0287)
Spouse	0.2478 (0.0218)	0.2476 (0.0085)	0.0002 (0.0234)
Other related	0.1381 (0.0260)	0.1226 (0.0082)	0.0154 (0.0272)

Cluster robust standard errors are in parenthesis.
*** significant at 1% level, ** significant at 5% level, * significant at 10% level.
Source: Author' calculation using data from LSMS 2015.

In terms of rate of adoption of the solar home system, it appears that 12.7% of individuals in the sample belong to a household with access to solar home system. This proportion is 16.0% among entrepreneurs and 12.1% among non-entrepreneurs. However, this difference is statistically significant only at 10% level.

While analysing the individual characteristics, it follows that in comparison to non-entrepreneurs, the entrepreneurs are older (aged 39) mainly female (52.9%) and spouse of the household' head (32.5%). The statistical comparison tests do not show any significant difference at 10% level between entrepreneurs and non-entrepreneurs in terms of years of education. The average years of education in the sample is very low (1.5) with more than three out of four (76.6%) of surveyed people that are not educated. The household heads are equally engaged in entrepreneurial activities, with 62.6% among entrepreneurs and 62.8% among non-entrepreneurs.

The business environment variables, that are not specific to entrepreneurship status, are varying across regions (see Table 3). The average wage at the regional level is XOF 284,910 (i.e., 434.34 euros) and exhibits important variations, from a minimum of XOF 110,727 to a maximum of XOF 584,051. The unemployment rate is 5.1% in average and reaches a maximum of 13.5%. The inflation rate in percentage of the inflation rate of the capital of the country is 85.78% in average and it varies between 77.48% and 94.27%.

6. Estimation results and discussions

I first analyse the determinants of entrepreneurship with a focus on the role of solar home system, regardless the type of entrepreneurial activity. To provide further insights for policy making, I also analyse the determinants of entrepreneurship in each of the four main sector of activity, namely agriculture, industry, service, and trade.

As discuss in Section 4, the adoption of the solar home system may be endogenous. I test for the exogeneity of the solar home system in the equation of entrepreneurship using both limited and full information maximum likelihood procedures. The two tests of exogeneity presented in Table 7 inappendix conclude to the non-rejection of the hypothesis of exogeneity; thus, the solar home system variable is not endogenous. Therefore, the results of the binary probit model for the overall analysis and the multivariate probit model for the analysis by sector are presented. These models are globally significant at one percent level.

6.1. Determinants of entrepreneurship: overall analysis

The estimated results (see Table 4 below) show that the use of solar home system promotes entrepreneurship in rural off grid areas in Côte d'Ivoire. The adoption of solar home system increases the entrepreneurship by 6.5% points. This result is consistent with the literature on the effect of (the conventional grid) electricity on entrepreneurship [14,18,44,45]. Thus, even if the level of service provided by solar home systems is relatively low compared to the grid connection and even if very few solar home system adopters use their solar home system for business purposes, the adoption of this energy source has a positive impact on micro firm creation. In fact, solar home systems are expected to provide power to small businesses [29] and allow individuals to engage in additional activities by increasing their business hours. This finding confirms that the channel of income through the creation of new business holds when analysing the effects of solar home system of welfare. This is an important contribution to the growing literature on the welfare effects of solar home system.

The estimates also confirm the inverted U-shaped effect of age on entrepreneurship usually found in the literature [9,35]. The estimated age at which the probability of being entrepreneur decreases is 61.7.[1] However, contrarily to the common findings in the literature, the estimates show that being female increases the probability of entrepreneurship. This result is in line with the fact that the largest part of entrepreneurs is involved in trade sector that is a sector commonly devoted to females in rural areas.

I did not find a nonlinear effect of the years of education. However, a unit increase in the years of education is associated with an increase of the probability of entrepreneurship by 1.2% points. This result is in line with the literature that states that an increase in

[1] The threshold for age is found by dividing the opposite of the coefficient of age by twice the coefficient of the square of the age, i.e. $-0.037/(2^{*}-0.0003) = 61.67$. Notice that age varies between 14- and 86-years olds in our sample.

Table 3
Descriptive statistics on the sample.

Variables	Overall	Standard error	Minimum	Maximum
Solar home system user (1 = yes, 0 = no)	0.1271	0.0103	0	1
Entrepreneurs (1 = yes, 0 = no)	0.1561	0.0079	0	1
Individual characteristics				
Age	36.10	0.3241	14	86
Gender (1 = female, 0 = male)	0.3614	0.0090	0	1
Years of education	1.5167	0.0750	0	16
Not educated (1 = yes, 0 = no)	0.7658	0.0131	0	1
Head of household (1 = yes, 0 = no)	0.6278	0.0092	0	1
Spouse (1 = yes, 0 = no)	0.2476	0.0079	0	1
Other related (1 = yes, 0 = no)	0.1246	0.0079	0	1
Environmental variables				
Wage (x 1000 XOF)	284.91	17.52	110.73	584.05
Unemployment rate	5.13	0.64	0.1	13.49
Inflation rate	85.78	0.82	77.48	94.27

Source: Author' calculation using data from LSMS 2015

Table 4
Estimated effects of SHS on entrepreneurship.

Variables	Coefficient (se)	Marginal effect (se)
Solar home system	0.2682** (0.0940)	0.0652** (0.0247)
Individual characteristics		
Age	0.0370** (0.0144)	0.0024*** (0.0006)
Age squared	−0.0003** (0.0002)	
Gender (ref = male)	0.7801*** (0.1122)	0.1910*** (0.0297)
Years of education	0.0681** (0.0339)	0.0116** (0.0054)
Years of education squared	−0.0051 (0.0032)	
Link (ref = head)		
Spouse	−0.3856** (0.1251)	−0.0832** (0.0252)
Other	−0.6109*** (0.1435)	−0.1184*** (0.0229)
Environmental characteristics		
Unemployment rate	−0.0498 (0.0309)	−0.0061* (0.0034)
Unemployment rate squared	0.0027 (0.0029)	
Regional average wage	−0.0015*** (0.0004)	−0.0003*** (0.0001)
Regional inflation rate	−0.0293*** (0.0083)	−0.0065*** (0.0018)
Intercept	0.9886 (0.7715)	
Log pseudolikelihood	−519,516.91	
Wald statistics (p-value)	128.42 (<0.001)	
Pseudo R2	0.0705	

Cluster robust standard errors are in parenthesis.
*** significant at 1% level, ** significant at 5% level, * significant at 10% level.
Source: Author' calculation using data from LSMS 2015.

education level is positively associated with entrepreneurship [9,37]. In comparison with the household's head, the spouses and the other related are less likely to engage in entrepreneurship.

While analysing the environmental variables, I find no effect even linear or nonlinear of unemployment rate on entrepreneurship. However, as expected, an increase in the regional inflation rate reduces the probability of engaging in entrepreneurship. This result confirms the common finding in the literature that highlight the negative effects of inflation on entrepreneurship [39]. The same type of result is found for the regional average wage, i.e., an increase in the regional average wage reduces the probability of engaging in entrepreneurship. This implies that an increase in the regional average wage leads to an increase in the salaried job that can switch individuals from entrepreneurship to salaried jobs [41].

6.2. Determinants of entrepreneurship: analysis by activity sector

The analysis of the determinants of engaging in entrepreneurship by sector of activity (see Table 5 below) confirms that the access to solar home system promotes entrepreneurship in all the activity sectors apart from the agricultural sector. This result can be explained by the fact that, contrarily to the other sectors, the agricultural sector is lowly mechanised and mainly undertaken during days. As a result, in the agricultural sector there is no need for energy as input or for lighting in this sector. This includes the

Table 5
Estimated effects of SHS on entrepreneurship activities by sector.

Variables	Agriculture	Trade	Industry	Services
SHS	−0.1037 (0.2101)	0.4226** (0.1551)	0.4406** (0.1886)	0.5186** (0.2572)
Individual characteristics				
Age	0.0411 (0.0275)	0.0472* (0.0242)	0.0876** (0.0334)	0.0464 (0.0384)
age squared	−0.0003 (0.0003)	−0.0004 (0.0003)	−0.0011** (0.0004)	−0.0006 (0.0004)
gender (female)	0.1975 (0.2065)	1.3363*** (0.1798)	0.6417** (0.2425)	1.0055*** (0.2459)
Years of education	0.0839 (0.0719)	0.1655** (0.0571)	−0.0441 (0.0706)	0.0429 (0.0767)
Years of education squared	−0.0088 (0.0066)	−0.0146** (0.0057)	0.0049 (0.0063)	−0.0001 (0.0070)
Link (ref = head)				
Spouse	−0.3483 (0.2309)	−0.4383** (0.1951)	−0.3839 (0.2769)	−0.9631** (0.2967)
Other	−1.2445** (0.4482)	−0.5726** (0.2270)	−1.1661** (0.3948)	−0.9982* (0.5521)
Environmental characteristics				
Unemployment rate	−0.1335* (0.0653)	−0.0844 (0.0522)	−0.0466 (0.0679)	0.2710** (0.1140)
Unemployment rate squared	0.0064 (0.0068)	0.0039 (0.0050)	0.0050 (0.0061)	−0.0186* (0.0104)
Regional average wage	−0.0011 (0.0008)	−0.0022** (0.0007)	−0.0029** (0.0001)	0.0008 (0.0012)
Regional inflation rate	−0.0483*** (0.0162)	−0.0228* (0.0137)	−0.0664*** (0.0180)	−0.0244 (0.0231)
Intercept	1.2812 (1.4461)	−0.6128 (1.2740)	2.3107 (1.7344)	−2.8023 (2.0874)
Log pseudolikelihood	−721,160			
Wald statistics (p-value)	224.24 (<0.001)			

Clustered standard errors are in parenthesis. *** significant at 1% level, ** significant at 5% level, * significant at 10% level. The reference category for the multivariate probit model is the "non entrepreneur" category.
Source: Author' calculation using data from LSMS 2015.

development of trade businesses on the roadside [29] especially by night and as a secondary activity, as well as service provision including activity like charging battery for other [31] or other businesses related to the supply and the maintenance of solar home systems equipment.

The nonlinearity of the years of education is confirmed only for the trade sector. This result implies that individuals with low or high years of education are less likely to engage in entrepreneurial activities in the trade sector.

I find an inverted U-shape relationship for age only for engaging in entrepreneurship in the industry sector and a positive linear effect of age on entrepreneurship in the trade sector. These results imply that as age increases, the probability of engaging in entrepreneurship in the trade sector increases. The age at which the probability of entrepreneurship in the industry sector starts to decrease is estimated at 39.8, that is earlier than the threshold age found in the full sample. However, this threshold age is in line with the findings of Reynolds et al. [35].

Even if the regional unemployment rate is not associated with entrepreneurship in general and in the trade and industry sectors, I find an inverted U-shaped relationship between unemployment rate and the probability of engaging in entrepreneurship in the service sector with a threshold at 7.3%.[2] This result implies that an increase in unemployment rate up to 7.3% is associated with an increase in the probability of engaging in entrepreneurship in the service sector. This result is in line with the literature [39] and implies that when salaried jobs are scarce, individuals are constrained to engaging in entrepreneurial activities. Above 7.3%, an increase in the unemployment rate is negatively associated with the probability of engaging in entrepreneurship in the service sector [39]. It means that the high unemployment rate reduces the demand that entrepreneurs can face, and thus, reduces the probability of engaging in the service sector. I also find that an increase in the regional unemployment rate decreases the probability of engaging in the agricultural sector.

The negative effect of the regional inflation rate on the probability of engaging in entrepreneurship is confirmed for all sectors apart from the service sector. In fact, inflation creates a risky environment that acts as a barrier for engaging in entrepreneurship [39]. The negative effect of the regional average wage on the probability of engaging in entrepreneurship is only confirmed for the trade and industry sectors. As expected, an increase in the wage level makes salaried jobs more attractive, thus it reduces the probability of engaging in entrepreneurial activities [41].

7. Conclusion

This aim of this paper is to analyse the effects of solar home system on entrepreneurship in off-grid areas. It specifies a theoretical model that aims at explaining the choice made by individual on the job market in those areas. This model highlights the role of solar home system, individual entrepreneurial abilities, as well as the wage rate on the decision to engage in entrepreneurship.

The empirical analysis of the role of solar home system is conducted using data from the 2015 living standard measurement survey of Côte d'Ivoire. By estimating a binary probit model and a multivariate probit model, I show that solar home system promotes entrepreneurship in off grid areas in Côte d'Ivoire. The access to solar home system increases by 6.5 points of percentage the

[2] The threshold for unemployment rate is found by dividing the opposite of the coefficient of unemployment rate by twice the coefficient of the square of the unemployment rate, i.e. $-0.027/(2^{*}-0.0186)=7.3$. Notice that unemployment rate varies between 0.1 and 13.49% in our sample.

probability of engaging in entrepreneurship. Furthermore, the positive effect of solar home system on entrepreneurship is confirmed for the sectors of trade, industry, and service while for the agricultural sector, no significant effect is found. These results imply that even if solar home system has relative low range of usage due to its suitability to low power consumption appliance and even if few of the solar home system adopters use their solar home system for business purposes, it has a positive impact on micro firm creation especially in trade, industry and service sectors.

These results call for implementing policies to accompanying the diffusion of solar home system in off-grid areas in Côte d'Ivoire. This might include the alleviation of tax rate on technologies for the use of solar home system as well as subsidies that could afford the initial capital investment necessary for solar home system. It might also include free distribution of equipment related to solar home system. However, such a policy implication will require further analysis to consider all the possibilities while designing these policies. Those analysis might include the setup of a panel data to analyse the dynamic of the relationship between adoption of solar home system and entrepreneurship and to assess entirely the reverse causality. Further analysis might include cost effectiveness analysis of tax alleviation or subsidies policy for affording the initial capital investment constraint.

Declarations

Author contribution statement

Richard K. Moussa, Ph.D.: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data will be made available on request.

Declaration of interest's statement

The authors declare no competing interests.

Additional information

No additional information is available for this paper.

Appendices.

Table 6
Comparison tests between entrepreneurs and non-entrepreneurs

Variables	Entrepreneur	Non entrepreneur	Difference
Solar home system user	0.1601 (0.0213)	0.1210 (0.0104)	0.0391* (0.0207)
Age	39.03 (0.74)	35.56 (0.35)	3.47*** (0.82)
Gender (female)	0.5288 (0.0280)	0.3305 (0.0102)	0.1983*** (0.0315)
Years of education	1.5721 (0.1941)	1.5065 (0.0807)	0.2090 (0.2135)
Not educated	0.7515 (0.0254)	0.7684 (0.0109)	−0.0169 (0.0273)
Head of household	0.6260 (0.0261)	0.6281 (0.0106)	−0.0021 (0.0299)
Spouse	0.3248 (0.0259)	0.2333 (0.0091)	0.0915** (0.0291)
Other related	0.0492 (0.0113)	0.1385 (0.0091)	−0.0893*** (0.0146)

Cluster robust standard errors are in parenthesis.
*** significant at 1% level, ** significant at 5% level, * significant at 10% level.
Source: Author' calculation using data from LSMS 2015.

Table 7
Tests of exogeneity.

Type of model	Wald statistics	p-value
Limited information maximum likelihood estimator (instrumental variable approach)	1.18	0.2774
Full information maximum likelihood estimator (equations system approach)	0.3416	0.5589

Source: Author' calculation using data from LSMS 2015.

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