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WORKING PAPER

Pay-as-you-go contracts for electricity access: bridging the "last mile" gap? A case study in Benin

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We analyze pay-as-you-go (PAYG) contracts subscribed by 10,120 consumers living in Benin (Sub-Saharan Africa) to purchase solar kits or panels for lighting and charging services. PAYG are flexible loans that allow fees payment through mobile banking. Most of the PAYG consumers live in well electrified areas (Cotonou, Porto Novo, Abomey Calavi, in the coastal zone). By estimating a very simple multinomial logit model, we find that these customers have a high probability to enroll in PAYG contracts. Living in urban and peri-urban areas, they use solar devices to substitute expensive and often unreliable grid electricity services. Consumers located in more periferic and less electrified areas (Savalou) have a low probability to default, as the substitution effect is weaker. Overall, in our case study, PAYG targets credit worthy consumers, in order to decrease the investment risk of the company providing solar devices. These results cast some doubts as to whether PAYG bridges the "last mile" electrification gap.

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1 Introduction

Access to a reliable and affordable energy is a prerequisite for any industrial development (Eberhard et al., 2011) and economic growth (Louw et al., 2008). Yet, approximately 1.06 billion people (about 14% of the global population) live without electricity and an additional one billion are under-electrified, a status characterized by unstable grid connection with regular power outages.[1] The Africa Energy Outlook (IAE, 2019) points out that Africa is the continent most in need of a significant scale-up in electricity generation and grid investment, for which it currently ranks among the lowest in the world. Despite being home to 17% of the world's population, Africa currently accounts for just 4% of global power supply investment. Achieving reliable electricity supply for all would require an almost fourfold increase, to around USD 120 billion a year through 2040.

According to the World Bank's Energy Sector Management Assistance Program (ESMAP), access to electricity is not a binary variable, but it rather refers to the ability to obtain electricity that is characterized by the following attributes: "adequate, available when needed, reliable, of good quality, affordable, legal, convenient, healthy and safe for all required applications across households, productive enterprises and community institutions "(Bhatia and Angelou, 2015). The ESMAP framework measures electricity access across five Tiers ranked by increasing availability of electricity usages, spanning from basic lighting to 23 hours of uninterrupted electricity services. In this paper we focus on accessing Tier 1 and Tier 2 electricity capacity levels. At Tier 1 level (3W), electricity access is defined as providing lighting and mobile charging for a minimum of four hours per day. At Tier 2 level (50W), access additionally includes the ability to power a fan and/or television for four hours. Distributed renewables for energy access (DREA) systems are increasingly being considered as a solution to electrification through the deployment of renewable-based mini-grids and off-grid solar systems. DREA are so far the most significant technology in the sector, providing electricity access to more than 360 million people worldwide (Sawin et al., 2018).

We study the case of Benin, located in Sub-Saharan Africa. The country has a 121-kilometer-long coastline on the Gulf of Guinea and a population of 11.2 million.[2] Benin has recently been carrying out key economic and structural reforms, among which ambitious programs for expanding electricity access. To overcome a situation where around 30% of the population is electrified, the Government has launched several initiatives, including intensive deployment of renewable energy. Therefore, Benin provides an interesting case study to analyze DREA deployment.

Our study provides evidence on a specific financial service easing electricity access, namely

[1] A.T. Kearney, and GOGLA (Global Off-Grid Lighting Association). 2014. Investment and Finance Study for Off-Grid Lighting. Retrieved from GOGLA website: http://global-off-grid-lighting-association.org/wp-content/uploads/2013/09/A-T-Kearney-GOGLA.pdf.

[2] https://www.worldbank.org/en/country/benin, accessed March 2019.

the pay-as-you-go (PAYG) contract. PAYG is a technology-driven method that allows consumers to get a stand-alone electricity system by paying loan fees and using mobile banking. More precisely, the installed devices (solar kits or panels) use information technology to enable remote activation with payment receipt or disconnection in case of failure. The PAYG service is more flexible than a standard microcredit as no guarantees are demanded. Combining PAYG financing with digital payments has been a boon for the sector: a mobile banking account and an ID card and a pre-payment of the 10-20% of the total equipment price suffice to subscribe a contract. The insurance comes from the machine-to-machine technology. The key success factor of PAYG is then the financial inclusion of consumers, through flexible payment methods, which ensures electricity providers to repay kits or solar home systems (SHS)[3] investments at low transaction costs.

Investment in PAYG in Africa and Asia has been estimated at USD 263 million in 2017 with a 1,400% increase over the period 2013-2017 (REN21, 2018). According to Gogla (2019), in 2018 PAYG has reached its greatest volumes ever recorded, at 1 million units with a value of USD 216.85 million. PAYG-based plug-and-play solar solutions spread at an average annual growth rate of 140% between 2013 and 2016. The sector is estimated to exceed USD 20 million in annual sales and to generate USD 6-7 billion in annual revenue by 2022.

East African countries like Rwanda and Tanzania have implemented PAYG schemes at a very fast pace, and many other countries are following the same path. The growth of these payment systems is based on a complex business model: strong field presence, marketing close to people, technical assistance, high investment from the providers to buy in advance the equipment (Advisors and Global, 2018). Mobisol and M-Kopa have introduced this electricity services as from 2009 (Rolffs et al. (2014)). PAYG companies have also attracted international private sector investors and have been successful in raising grants, equity capital, and debt. East Africa has been leader in the expansion of these services, whereas West Africa represented only 12% of total PAYG sales in Africa over the period 2013-17. This slow diffusion effect is explained by slower penetration rate of mobile money.

Research on PAYG as financial instrument to provide electricity access is scarce and generally based on surveys or field experiments. As Alstone et al. (2015) point out: "If customers do continue to sign up and make regular payments, however, energy service providers will be able to demonstrate their viability. What is now required, in order to secure long-term financing *at* competitive rates, is clear evidence of regular payments on a larger scale. This is a rich topic for future investigation." To the best of our knowledge, this work is the first paper providing such

[3]SHS are stand-alone photovoltaic systems that can be used to meet a household's energy demand fulfilling basic electric needs. They usually operate at a rated voltage of 12 V direct current (DC) and provide power for low power DC appliances such as lights, radios and small TVs for about three to five hours a day. A SHS typically includes one or more PV modules consisting of solar cells, a charge controller which distributes power and protects the batteries and appliances from damage and at least one battery to store energy for use when the sun is not shining.

an evidence.

We exploit a unique and original database of a leading private company, selling solar kits and panel as from 2012 in Benin. We analyze contracts of 10,120 consumers having subscribed PAYG. We aim to unveil the determinants of successfully conducting PAYG credit that allows, with a minimum of 6 months loan, to access Tier 1 and 2 devices. Our purpose is to understand whether consumers in our sample are able to commit to long-term payments in order to get solar kits/panels. After a thorough description of our database, by means of detailed maps, we test whether the localization of consumers, which proxies their access to grid electricity, leads to significative differences in payment behavior for off-grid electricity and thus PAYG services. We thus estimate a simple multinomial logit model (Ben-Akiva et al., 1985). We calculate the relative probability of regular payments, failures, enrolment in PAYG services with respect to the base case of cash payment for small SHS, considering these latter as "early adopters" of solar electricity devices. In order to understand the impact of some simple structural factors, we control for the available information in the database that is consumers' gender and location. We take into account four possible urban areas, three of which (Cotonou, Abomey-Calavi, Porto Novo) being the biggest cities in Benin, near the coastal area, and displaying almost 100% access rate; and a fourth locality, Savalou, in the center region, by only 9% access rate to the electricity grid.

Addressing an area neglected within the field of energy access, the " last mile " scaling challenge, we show that PAYG flexibility has a clear value for consumers, as few of them default. However, important geographical differences exist. Given that households with PAYG electricity access services are mainly located in electrified zones, our results point out a substitution effect from expensive and unreliable on-grid electricity service to off-grid devices allowing lighting, radios, mobile charging. This effect is smoothed in the case of Savalou, where the electricity access rate is lower and the value of solar kits to consumers is perhaps higher. This result is confirmed by marginal effects estimation in the multinomial logit. We show that people living in Savalou have a lower probability to default compared to other locations. Overall, given the global small failure rate in our sample (only 10% of consumers are disabled due to a discontinued payment), we argue that in our case study, PAYG services mainly targets credit worthy consumers. At an early development stage, PAYG improves energy affordability or vulnerability, instead of really bridging the electricity gap of households not connected to the grid. This cream skimming effect decreases the default risk in the business model of the PAYG provider and ensures the bulk of its development, an issue also raised at a broader scale in Africa by Fondem (2019)[4]. Therefore this seems to be the first step toward a broader adoption of PAYG services, possibly in rural areas, but further efforts are needed to meet the last mile electricity challenge.

[4]Fondem is a Non Governmental Organisation working on issues related to access to electricity in rural areas of developing countries.

The paper is organized as follows. Section 2 explains the details of PAYG services and reviews the relevant literature. Beninese economic situation is summarized in Section 3, together with the specificity of its electricity sector. Section 4 describes our case study. The estimation method and results are presented respectively in Section 5 and 6. Section 7 briefly concludes. The Appendix provides a few details on the model estimation.

2 Pay-as-you-go services: literature review

So far, the literature on solar lighting and SHS has focused on the impact assessment of electrification. Different surveys have recently been written, highlighting crucial points to be addressed when assessing the ex-post impact of electrification, such as for instance geographical bias for decentralized projects (Jean-Claude and Arnaud, 2018; Hamburger et al., 2019), or links with specific usages, like substitution with kerosene lighting or socio-economic constraints (Rom et al., 2017; Lemaire, 2018), child health and study time (Furukawa, 2014; Kudo et al., 2019; Stojanovski et al., 2018; Grimm et al., 2016). Nevertheless, the existing evidence on household light use, expenditure, wellbeing, and productivity is not conclusive and calls for further analysis to clarify the advantages of electrification (Hamburger et al., 2019).

We take a different perspective, considering incentives to buy off-grids devices allowing electricity access through PAYG, which is a specific micro-credit contract. Relying on the widespread diffusion of mobile phones, PAYG energy services offer a flexible service. Users make a small up-front payment for the installation and commit to topping up their units by buying scratch cards or using mobile payment platforms. If scratch cards are used, the number in the card is validated by sending a text message to the server of the electricity service company (ESCO) and then a pass code is introduced in the household energy system, which allows it to operate for a period of time. The consumer must usually pay upfront a fraction of the total cost of the solar kit or photovoltaic (PV) panels with batteries, but the rest is paid through small installments that give credit to consume the electricity generated by the system for a period of time. Usually, after several payments for the energy service provided, once the cost of the system has been covered, the device is permanently unlocked and ownership is granted to the consumer. A machine-to-machine system allows the monitoring of the payments. The initial commitment specifies the period during which they must buy scratch cards or pay the credit fee directly by using mobile banking, at the end of which their system can be either unlocked or upgraded to a larger system. If the payment is not made, the system automatically disconnects the customer. This contract reduces the transaction costs for providing and enforcing small loans, given that the periodic fee for PAYG off-grid power is similar to the typical expenditures for traditional fossil or biomass fuels being replaced by electricity. Customers thus do not

need to set aside additional funds to purchase the new service. This approach to financing fits people's ability and willingness to pay in the context of uncertainty and careful budgeting of scarce cash. Notably, the PAYG has the advantage of giving the opportunity to the liquidity-constrained people, who cannot contract credit from traditional banking system, to switch to a modern and less pollutant source of energy. Small payments and some flexibility to account for unforeseen circumstances may be sufficient to attract consumers' interest (Moreno and Bareisaite, 2015).

Some systems include remote monitoring features, enabling better knowledge about user behavior and the performance of decentralized devices (Alstone et al., 2015). Therefore PAYG represents an interesting alternative to microfinance programs, whose success in terms of electricity access has been questioned by several studies (Karplus and von Hirschhausen, 2019). Moreover, prepayment systems have often presented fraud and metering problems (Tewari and Shah, 2003).

Jack and Smith (2015, 2017) have done pioneering studies on the willingness to pay, electricity usage and expenditures in South Africa when different billing services are proposed. In particular, they study prepaid metering that helps the poorest in paying bills, both by using data of consumers in Cape Town and making a field experiment. They find that flexibility of prepaid meters allows customers to smooth expenditures to income and potentially improves customer welfare. Nevertheless, when customers on monthly billing are involuntarily assigned to receive a prepaid electricity meter, with exogenous variation in the timing of the meter replacement, electricity use falls by about 13 percent as a result of the change in meter type. Although we share with this paper the use of real consumer data, we differ in the typology of the service used. Jack and Smith analyze on-grid electricity services subscription, whereas we look at off-grid electricity, also providing the ownership of the device generating electricity. Grid connections and electricity demand is also what Lee et al. (2020) study. Using a randomized control trial experiment, they find that demand for connections falls sharply with price, and is far lower than anticipated by policymakers. Among newly connected households, average electricity consumption is very low, implying low consumer surplus. The methodology of randomized control trials is also used by Grimm et al. (2020) for off-grid services. The authors elicit the revealed willingness-to-pay for different off-grid solar technologies in a field experiment in rural Rwanda and show that households are willing to dedicate substantial parts of their budget to electricity, but not enough to reach cost-covering prices. This result questions the viability of business models used by off-grid electricity providers, an issue we are also interested in.

Although PAYG is often advocated as an interesting research avenue (Lee et al., 2016, 2017), a few studies have analyzed it. Rolffs et al. (2015) focus on a case-study of PAYG services in Kenya, showing that the success of this kind of micro-finance is crucially linked to socio-economic factors that make the contract successful. The data collected are qualitative, with 20

quasi-directed interviews. On a similar vein, crossing the results of interviews and best practices of PAYG providers in East Africa, Yadav et al. (2019) present the advantages of eventual PAYG diffusion in India. While the scope of these latter paper is similar to ours, the focus, data and methodology differ.

We use data from consumers actually involved in PAYG electricity provision, and investigate their behavior in terms of fees payment along the contract duration. To this extent, the objective of our paper is more similar to Stojanovski et al. (2017) who studied how 500 early adopters use solar kits, finding that they replace kerosene lighting and phone charging. Collings and Munyehirwe (2016) conducted a survey evaluation of PAYG systems for the solar kit Indigo (a battery charger and 2 led lights) in Rwanda, provided by the company Azuri to 480 customers. Households that adopted Indigo as their sole source of lighting or in combination with others had respectively 1.75 and 2.5 times more lighting time per day than the control group with no kit. This allowed Indigo users to find extra time for family gathering, education of children and reading for adults. In the majority of cases it did not fully replace other devices, but rather allowed for additional lighting or phone charging. More importantly, seventy-six percent of Indigo customers said that the monthly payment was too high. In fact, thirty-two percent of customers had been out of credit at least once because they do not have money to pay for the top up. This result questions the affordability of the service offered. Issues related to credit fees are also analyzed by Barrie and Cruickshank (2017) who explain the main drivers of PAYG diffusion according to the theory of social innovation. By conducting 118 semi-directed interview, the authors focus on default consumers and find that the last mile challenges associated with PAYG are far greater than traditional retail models. Indeed the SHS distributor is required to retain a long-term relationship with each customer as well as provide support services, such as system maintenance, to ensure regular payments. In a similar vein, Sanyal et al. (2016) analyzed several business model that can make profitable the supply of PAYG services.

Even if we do not focus on mobile banking adoption, our paper supports general evidence on the link between economic development and mobile phone/banking use. There are few studies that analyze specifically these telecommunication services in Africa. Aker and Mbiti (2010) offer a very complete review of the factors that explain mobile phones adoption and its potential for African economic development, since the pioneering experience of "banking the unbanked" done by the leader company M-Pesa in Kenya (also studied by Mbiti and Weil (2013)). Reducing searching costs and risks, improving coordination among firms and introducing new markets are key factors. Nevertheless, the authors affirm: "Yet even if mobile phones can enhance access to resources and information, they cannot replace investments in public goods such as roads, power, and water. In fact, they are less effective without them [...] Without power, a firm could receive more customer orders via mobile services but would still have work hours limited by the available sunlight [...] For economic development to occur, complementarity between mobile adoption and investment in these other forms of capital

is needed". This view is shared by Mothobi and Grzybowski (2017), who find that adoption of mobile phones is higher where there are infrastructures, but mobile transactions are more frequent in areas with less infrastructures. More recently, Asongu (2018) studies the motives for mobile banking adoption in 49 Sub-Saharan African countries and finds that using mobile banking is also positively correlated with trade openness, remittances volume and human development indexes, which can amplify the welfare impact of physical infrastructure.

Our study is the first one to investigate PAYG services on a very large sample of actual users. The aim of this paper is thus to provide insights on PAYG users' behavior in repaying PAYG loan fees, all along the contract duration. More specifically, we look at customers payment behavior during the contract lifetime, controlling for customers' location and gender, type of contract, number and amount of payments. Our results shed light on the determinants and reliability of PAYG contracts. Unfortunately, we do not have any information on customers' level of education and income, household composition, dwelling characteristics, which, of course, would be relevant to study technology adoption. However, despite these limitations, we believe that insightful conclusions can be drawn from this study, in particular on the feasibility of large scale PAYG services, both in rural and urban areas.

3 Benin: country profile

Benin is a small country located in West Africa, bordered by Togo on the West, Nigeria on the East, Burkina Faso and Niger on the North and the Atlantic Ocean on the South. The population, predominantly young, is concentrated in the Southern region. The urbanization rate has kept growing since the last two decades. In recent years, Benin's economy has experienced positive economic growth. Its Gross Domestic Product (GDP) growth averaged 6% between 2012 and 2015, and amounted to 5.6% in 2017. According to the initiative Power for All (US Government), the GDP per capita in PPP is $2,266.[5] Despite a recent downward trend, the poverty rate remains high, at 46.4% in 2018, with a poverty line of $1.90 a day in purchasing power parity (WB, 2019). Benin growth is driven by two sectors: agriculture and services that account respectively for 23% and 56% of GDP. Cotton and pineapple are the main export products of the agricultural sector. Likewise, the services sector core activity is formal or informal import/export of goods to Nigeria. As a consequence, Benin economy is heavily dependent on Nigerian economic cycles. The industrial sector is not very well developed. This is probably due to barriers in obtaining financial credit and accessing energy. Benin is ranked 153 among 190 economies in the ease of doing business, according to the latest World Bank annual ratings. The index averaged 165 from 2008 until 2018, reaching an all time high of 175 in 2011 and a

[5] `https://www.powerforall.org/` (accessed November-2019)

record low of 151 in 2017. Noteworthy for this study, with 9,3 millions of subscribers, the mobile penetration rate is 81%(ARCEP, 2019). The bankarisation rate has been estimated at 27% in 2017, the largest in the countries belonging to the Franc CFA monetary Union.[6] According to the G20 financial inclusion indicators (World Bank, 2018), with a population of age 15+ of 8 millions, 38,5% of the population has a financial account (against 10.5 in 2011) and 60% a mobile phone. The mobile bank account has made a substantial jump, counting today 18% of the adult population, against only 2% in 2011 (WB, 2018). Similarly, digital payments by phone are made by 28.5% of the adult population. Among adults having a mobile banking, 41% of the poorest have an account, probably to receive remittances, and 25% are in rural areas.

The country nationwide access to electricity in 2016 was 32% of the population. There is a huge gap between access to electricity in rural and urban areas. In 2015, only 5.5% of the rural population was connected to the electric grid, whilst in urban areas it is estimated that 56.4% of the population access electricity. The actual installed capacity amounts to 349 MW, of which diesel and fuel oil is 249 MW and the remaining capacity is hydro. Benin is characterized by a relatively low energy consumption and a predominance of biomass energy with high carbon emissions. Energy consumption was 3344 ktoe in 2010, or about 0.4 toe/ capita. This figure is well below average worldwide, which is 1.7 toe/inhabitant. The consumption of firewood and charcoal represents approximately 59.5% of the total final energy consumed in 2010, 38.3% oil and 2.2% electricity. In 2012, the consumption of fuelwood and charcoal accounted for approximately 48.8% of the total final energy consumed; petroleum products 49.1% and electricity 2.1%.[7] This latter has been increasing over time, reaching 100 kWh/hab in 2014 compared to 33kWh/hab in 1984.[8]

According to ARE (2018)[9] in 2016, total residential electricity consumption amounted to 411 GWh in Benin. Around 41% of Beninese currently have access to electricity, with a sharp divide between urban (70%) and rural areas (18%). The average consumption per capita with electricity access was 138 kWh. Electricity consumption is below the average for Africa's low income countries. Accounting for an average tariff of 100 FCFA per Kwh and a monthly subscription rate of 500 FCA per month (ARE, 2010), the total annual average electricity expenditure amounts at 149 000 FCFA, that is 240$ or 20$ per month. Rom et al. (2017) estimate at $2.99 per month on kerosene expenditure for lighting.

Irregular connections as well as disruptions are quite frequent. Above all, electricity bills are extremely expensive. As reported by Sinsin (2017) the average monthly bill is 11 110 FCFA (19 dollars) compared to and average income of 38 500 FCFA (66 dollars). Beninese households

[6] The CFA Monetary Union (UEMOA) is composed of Benin, Burkina Faso, Côte d'Ivoire, Guinea-Bissau, Mali, Niger, Senegal and Togo.

[7] Source: `https://www.benin-energie.org/`.

[8] Source: `https://donnees.banquemondiale.org/indicateur/EG.USE.ELEC.KH.PC?locations=BJ&view=map`

[9] ARE is Benin's Electricity Sector Regulator

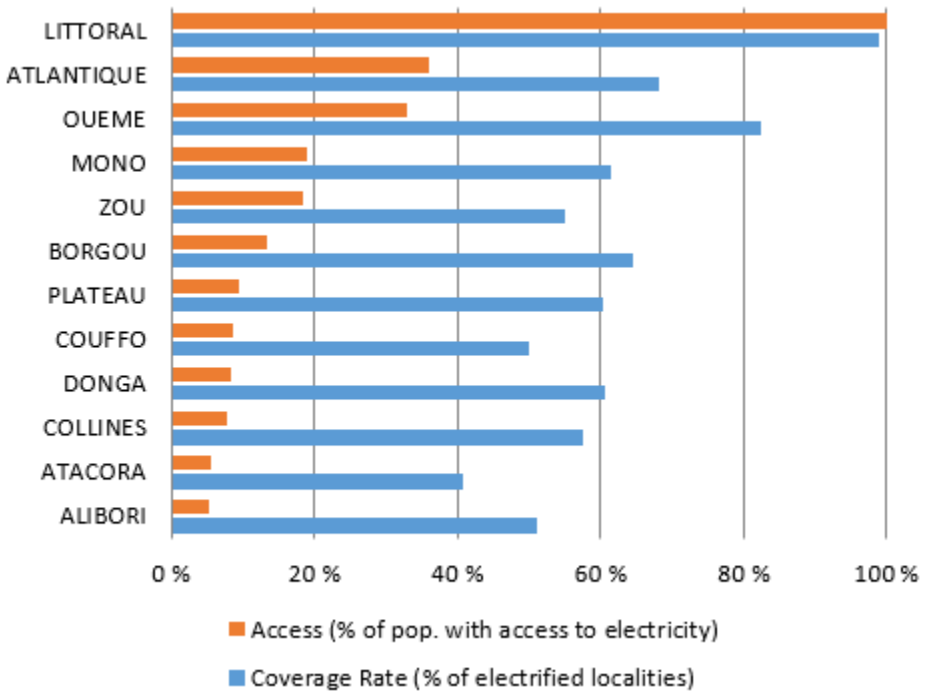

Figure 1: Access to electricity by municipality
Source: www.benin-energie.com

thus spend about 28.9% of their monthly income to pay the electricity bill, which means that there is a serious issue of energy poverty even for electrified people.

Territorial diversity in accessing electricity is one of the difficulties in reaching universal access by 2030, together with full coverage of public lighting. The departments with the lowest service rates are Atacora, Alibori and Couffo, with less than 53% and a number of electrified localities of less than 40%. At the top ranking, the departments which have the highest electrification rate are Littoral, Ouéme and Atlantique (see Figure 1).

In order to overcome energy import dependence and inability to develop adequate electricity infrastructure, the Government has traditionally reacted to this unsatisfactory situation by installing large-scale diesel-powered generators, but at a substantially higher cost and strong environmental impact. Although in 2016 Benin's share of DREA amounted to 8.6%, below the endowment of developing economies (9.6%), off-grid photovoltaics units have been growing during the latest years. In fact, as from 2017, the Government of Benin has changed and adopted a far-reaching policy reform agenda in partnership with the Millennium Challenge Corporation (MCC) to establish an independent electrictrification regulator with the authority to set tariffs, pass a new law encouraging public-private consortia, and approve a performance plan with measurable targets for electrification. [10]

[10]To reach these goals, the Communauté Electrique du Bénin (CEB), the joint generation and transmission utility of both Benin and Togo, and the national utility, SBEE (Société Béninoise d'Energie Electrique), heavily indebted, are undertaking institutional reforms to ensure a viable energy sector. This would arguably reduce the country's

Even if it is difficult to get precise information on off-grid initiatives, the "Benin Energie MCC Initiative" reports that 72,500 pico systems and 1,640 solar kits were registred in 2017. As of June 2018, 3804 cities and villages were electrified (Benin-Energie, 2019).[11] This new path toward electrification has eased the entry of new investors offering innovative services like PAYG.

Gogla (2019) reports that private investment in the off-grid solar sector in Benin has been limited. By creating a long-term electrification policy and benefiting from international donors funds, the government is now aiming to attract private investors. Targeting universal access to electricity by 2030, OnSSET (2018) calculates a total investment costs ranging from 1.2 to 5.9 billion USD, depending on the level of service provided, mixing on-grid and off-grid services, and technology cost development.

4 PAYG case study

We analyze 10,120 PAYG contracts, subscribed over the period of September 2016 to January 2019. We gathered our data from commercial sales of African Renewable Energy System and Solution (ARESS), one of the ninth biggest ESCOs selling PV panels and kits in Benin. ARESS, located in Cotonou, specializes in the installation and distribution of certified electricity products and services. Her activities are divided into four areas: distribution of existing solutions (pico and solar home systems); management of solar stores throughout the country in order to bring electrification solutions closer to end users and local communities, training and development and monitoring public private partnerships. Since 2015, ARESS imports lighting products from the Asian manufacturer Sun King and has organized PAYG services, allying with the largest Benin mobile telephone provider, MTN.

ARESS sales different solar products, ranging from the pico solar system to the solar home system. The company's flagship product is the pico solar system. It consists of the Sun King Pro and the Sun King Boom costing 42 Euros and 56 Euros, respectively. Sun King Home 60 is the most expensive product ARESS sells and its price is approximately 96 Euros, nearly twice the legal minimum wage (40,000 FCFA approximately 61 Euros) in Benin. The main difference between these products, is their respective electricity production capacity. While the pico solar can, for instance, provide sufficient electricity to charge low power gadgets such as

energy dependence from its neighbors, underpin its economic development, and achieve universal access by 2030. The Off-Grid Clean Energy Facility is providing grant funding to proven, sustainable off-grid clean energy solutions within four windows nationwide in Benin: essential public infrastructure; decentralized community-level generation and distribution (minigrids); household energy systems and products (solar home kits and panels); and energy efficiency measures.

[11] There are no doubts that PV systems will have a widespread diffusion, representing interesting business opportunities for private investors. According to the SE4All initiative, given the solar irradiation potential of the country, the estimated PV production between 2020 et 2030 will be of 1098 GWh and 2412 GWh respectively, with an installed capacity of 427 MW increasing to 843 MW in the best scenario of Benin economic growth.

mp3 players, mobile phones and radios, the solar home system on the other hand, is capable of running high energy-consuming appliances (i.e. fan or television).

ARESS offers two payment options to acquire its products : the cash payment or the pay-as-you-go option. If the consumer chooses the cash payment option, he must purchase the solar panel in a one lump-sum payment. However, if he opts for the PAYG scheme, the consumer must make a prepayment of 10% or 15% of the price of the solar device and the rest has to be paid through weekly installments. While under normal condition (without experiencing payment default) ownership of the device is granted under 24 weekly instalments, it is possible to anticipate the ownership date. Put differently, the customer can own the solar panel earlier than 24 weeks if he pays the remaining balance. Hence, based on this information, PAYG users are either classified in the group of "anticipated payment" or "normal payment".

As the data used in this study comes from commercial sales of ARESS, we only have PAYG users. In addition to this, the dataset provides limited socio-economics information on PAYG users. For instance, we do not have any information on customers' level of education, age, electric appliances ownership, past electricity consumption or level of income. However, the dataset provides some basic information such as the costumer's gender, type of product under the PAYG contract, geographic location and solar panel status. The status of each solar panel is either enabled, disabled or unlocked. When the status of the solar panel is unlocked, it means that the consumer has completely finished paying off the solar panel. The disabled status is attached to clients under payment default. Contrary to the unlocked status, the enabled status is associated to new PAYG clients who are still paying off the solar panel.[12]

Figure 2 depicts solar panel status by gender. As it can be noticed, there is no gender differences with regard to successfully going through the program. The percentage of unlocked solar panels for both female and male PAYG users is quite similar, nearly 70%. However, examining the enabled status, we notice some discrepancies. Indeed, new purchases of PAYG solutions in Benin are more likely to be undertaken by women than men. Finally, breaking down the disabled status by gender, one can notice that the percentage of male PAYG users in a default payment is greater than that of female. Hence, this suggest that male PAYG users are more likely to default than female ones.

Figure 3 displays the geographical location of early PAYG users, that is consumers who have entirely repaid their credit. As it can be noticed, the vast majority of early PAYG users are located in already electrified departments. In these departments, despite the existence of the grid and a relatively high access rate to electricity, still, a growing number of people rely on PAYG solutions to have to electricity. Littoral, Ouemé and Zou are the departments that concentrate the highest rate of PAYG adoption. This figure is indicative of an unreliable supply of electricity, characterized by frequent power outages. In such settings, solar home systems

[12] Also, while the mobile phone number of the customer is available, unfortunately, we do not have any information on his historical credit refill. This information, if available, would have been a good proxy for income.

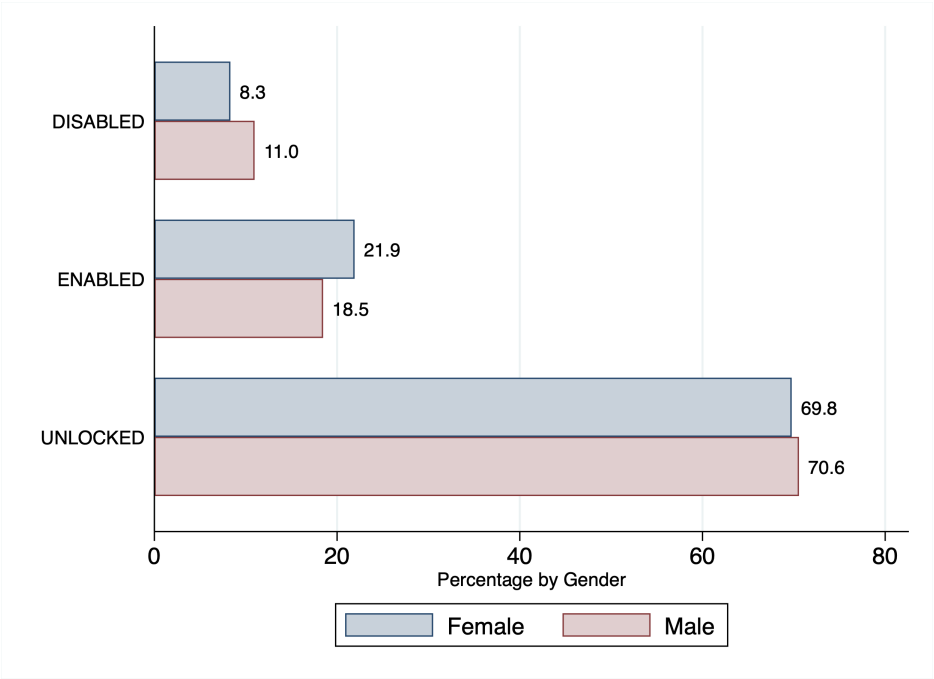

Figure 2: Solar status by gender
Source: Authors' elaboration from ARESS sales database.

can, therefore, be considered as a complementary solution to the unreliable grid in providing continuous electricity services to households. Likewise, in many low electrified departments such as Alibori, Atakora, Borgou and Donga, PAYG services are penetrating, albeit, at a very slow pace. In these localities, PAYG services are rather used to access basic electricity services as the grid is almost nonexistent.

Figure 4 on the other hand shows the location of new PAYG users by departments. Again, Littoral, Oumé and Zou are the departments that registered a strong growth of new PAYG users. Oumé and Zou account for 2.7% to 19.57% of new PAYG users followed by remote departments like Borgou and Atlantique which account for 1.1% to 2.7% of new solar kit purchases. Surprisingly, in the north of Benin where the electric grid is almost nonexistent, the adoption rate of PAYG solutions remains very low. This is mainly due to high operation costs PAYG services provider faces in reaching these locations. Clearly, the main insight one can draw from these statistics is that PAYG services providers are not serving the "last mile". Nearly all PAYG users in Benin have access to the grid.

Finally, Figure 5 depicts default rate statistics by department. First of all, it is important to note that ARESS has a relatively low default rate (i.e. less than 11%). Littoral is the department that concentrates the bulk of defaulters (14% to 68%). It is followed by Ouemé and Zou that account for 2% to 14% of the defaulters. The geographical patterns displayed in the previous figures suggest that there is a link between access to grid electricity and PAYG enrollement, as well as regularity and frequence of the payments. Is PAYG targeted to reliable clients, perhaps

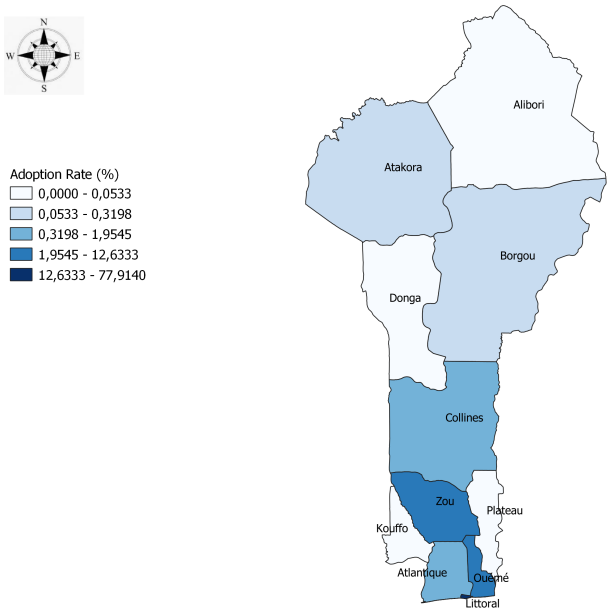

Figure 3: Early PAYG users by department
Source: Authors' elaboration from ARESS sales database.

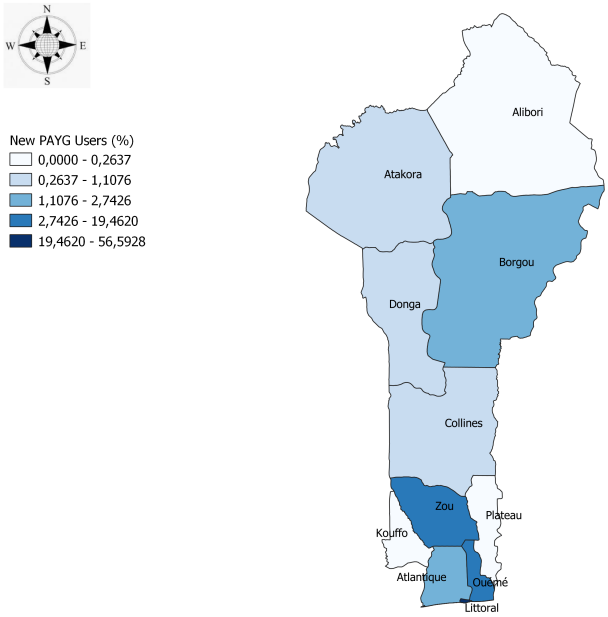

Figure 4: New PAYG users by department
Source: Authors' elaboration from ARESS sales database.

located in richer regions, where access to electricity is rather satisfactory? To test this hypotesis, we estimate in Section 5 a simple model that takes into accout enabled, disabled or unlocked status and the payment behavor of PAYG consumers.

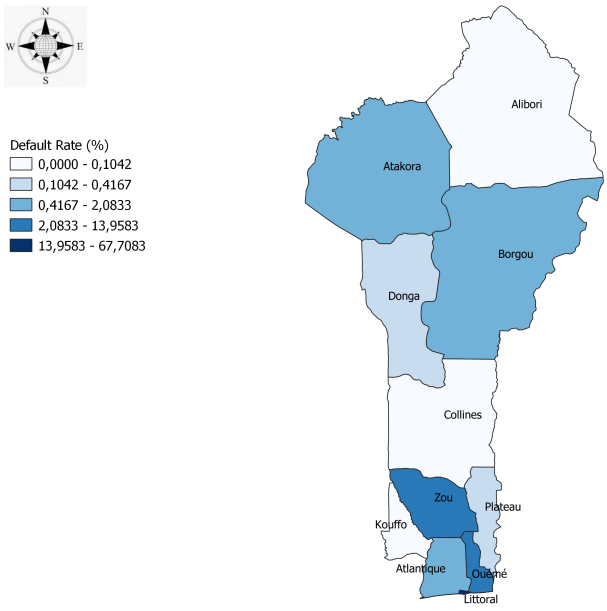

Figure 5: Default rate by department
Source: Authors' elaboration from ARESS sales database.

5 A simple empirical model

Based on the solar panel status (enabled, disabled or unlocked) and the payment patterns (cash payment or PAYG payment plan), 5 groups were defined: anticipated payment, cash payment, failure, normal payment and ongoing payment).

We resort to a minimalist Multinomial Logit Model to estimate the probability of falling into a group of payment given a set of control variables. For instance, the same modelling approach has been used to model alternative fuel choices in emerging countries (see for instance Alem et al., 2016). The Logit model is often used to predict categorical placement in or the probability of category membership on a dependent variable based on multiple independent variables. The independent variables can be either dichotomous (i.e., binary) or continuous (i.e., interval or ratio in scale). Multinomial logistic regression is a simple extension of binary logistic regression that allows for more than two categories of the dependent or outcome variable.[13] Like binary logistic regression, multinomial logistic regression uses maximum likelihood estimation to evaluate the probability of categorical membership. Multinomial logistic regression does necessitate careful consideration of the sample size and examination for outlying cases. Data normality, linearity, or homoscedasticity, instead, are not needed to perform the estimate. The multinomial logit model relies on a very restrictive assumption: the independence of irrelevant alternatives (IIA). It supports the idea that the probability of choosing an alternative is not affected by the existence of other alternatives. In our model, the independence of irrelevant

[13] A comprehensive analysis of multinomial logit models can be found in Ben-Akiva et al. (1985).

alternative holds as the probability of choosing is independent from other alternatives. Additionally, in our sample there are no consumer subscribing to more than one contract.

Formally, the conditional probability of a PAYG customer i falling into a category of payment $j = (1, 2, 3, 4, 5)$ is defined as follow:

$$Prob(y_i = j) = \frac{exp(\beta_j X_i)}{\sum_{k=1}^{J} exp(\beta_k X_i)} \tag{1}$$

where X_i represents a vector of control variables such as geographic location, gender and type of payment contract. A reference outcome in order to fit the model must be defined. We choose the cash payment as the base category. The model is estimated using the Maximum Likelihood Estimator. Notice that we tried to retrace the history of payment of the customers in order to shed light on the payments dynamic with a panel model. However, due to persistence and low variability in the data, the panel multinomial logit model could not converge. Hence, we used a multinomial logit model on cross-sectional data.[14]

6 Results

6.1 Summary statistics

Table 1 summarizes the definitions and statistics of the main variables used in our empirical analysis. Our statistics indicate an unequal spatial distribution of PAYG users between cities. Cotonou, Porto Novo and Abomey Calavi concentrate the most important share of PAYG users, with respectively 59.43%, 9.39 % and 8.13% of the sample size.

The mean number of payment by PAYG users is 10.17, which is twice below the normal 24 weekly installment payments. The anticipation of installment payments might also reflect customers' uncertainty about their future revenues. We argue that customers falling into this category of payment could be risk averse. The proportion of customers in this category is 50.18% while cash payment, normal payment and ongoing payment represent respectively 18.7%, 10.4%, 4.4% and 16.3% of our sample.

Another important characteristic worth mentioning is the proportion of customers' in default payment situation, which we believe is relatively low (10.4%). People joining this program are less likely to be in the lowest distribution of income. Examining the ongoing payment cat-

[14]More precisely 87,4% of our sample size consists of Sun king Pro and Sun king Boom, which are quite similar products. In our main results we do not control for the type of products. However, to be sure that our results hold when the type of product is controlled for, we estimate a model including dummy variables to control for product type. We find that the results were not altered. The results can be provided upon request.

egory, one can notice that despite the low proportion of enrolment into the program, there is a positive dynamic in adoption of solar panels.

Table 1: Summary statistics

Variables	Mean	Std. Dev.
Nb. of payments	10.169	7.685
Anticipated payment	.502	.5
Cash payment	.187	.39
Failure	.104	.305
Normal payment	.044	.205
Ongoing payment	.163	.369
Gender (dummy=1 if male, 0 otherwise)	1.828	.378
Cotonou (dummy=1 if lives in Cotonou, 0 otherwise)	.594	.491
Porto Novo (dummy=1 if lives in Porto Novo, 0 otherwise)	.094	.292
Abomey (dummy=1 if lives in Abomey, 0 otherwise)	.081	.273
Savalou (dummy=1 if lives in Savalou, 0 otherwise)	.011	.103
Contract (dummy=1 if PAYG, 0 otherwise)	.644	.479
N: 10,120		

6.2 Key findings

The results of the determinants of group membership are presented in Tables 2.[15] It is important to note that the estimated parameters from the multinomial logit cannot be interpreted directly. Scholars often resort to the relative risk ratio or the marginal effects. As we are interested in studying the factors influencing group membership, we begin by looking at how variables influence the choice of one outcome compared the base category (cash payment). To this end, odds ratios, which are also known as relative-risk ratios are calculated, even if we are aware that the relative-risk ratios does not convey a clear picture of the impacts of variables on outcomes.

Columns 2 to 5 of Table 2 present the odds ratios of falling into an alternative j compared to our base outcome (cash payment). Geographic location, PAYG payment contract and the number of payment are key determinant of group membership. For a PAYG customer living in Savalou for example, the odds of falling into the anticipated group of payment versus cash payment are expected to increase by a factor of 8.5, holding all others covariates constant. For a unit increase in the number of payment, holding all other variables constant the odds of falling into the anticipated group are multiplied by a factor of 129. Contrarily to Savalou, living in Abomey Calavi reduces the odds of anticipating the payment versus cash payment by 72%.

For the failure group outcome, we find that customers using the PAYG payment contract and living in Cotonou are more likely to experience default payment than cash payment. An

[15] Marginal effects results are presented in the Appendix (see Table 3).

Table 2: Odds Ratios Results

Variables	Ant. Payment vs Cash. Payment	Failure vs Cash. Payment	Norm Payment vs Cash. Payment	Ong Payment vs Cash. Payment
Male	0.682*	1.052	0.489	0.664**
	(0.145)	(0.237)	(0.216)	(0.128)
PAYG contract	33.37***	10.86***	39.46***	4.136***
	(7.011)	(2.346)	(27.94)	(0.820)
Nb of payment	128.8***	111.6***	103,923***	109.3***
	(39.77)	(34.44)	(132,067)	(33.59)
Cotonou	0.891	1.542**	0.579	1.536**
	(0.170)	(0.329)	(0.229)	(0.277)
Porto Novo	0.757	1.383	0.496	1.277
	(0.251)	(0.493)	(0.348)	(0.408)
Abomey Calavi	0.282***	1.214	0.198*	1.994***
	(0.0794)	(0.364)	(0.166)	(0.514)
Savalou	8.506***	2.74e-07***	265,722**	1.690
	(5.396)	(8.63e-08)	(1.325e+06)	(0.739)
Constant	0.000101***	6.89e-05***	0***	0.000495***
	(6.42e-05)	(4.47e-05)	(0)	(0.000291)
Observations		10,120		
Log likelihood		-6087		

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

explanation for this result could be that customers living in Cotonou are using kits to backup unreliable and expensive electricity services and they can somehow decide to give up paying for solar devices. Lack of detailed screening to calculate future financial ability to make regular payments might also explain why some customers experience payment default. Moreover, we also find that for a unit increase in the number of payment, the odds of falling into failure group versus cash payment are expected to rise by a factor of 111 holding all other variables constant. We interpret this effect as a possible time inconsistency issue. Clearly, beyond a certain number of payments, people with low and unpredictable revenue may give up regular weekly instalments fees. Indeed, when implementing this kind of services in developing countries, it is important to think about the optimal number of payments that reduces the risk of failure.

Positive and significant odds for PAYG payment contract and number of payment for the group of consumers in the normal payment and ongoing payment groups highlights the positive value of flexibility in contract which only requires weekly payments. The PAYG contract relaxes the budget constraint of its users.

Geography also matters for both ongoing payment and normal payment groups. For instance, the odds of falling into the normal payment versus cash payment, holding all other variables constant are higher for those living in Savalou than elsewhere. For the ongoing payment outcome, the odds are statistically significant for only those living in Abomey Calavi. The

chance of being in the ongoing payment category rather than in the cash payment category is twice as important for those living in Abomey, holding all other covariates constant. These geographical differences in group membership might be attributed to disparities in economic development of the different regions. It might also reflects disparities in access to electricity or reliability of the electric grid. We believe that solar kits are more likely to be used by customers as they are more affordable and reliable than on grid electricity, since the bulk of PAYG users are located in highly electrified cities.

Except for the ongoing payment category, gender in general, does not seem to be a key determinant of group membership.

7 Conclusion

PAYG aims at providing clean and reliable energy services to those without access to electricity or as a backup solution to those connected to the electric grid. Its business model relies on mobile money technology which reduces transaction costs. Beyond the transaction costs, PAYG service providers in developing countries operate under high costs, as they buy in advance the SHS devices, find consumers and offer post-sales services. However, they get uncertain revenues, due to eventual irregular payments or default. These are major impediment to PAYG services expansion at a larger scale.

We study the behavior of a large sample of PAYG consumers for electricity access, by using commercial data on PAYG users provided by a leading PAYG electricity operator in Benin. The main results of the model show that consumers in electrified areas still find interesting to get lighting and domestic electricity services by embarking on a flexible SHS loan. However, in a country where nearly half of the population live below the international poverty line of US$ 1.90 per day, PAYG services might still be very expensive for the ultra-poor more specifically, those living in rural areas (Bensch et al., 2018). Matching our data with socioeconomic and dwelling information would be a valuable extension of our work.

In the years to come, flexible credit services could help addressing rural electricity access in Sub-Saharan Africa, but this will require Government intervention and adequate financial guarantees for electricity service companies. International donors or private sector funds will play a significant role toward this direction.

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I. Appendix: marginal effects

Marginal effects inform about the change of the probabilities estimated in the multinomial logit in response to an instantaneous change of a continuous variable or a discrete change for a categorical variable. For instance, understanding how the probability of falling into the failure category changes in response to a unit increase in the number of payment is relevant to the PAYG service provider. For example, it could help the PAYG service provider to define an optimal number of payment that reduces the risk of failure.

Column (1), (2), (3), (4) and (5) gives the predicted probability of the anticipated payment, failure, normal payment and ongoing payment respectively in response to a discrete or marginal change of an explanatory variable. Looking at the anticipated payment category, we find that

Table 3: Marginal Effects

VARIABLES	(1) Ant. Payment	(3) Failure	(4) Norm Payment	(5) Ong Payment
Male	-0.382*	0.0509	-0.716	-0.410**
	(0.213)	(0.225)	(0.442)	(0.193)
PAYG contract	3.508***	2.385***	3.675***	1.420***
	(0.210)	(0.216)	(0.708)	(0.198)
Nb of Payment	4.858***	4.715***	11.55***	4.694***
	(0.309)	(0.309)	(1.271)	(0.307)
Cotonou	-0.116	0.433**	-0.546	0.429**
	(0.191)	(0.214)	(0.395)	(0.181)
Porto Novo	-0.278	0.324	-0.701	0.245
	(0.332)	(0.356)	(0.702)	(0.319)
Abomey Calavi	-1.266***	0.194	-1.620*	0.690***
	(0.282)	(0.300)	(0.840)	(0.258)
Savalou	2.141***	-15.11***	12.49**	0.525
	(0.634)	(0.315)	(4.985)	(0.438)
Constant	-9.203***	-9.583***	-166.4***	-7.612***
	(0.638)	(0.649)	(29.53)	(0.589)
Observations		10,120		

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

for two average PAYG customers, the predicted probability of making an anticipated payment is higher for female customers than for male. Being a male PAYG customer reduces the probability of making an anticipated payment roughly by 4%. An increase in the number of payment made by a PAYG customer is positive and significant for all groups of payments, the marginal effects are however different. We found the highest marginal effect for the normal payment group. For instance, a unit increase in the number of payment made by PAYG client increases the probability of making a normal payment by 11.5%.

We also observe geographical patterns in group membership. People living in Cotonou are more likely to fall into the failure and ongoing payment category. For example, for two hypothetical customers with mean characteristics, the one living in Cotonou has a 4.33% probability to experience failure than the one living elsewhere. Regarding the ongoing payment, the probability of entering the program is 4.3% for a person living in Cotonou than in another city. This might be due to the fact that there is still people living in the capital, who do not have access to a reliable electricity supply.

For these customers, the PAYG service could reflect a substitution effect (i.e. buying a solar panel to replace costly bills and unreliable electricity supply). Finally, we find some interesting related to Savalou. Living in that city reduces the probability of experiencing failure by 15.11% than being in other locations. People in Savalou are not only more likely to make normal payments, but also anticipated payment. The marginal effect of living in Savalou on the probability

of making normal and anticipated payment are 2.14% and 12.5% respectively.

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