What Limits Electricity Access?

Experimental Evidence from an Informal Market

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Abstract

Over half of grid-connected households in urban Benin buy electricity from their neighbors rather than the utility. This informal market has emerged to offer the opposite of the utility's single, regulated price schedule: a low connection fee and a high marginal price. What does this market reveal about how much the utility's schedule limits electricity access and welfare? We design a field experiment with over 4,000 households that randomizes subsidies to connection fees and to formal and informal marginal prices. The experiment generates price variation to estimate not only household demand for electricity but also informal supply because informal resellers are themselves formally connected. Experimental estimates show that the informal market electrifies households with lower electricity demand, and subsidized formal electricity makes formal households 80 percent more likely to resell. We use the experimental price variation to estimate an equilibrium model of electricity demand and informal supply. The model implies that the share of unelectrified households would nearly double, from 23 to 40 percent, without the alternative price schedule that informal resellers provide. These losses are concentrated among less wealthy households. The findings point to a new explanation for why expanding electricity access remains difficult: a rigid and regulated price schedule.

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Electricity access is critical for economic development (Dinkelman 2011; Lipscomb, Mobarak, and Barham 2013). But over 600 million people still live without electricity (IEA 2026). Substantial effort has gone into closing this gap by extending the grid and promoting off-grid alternatives such as solar (IEA 2022). Yet electricity access in many developing countries remains marked by theft, large utility losses, and low take-up of connections (Kojima and Trimble 2016; Lee et al. 2016; Blimpo, Postepska, and Xu 2020). It is still unclear how to expand electricity access effectively.

In this paper, we investigate whether rigid pricing with only one price schedule contributes to the challenge of expanding electricity access. Households pay both a connection fee and a marginal price for electricity consumption. Wealthy households can easily afford a large upfront payment, while many others earn irregular incomes and have little access to credit. Some need only a light and a phone charger, while others run a refrigerator or a television. But utilities in sub-Saharan Africa typically offer only a single price schedule with a high connection fee and a lower marginal price that is often subsidized (Golumbeanu and Barnes 2013; McRae, Blimpo, and Steinbuks 2018; Lee, Miguel, and Wolfram 2020). Given these wide differences across households, standard economic theory suggests that a single price schedule can leave households unelectrified.

We document that an informal alternative to rigid price schedules has emerged organically in sub-Saharan Africa. Households with a formal utility connection resell electricity to their neighbors, creating an informal market with its own price schedule.[1] We find that nearly *half* of all electrified households in urban Benin obtain electricity through this informal market. Informally connected households pay nearly twice as much per kilowatt-hour (kWh) for electricity as formally connected households. In exchange, informally connected households pay lower connection fees. We find that informally connected households tend to be less wealthy and consume much less electricity than formally connected households.

We then study the welfare and distributional consequences of the informal electricity market that relaxes this rigidity. Our analysis has two parts. First, we collaborate with the national utility to design and implement a randomized controlled trial (RCT) with over 4,000 households. The experiment separately subsidizes the connection fee and marginal price. Second, we develop and estimate an equilibrium model of electricity demand and supply using our experimental variation. We use the estimated model to conduct counterfactual policy analysis. Our analysis highlights how heterogeneous households trade off the menu of price schedules and quality across all electricity sources. We also capture how resellers enter and set prices in equilibrium in response to the utility's prices.

We construct new data to study this informal market, which is largely invisible to the utility. The utility's administrative data record each formal connection and its consumption. They do

[1] Unlike electricity theft, which is a criminal offense and heavily enforced, informal reselling is technically prohibited but tolerated by the utility because resellers pay for the electricity that they resell (Autorite de Regulation de l'Electricite 2020).

not record whether a formal household resells electricity, to how many households, or how the measured consumption is split among them. We overcome this by first conducting a representative survey of over 10,000 households in Abomey-Calavi, Benin. This survey measures the prevalence of the informal market and the prices that households pay.[2] We then follow up with over 4,000 households in two later survey rounds and link the surveys to administrative data from the utility. This lets us separately measure electricity consumption in the formal and informal markets and link it to household characteristics.

The data reveal that the price schedules in the formal and informal markets combine to create a menu in which households trade off the connection fee against the marginal price of electricity. This implies that the welfare and distributional consequences of the informal electricity market depend on household demand for electricity at the extensive and intensive margins. Because the informal resellers are themselves formal consumers, these consequences also depend on how informal resellers respond to the utility's price schedule.

We estimate household demand and reseller supply elasticities with respect to the connection fee and the marginal price, using experimental price variation from the RCT. The experiment randomizes a subsidy for informal connection fees to understand the extensive margin of household demand for informal electricity. Further, it randomizes consumption subsidies separately for formally and informally connected households. The subsidy for informally connected households roughly equalizes their marginal price with that of the utility. The subsidy for formal households is also a cost shock in the informal market because it lowers the marginal cost for resellers.

The experiment yields three main findings about the demand and supply responses at both the extensive and the intensive margins in the informal electricity market. First, lower connection fees electrify households that use little electricity. Subsidizing informal connection fees by an average of 60 percent increases the share of households with an informal connection from 20 to over 60 percent. These new buyers use roughly 30 percent less electricity than buyers who connect without the subsidy. When we subsidize the marginal prices for informal households, equalizing the prices closes only about 9 percent of the consumption gap between informal and formal households. Second, cheaper electricity from the formal utility expands informal supply. Subsidized formal households are over 80 percent more likely to start reselling, and existing resellers serve 12 percent more buyers. Third, we find suggestive evidence that resellers have local market power. We estimate an average pass-through rate of 10 percent of the formal consumption subsidy to informal prices, but it rises to 37 percent in the most competitive local markets.

While the experimental results are informative about the welfare consequences of the informal

[2]To our knowledge, there is no systematic evidence on the prevalence of informal resale or on the prices that households pay. Informal electricity resale has been documented in several cities in sub-Saharan Africa at small scales (Franks and Prasad 2014; Mensah 2022; Kersey et al. 2025), and practitioners describe it as tacit knowledge that "cannot be seen" (Power Africa 2019).

electricity market, they are insufficient by themselves. The experiment varies the connection fee for only one source, so it cannot show the full pattern of substitution across formal, informal, and off-grid solar electricity. It also shows how resellers respond to one cost shock, but not how entry and pricing in the informal market would adjust in equilibrium under other utility policies.

We therefore develop a model of electricity demand and supply to quantify the welfare and distributional consequences of the informal market and conduct counterfactual policy analysis. We model the household's trade-off between the differentiated electricity sources by embedding a continuous choice for electricity consumption in a discrete choice model with unobserved product characteristics (Dubin and McFadden 1984; Berry 1994). We specify preference heterogeneity that varies with observed (e.g., wealth and credit constraints) and unobserved household characteristics in the style of Berry, Levinsohn, and Pakes (1995, 2004). We incorporate the household's choice to enter into reselling as part of the demand model. Conditional on entry, resellers compete in a Nash-Bertrand pricing game by setting connection fees and marginal prices. The model structure allows us to consider flexible substitution patterns across all sources of electricity and the equilibrium number of resellers and prices in the informal market.

We estimate the model following the tradition of Berry, Levinsohn, and Pakes (1995) using the experimental price variation. We construct moment conditions using the experimental treatment effects. Heterogeneity in experimental treatment effects and take-up identifies preference heterogeneity in household demand for electricity. We recover the marginal cost per kWh and cost per buyer for informal resellers using the first-order conditions implied by profit maximization and the estimated demand system. Model estimates show that households that are more sensitive to the connection fee also demand less electricity, even conditional on observed characteristics. While informal resellers set marginal prices well above marginal cost, about 70 percent of this markup makes up for the loss incurred from the cost of serving each buyer. The median reseller earns modest profits equivalent to 2 percent of median household income.

We first use the estimated model to examine the extent to which the alternative price schedule provided by the informal market increases electrification and household surplus. We do so by considering the counterfactual scenario in which the informal electricity market is banned (Trajtenberg 1989; Petrin 2002). This counterfactual is also relevant to an ongoing debate because there has been precedent for banning informal markets (United Nations 2005; Fahmi and Sutton 2006; Ackrill and Olusanya 2023). Within electricity, policymakers have also expressed concerns over unregulated pricing behavior (Starrfm.com.gh 2017; Daily Monitor 2026). We find that the informal electricity market increases electrification rates by 29 percent and total surplus by 9.6 percent. Less wealthy households benefit the most from the informal market, as they are more likely to be electrified through it and value the little electricity that they consume highly.

While the informal market creates a menu of price schedules, the utility, as the monopoly supplier, could price discriminate directly by offering such a menu. Direct provision of the price

menu would avoid the lower electricity quality and unregulated local market power of informal provision. We consider a counterfactual in which the utility adds a single low-fee schedule, with the same connection fee as the informal market, alongside its current prices. This menu raises electrification rates by 50 percent and total surplus by 35 percent, more than three times the surplus gain from the informal market. The informal market then unravels and adds little surplus beyond the utility's price menu. Together, these results suggest that the rigid price schedule is contributing to the challenge of expanding electricity access, because it does not fit the demand of many households.

Related Literature. Our primary contribution is to provide a new explanation for low electricity access: rigid pricing with only one price schedule. We do so by studying the informal electricity market, which offers alternative price schedules. We build on a literature that estimates the demand for electricity access using experimental variation (Lee, Miguel, and Wolfram 2020; Grimm et al. 2020; Burgess et al. 2025). This literature suggests that despite a clear preference for grid electricity (Burgess et al. 2025), households appear unwilling to pay high connection fees (Lee, Miguel, and Wolfram 2020), which is a reason why electricity access remains low. These papers consider one part of the price schedule at a time: Lee, Miguel, and Wolfram (2020) and Grimm et al. (2020) vary upfront prices, and Burgess et al. (2025) vary monthly payments. We contribute by providing evidence that the structure of price schedules matters because a single schedule cannot serve all households well when they differ widely in their constraints and electricity demand. We show this by studying an informal market that has emerged to offer an alternative to the utility's price schedule. Moreover, the literature on electricity access has focused primarily on formal grid connections and off-grid solar electricity. We are not aware of any systematic evidence on the prevalence of informal electricity markets or on how households choose between formal and informal electricity.[3]

Our second contribution is to combine experimental price variation with an equilibrium model of electricity demand and supply. The previous experimental literature estimates the demand for electricity one source at a time (Lee, Miguel, and Wolfram 2020; Grimm et al. 2020) or a demand system without an explicit supply side (Burgess et al. 2025). In these settings, electricity supply is simply a policy choice of the utility. But in our setting, it also depends on how the informal market responds to utility policy in equilibrium. We therefore model endogenous entry into reselling and price competition among resellers, who buy formal electricity as an input. Our model builds on a long tradition of empirical models of supply and demand for differentiated products (Berry, Levinsohn, and Pakes 1995, 2004) by incorporating a continuous choice in the manner of Dubin and McFadden (1984). Our model most closely relates to Benetton (2021) and Benetton, Gavazza, and Surico (2025), who apply these methods to study the mortgage market.[4]

[3] More broadly, this paper relates to a rich literature on public versus private provision of a broad range of goods, anywhere from schools to water access (Besley and Ghatak 2001; Epple, Figlio, and Romano 2004; Galiani, Gertler, and Schargrodsky 2005).

[4] We join a broad literature that combines experimental variation with structural models that introduce economic restrictions to extend the interpretation of the experimental results (Todd and Wolpin 2006; Kaboski and Townsend 2011;

Our results have policy implications for ongoing initiatives to expand electricity access. Mission 300, led by the World Bank and the African Development Bank, aims to newly connect 300 million people in Africa to electricity by 2030 through subsidies for grid connections and off-grid solar technologies (World Bank 2026a). Where the informal market is prevalent, subsidies for formal electricity interact with it in two ways. First, they may displace informal connections, formalizing households that already have electricity. Second, formal households may begin to resell, which expands informal supply to households that have no electricity. The number of households that such programs newly electrify thus depends on both responses, and it may differ substantially from the number of new formal connections. Our counterfactuals also point to another lever that requires less external funding—a utility price menu with a low-fee schedule expands access without adding to the utility's losses.

Beyond electricity, our results have broader policy implications in developing settings where many low-income households rely on informal private markets (La Porta and Shleifer 2014; Ulyssea et al. 2025). This is often because there are high barriers to entering formal markets such as a utility connection fee or the cost of registering a business (Ulyssea et al. 2025). Informal markets typically offer lower entry costs but either higher marginal prices or lower wages in exchange (Meghir, Narita, and Robin 2015; Ulyssea 2018; Bachas, Gadenne, and Jensen 2020). Policymakers often try to restrict or ban these markets (United Nations 2005; Fahmi and Sutton 2006; Ackrill and Olusanya 2023). Our results suggest that designing formal markets to include menus that feature lower entry costs and higher marginal prices can be a more effective way of reducing informality than enforcement.

The remainder of the paper is organized as follows. Section 1 describes the setting and the data. Section 1.3 documents the structure of the informal electricity market. Section 2 describes the experimental design and reports the reduced-form demand and supply responses. Section 3 develops the structural model, and Section 4 presents the estimates. Section 5 uses the estimated model to conduct counterfactual analysis. Section 6 concludes.

1. Setting and Data

The paper's setting is in Abomey-Calavi, the most populous and fastest-growing municipality in Benin. The national utility offers one price schedule with a high connection fee and lower marginal price, and faces political economy and credit constraints in offering alternative schedules. The utility implicitly tolerates the informal electricity market, but enforces against electricity theft. To document the informal electricity market, we link novel representative surveys to utility records.

Attanasio, Meghir, and Santiago 2012; Duflo, Hanna, and Ryan 2012; Duflo et al. 2018; Lagakos, Mobarak, and Waugh 2023; Burgess et al. 2025).

1.1. Setting

Electricity access in Abomey-Calavi. Abomey-Calavi is the largest and fastest-growing municipality in Benin with over 1 million people (WorldPop 2026). We view Abomey-Calavi as an ideal setting to study electricity access in urban areas. As sub-Saharan Africa continues to urbanize (two out of three people are expected to live in an urban area by 2050), the challenges of expanding electricity access in urban areas that are predominantly within the grid's footprint will become increasingly important (Lee, Miguel, and Wolfram 2020).

Electricity access has expanded rapidly in Benin, particularly in urban and peri-urban areas, since 2017. Nationally, electricity access was declared a "priority" in 2016. Benin secured a landmark "energy compact" that saw over $300 million in investments in the electricity sector in 2017 with the Millennium Challenge Corporation. The investments expanded the reach of grid electricity with over 800 km of transmission lines. Since then, electrification rates have increased from 30% in 2017 to 57% in 2023 (World Bank 2024).[5]

Utility pricing in Benin. The distribution of electricity is managed by the national utility, Société Béninoise d'Énergie Électrique (SBEE), which offers a single residential price schedule where every household pays the same connection fee and the same marginal price for electricity consumption.

Connection fees remain a significant barrier to electricity access, even if the grid has expanded its footprint (Lee et al. 2016; Blimpo, Postepska, and Xu 2020).[6] To obtain an electricity connection, households must submit an application at the local SBEE office and pay a one-time connection fee at the time of installation. The standard residential connection fee is 85,000 FCFA (152 USD), which is roughly 2 months of median household income in our surveyed sample. The connection fees are reported to be sufficient to recover the fixed costs of electricity provision. However, as we show in Appendix Figure A8, households are paying additional costs for wiring and installation as well as bribes to utility officials to obtain a connection. The average reported connection fee is $176, which exceeds the standard connection fee (Figure 1 Panel B).

The marginal price of electricity is implicitly subsidized by the state. Households with a prepaid meter pay a flat price of 150 FCFA per kWh (0.27 USD per kWh) for their electricity usage. In Benin, there is not an increasing block tariff, and the marginal price does not vary with consumption. This tariff is below cost-recovery levels due to high technical and commercial losses in Benin (World Bank 2021a). The average tariff revenue recovers approximately 80 percent of the cost of service (World Bank 2021a). As a result, the utility relies on government subsidies to remain functional.

[5] This measure simply asks households whether their household has electricity. It thus includes households that are formally connected, informally connected, and those that have access to electricity through other means (e.g., solar).

[6] This problem is not specific to Benin, as connection fees are cited to be the most common barrier to a grid electricity connection (Kojima and Trimble 2016; McRae, Blimpo, and Steinbuks 2018).

Utility constraints. There are at least three constraints that make it difficult for SBEE to offer an alternative price schedule with a lower connection fee and higher marginal prices.

First, the norm of "electricity as a right" makes higher marginal prices politically costly (Burgess et al. 2020).[7] The utility has been reluctant to implement pricing reforms as a result. Indeed, tariffs have not changed since 2020, which was mandated by the Millennium Challenge Corporation (MCC) (Hughes et al. 2025).[8] Further MCC-proposed tariff reforms from the energy compact have not been implemented by the utility despite the utility's revenue losses (Hughes et al. 2025). McRae, Blimpo, and Steinbuks (2018) suggest that this norm directly leads to higher upfront connection fees.

Second, the utility has limited administrative capacity. The energy compact also implemented utility management reforms and set key performance indicators for the utility to meet. However, at the conclusion of the energy compact, none of the key performance indicators were met (Hughes et al. 2025). More broadly, Kojima and Trimble (2016) find that operational inefficiencies are a key driver for sustained losses in the power sector across sub-Saharan Africa.

Third, and perhaps a consequence of the first two constraints, the utility is credit constrained. Limited administrative capacity and pricing electricity below marginal cost lead to sustained losses, which limit its ability to finance new connections for consumers. A price schedule with a lower connection fee requires the utility to finance each connection upfront and recover the cost over time, which a loss-making utility is poorly placed to do. Outside of Benin, there have been several attempts to lower the connection fee by raising the marginal price or the repayment period.[9] Each of these programs required substantial outside financing. The Hybrid Electricity Customer Connection Credit Framework in Uganda was one such program that relied on the Global Energy Alliance for People and Planet (GEAPP, funded by the Rockefeller Foundation) and the Uganda Development Bank. However, conversations with program managers suggest that the program did not materialize once GEAPP withdrew their financing.

Informal reselling and the utility. The informal sharing of electricity (even if the household shares for free) is tolerated in practice, but technically prohibited (Autorite de Regulation de l'Electricite 2020).[10] The treatment of informal sharing is contrasted with electricity *theft*—which is illegal and

[7] The regulatory document from the electricity authority regulatory agency states: "The objectives of this Act are [...] to: [...] guarantee social and territorial cohesion by ensuring that all households have the right of access to electricity at an affordable cost" (Autorite de Regulation de l'Electricite 2020).

[8] Prior to the MCC-led tariff changes, electricity tariffs had not changed since 2009.

[9] Examples of these programs can be found in Côte d'Ivoire, Kenya, and Uganda (Agence Française de Développement 2012; Ministère de l'Économie et des Finances de Côte d'Ivoire 2022; Electricity Regulatory Authority 2023).

[10] If such sharing is detected, the utility holds the right to disconnect the household subscribed on the electricity meter. This does not happen in practice. Instead, it is implicitly promoted by other departments. A key input into reselling is "décompteurs," which are simple single-phase electricity meters that allow resellers to record how much electricity is used by their buyers. These "décompteurs" are sold by Agence de Contrôle des Installations Électriques et de l'Efficacité Énergétique (CONTRELEC), the agency that regulates electrical safety.

considered a criminal act. The penalties for theft are harsh: If caught, households can face up to two years of jail time and fines from 500,000 to 5,000,000 FCFA. These are heavily enforced, as the utility is incentivized to reduce non-technical distribution losses.

Conversations with utility officials and regulators suggest that they are tolerating the informal reselling of electricity for two reasons. First, the utility is paid for each kWh of informally distributed electricity. Second, there is, again, an established norm of electricity as a right (Burgess et al. 2020). They are willing to tolerate "reasonable" financial losses to ensure households can have access to electricity.

1.2. Data

We design and implement three rounds of surveys, administered over eight months. The surveys capture household characteristics, choice of electricity source and consumption, and the price and non-price characteristics of electricity sources. We link the survey data to administrative data from the national electric utility to characterize the demand and supply of electricity.

The first survey round captures the market shares for each source of electricity and the identity of the resellers of informal electricity with a representative sample. We enumerate every household living in a market to estimate the market share of each source of electricity. The census thus constructs a representative sample of all households in Abomey-Calavi. The final sample consists of over 10,000 households across the 183 markets. The survey instrument captures basic information about household characteristics and the source of electricity. The census is the basis for the sampling frame for the experimental sample. Section 2.1.1 describes the experimental sampling procedure.

We construct the representative sample by sampling local "markets" in Abomey-Calavi as the basis for our data collection. We define a market to be a 377 by 377 meter square, which is constructed by aggregating 0.001 by 0.001 degree latitude and longitude cells (we used population rasters from WorldPop (2026)). Each market is intended to capture a "local" market for informal electricity reselling. Using collected GPS of resellers and buyers in the informal market, we find that 92% of informal buyers live within 377m of their reseller (Appendix Figure A2).[11] We randomly select 183 markets across seven out of the eight arrondissements in Abomey-Calavi (Appendix Figure A1 shows the study area and the markets enumerated in the census).[12] Appendix B details the construction of the markets.

The latter two rounds of the survey, baseline and endline, capture the electricity consumption of the households in the experimental sample and the price and non-price characteristics of each source of electricity. The modules on measuring the characteristics of electricity sources are adapted

[11] Appendix Figure A3 plots an example of the buyer and reseller recorded GPS in an enumerated market.
[12] We sample the markets such that no two markets are adjacent to each other.

from the Multi-Tier Framework Survey (World Bank 2026b). The baseline surveys the experimental sample, which includes over 4,000 households across 143 markets. Households in the experimental sample are randomly sampled from the representative census from the first round to participate in the experiment. The endline surveys the experimental sample and an additional 300 households who report solar as their main source of electricity in the census to capture characteristics of solar electricity access. These two rounds of the survey include modules on detailed household demographics, electricity consumption, and price and non-price characteristics of each source of electricity. For households that are reselling electricity, the survey instrument also asks for a complete roster of buyers. We measure the electricity consumption of informally connected households by taking meter readings at the baseline and endline.[13] Appendix Table A2 provides basic demographic summary statistics of the enumerated households across the census and the experimental sample.

We match each formally connected household in the experimental sample with their account records from the national utility, which we use to construct monthly electricity consumption. We use the survey record of the household's utility account number and name to match to the utility's administrative records. This enables us to observe electricity consumption across both formal and informal markets. We combine the prepaid transactions from the utility with the survey-collected prepaid balance of each household at baseline and endline to construct the *exact* electricity consumption and avoid imputing electricity consumption.

Appendix B provides details on the survey questions used to construct the variables used in the analysis.

1.3. Descriptive Facts on the Informal Electricity Market

We present seven facts on the demand and supply of informal electricity in Abomey-Calavi, using our census and surveys linked to utility records. We find that nearly half of all electrified households are informally connected. These households are poorer and consume much less electricity than formal households. Together with the utility, the informal market forms a price menu: an informal connection has a lower connection fee but a higher marginal price, and it has lower quality. The number and concentration of resellers vary widely across local markets, and resellers charge well above the formal tariff that they pay.

Fact 1: 22 percent of households are unelectrified. Table 1 shows the market shares of each source of electricity using the representative sample across 183 markets. We find that 21.9% of households remain unelectrified, implying a 78.1% electrification rate.

We follow the Multi-Tier Framework (MTF) Survey in assessing electrification status (World

[13] Appendix Figure A9 shows a photo of the informal meters.

Bank 2026b). In particular, some households may have small-scale solar lanterns that are only capable of lighting for a few hours a day. We follow the MTF's convention and consider a household as "unelectrified" if their solar lantern is incapable of charging a phone. Otherwise, a household is electrified if they are connected to the grid via informal and formal means or if their solar lantern can charge at least one phone. If a household reports that they are paying the utility for their electricity, they are considered formally connected to the utility. If a household reports that they are paying their neighbor or landlord for their electricity, they are considered informally connected.

Fact 2: Informal electricity makes up 55% of grid electricity connections. Table 1 also shows the share of households that are connected to the grid via informal and formal means. We find that 36.3% of all households report that they are informally connected, while 30.2% of all households report that they are formally connected and 10.6% access electricity through solar. If a household has multiple sources of electricity, we classify households based on their *primary* source of electricity.

We estimate that 55% of grid electricity connections are informal. Informal electricity connections are present across nearly all markets rather than concentrated in a few. Appendix Figure A7 plots each source's share across the 183 markets. Informal shares are dispersed across a broad range, with only 11 of 183 markets having no observed informal connections and a median informal share of 32.3%.

Fact 3: Informal electricity's market share has an inverted U-shape with income. Figure 1 plots the market share of each source of electricity by household income quintiles. The share of households with a formal electricity connection increases with quintiles of reported household income while the share of households with no electricity decreases. We find an inverted U-shape for the share of households with an informal electricity connection. This suggests that informal connections may serve households that value electricity but cannot afford the utility's upfront connection fee.[14]

Fact 4: Informal households consume less electricity than formal households. Figure 2 shows the distribution of monthly electricity consumption across households with formal and informal electricity connections. We find that households with an informal connection consume 21 kWh per month on average, while households with a formal connection consume 80 kWh per month on average. Despite the low average consumption in the informal sector, we find that informal electricity connections make up roughly 16.5% of all electricity consumption (Appendix Figure A14).

[14]Appendix Figure A5 plots the distribution of an asset index among households across different connection statuses and finds similar patterns. We also find that households with a formal electricity connection are more likely to have a formal bank account and to have attempted to borrow money in the past (Appendix Figure A6).

Fact 5: Informal electricity has lower connection fees and higher marginal prices. We find that households face a trade-off between the upfront connection costs and the marginal price of electricity. Informal electricity connections offer lower connection costs but higher marginal prices compared to the formal utility. Panel B of Figure 1 plots the average reported connection fees and marginal price of electricity across formal and informal electricity connections. We find that the average reported connection cost is 174 USD for formal connections while it is 61 USD for informal connections.[15] However, the marginal price for a kWh of electricity is 0.27 USD in the formal market while it is 0.47 USD on average in the informal market. Given that the informal resellers are formal households, this fact suggests that resellers are earning a large margin.

Fact 6: Informal electricity offers more payment flexibility but lower quality. Table 2 describes the differences in payment flexibility, electricity and installation quality. Panel A shows that 40 percent of informal households report that their reseller would allow them to make a delayed or reduced payment, compared to 11 percent of formal households. Panel B shows that informal electricity is less reliable than formal electricity. For example, informal households report that electricity is available for 87 percent of the peak hours, compared to 91 percent for formal households. Panel C shows that the installation quality of informal electricity is lower than that of formal electricity. For example, 18 percent of informal households have exposed wiring in their dwelling, compared to 14 percent of formal households. We find no evidence for increased fire risks from informal electricity connections (Appendix Figure A13).[16]

Fact 7: The number and concentration of resellers vary widely across local markets. Panel A of Figure 3 shows the distribution of the share of formal households that are informal resellers across local markets. Roughly 27 percent of formal households are informal resellers in the median market, but this share ranges from 3 to 100 percent across markets.[17] We find that concentration in the informal electricity market is also heterogeneous across local markets (Figure 3 Panel B). The largest reseller in the median market has a 50 percent informal market share, but this share ranges from 14 to 100 percent across markets.[18] As we describe in Appendix B, the informal electricity market is highly localized, with 92 percent of buyers living within 377 meters of their reseller. But within a market, about half of the informal buyers do not choose the closest reseller to them (Appendix Figure A4).

[15] Appendix Figure A8 shows the items covered by the connection fee for each source of electricity. We note that the connection fees for connections are not wholly set by the formal utility or informal resellers as the connection process also includes additional wires or wooden poles. In regions where households are required to pay for a grid extension to obtain a formal electricity connection, households are purchasing the meter while running additional poles and wires to their dwelling.

[16] We examine this by correlating self-reported instances of fires in the neighborhood against the number of informal electricity connections. This lack of association is robust to considering all self-reports and only self-reports from households that are formally connected to the utility. This is consistent with qualitative evidence from interviews with resellers. Because the households are directly connected to the resellers' homes, the resellers are incentivized to ensure that the connection is appropriately installed.

[17] The median market has four resellers and the market at the 95th percentile has 15 resellers.

[18] The median reseller, however, has one buyer.

2. Experimental Evidence on the Demand and Supply of Informal Electricity

Two factors are key to understanding how the informal provision of an alternative price schedule expands electricity access. The first is how households trade off the connection fee against the marginal price, which involves both the extensive and intensive margins of electricity demand. The second is how informal price schedules are determined in equilibrium, which involves the extensive and intensive margins of the supply of informal electricity. We design an experiment with the national utility that separately varies the informal connection fee and the formal and informal marginal prices. Because the resellers are themselves formal households, the variation in the formal marginal price also lowers the marginal cost of resellers. The experiment allows us to learn about: (i) the price elasticity of electricity demand at the extensive and intensive margins, (ii) the entry and supply elasticities of resellers, and (iii) the determinants of informal pricing. Overall, our experimental results suggest that households select into the informal market based on their demand for electricity. We also find that informal electricity supply responds to utility price changes, and that resellers may have local market power.

2.1. Experimental Sample and Design

In collaboration with the national utility, we design and implement an experiment that generates extensive margin (connection fee) and intensive margin (marginal price) price variation, where the variation in the formal marginal price is also a cost shock for informal resellers.

2.1.1. Experimental Sample

To construct the experimental sample, we randomly select households from a restricted sampling frame from the census. We make the following restrictions. We exclude households that were unable to articulate their electricity source during the census, households whose informal reseller is their landlord, households whose main source of electricity was through solar sources, and households who do not face a price per kWh in the informal market. We also restrict the set of markets eligible for the experiment to markets that have at least two households with an informal connection paying a per-kWh price. This results in 6,095 eligible households in 143 markets.

We randomly select households from the restricted sampling frame of 6,095 eligible households into the various treatment arms that we describe in the next subsection based on their electricity source at the time of the census. Our final sample consists of 922 households without electricity access, 1,302 households with an informal electricity connection, and 1,985 households with a formal electricity connection. Appendix C provides further details on each step of the restriction and the random selection process.

2.1.2. Experimental Design

Interventions. The first intervention considers the extensive margin by subsidizing the connection fee for a new informal electricity connection. We denote this intervention as *T1*. We consider high (T1a) and medium (T1b) subsidy arms. In the high subsidy arm, we offer a maximum subsidy of 50,000 FCFA (89 USD) while the minimum price that should be paid by the household is 5,000 FCFA (9 USD). The median household in the high subsidy arm received an 85 percent discount on the total connection cost. In the medium subsidy arm, we offer a maximum subsidy of 35,000 FCFA (62 USD) while the minimum price that should be paid by the household is 12,500 FCFA (22 USD). The median household in the medium subsidy arm received a 65 percent discount on the total connection cost.

To take up this subsidy offer, households have to first find a reseller and send a cost estimate to the implementation team. A licensed electrician from the implementation team will verify the cost estimate. Households also have the option to choose to contact the licensed electrician on the implementation team to provide the cost estimate and forgo their independent cost estimate. Both of the subsidy offers are valid for six months, from January to June. The six month period allow households sufficient time to find a reseller and to complete the connection process. Relative to other similar interventions on the extensive margin (Lee, Miguel, and Wolfram 2020; Grimm et al. 2020), our subsidy offer available for a relatively long period of time. For example, the subsidy offer in Lee, Miguel, and Wolfram (2020) lasted for 8 weeks.

The second intervention subsidizes the marginal price for informal households to understand their intensive margin demand for electricity. Treated households receive 125 FCFA (0.22 USD) per kWh for each unit of electricity they consume. We denote this intervention as *T2*. This subsidy roughly equalizes, on average, the informal marginal price with the utility. We use T2 to directly assess whether informal households would consume as much electricity as formal households if they faced the same marginal price.

The third intervention subsidizes the marginal price for formal households to understand their intensive margin demand for electricity and the supply of informal electricity. We denote this intervention as *T3*. All treated formal households, whether or not they resell, receive 75 FCFA (0.13 USD) per kWh for each unit of electricity that they consume or resell. This subsidy is equivalent to a 50% reduction in the formal marginal price of 150 FCFA (0.27 USD) per kWh.

To receive the intensive margin subsidies (T2 and T3), households send proof of payment and electricity consumption to members of the implementation team.[19] Once the household's identity and treatment status are verified, the implementation team rebates the appropriate subsidized amounts back to the household. To ensure the salience of the subsidy, enumerators call the house-

[19] Households without the ability to electronically send the necessary information are visited once a month to process the subsidies.

holds every two weeks to remind them of the subsidy. Both subsidies are valid for five months, from February to June.

Randomization. We first randomize T3 across markets, and then stratify the household randomization of T2 and T1 by market treatment (T3) status. T3 generates local market cost shocks, which we use to measure how equilibrium prices in the informal market respond. T3 approximates a reduction in the utility's marginal price that would lower the costs of all formal households at once.[20] Figure 4 summarizes our experimental design. We randomize T3 across 145 eligible local markets, 143 of which are realized in the final experimental sample, and assign 72 markets to the subsidy arm.[21] *All* households with a formal electricity connection at baseline within treated markets are offered T3. In total, there are 1,985 households with a formal electricity connection in the experiment.[22]

We randomize T2 across 1,292 households with an informal electricity connection at census, of whom 1,181 complete the baseline survey and 1,145 remain informally connected at baseline.[23] We stratify the random assignment by whether a household lives in a T3-treated market.

We randomize T1a and T1b across a sample of 1,356 households, of whom 1,258 complete the baseline survey. T1 assignment is also stratified by whether a household lives in a T3-treated market. The T1 sample consists of 1,138 households without electricity access at census, 99 households with an informal connection at census, and 119 households with a formal connection at census.[24] The T1 and T2 samples are disjoint by construction. The T1 and T3 samples are mostly separated except for the 119 formal households who are eligible for both T3 and T1.

Attrition. Attrition is balanced across treatment and control arms of each experiment (Appendix Table A1). There are two sources of attrition. First, we assign households to treatment arms after the census, but prior to the baseline. Households are informed of their treatment status at the end of the baseline. But some households may not be reachable at baseline or may have experienced a change in status that made them ineligible. We see an overall attrition rate of 10.1%. Second, we also see a 16% attrition rate between endline and baseline. Most of this attrition was due to participants moving out of the neighborhood.

[20] Equilibrium prices respond differently to firm-level and market-level cost shocks (Muehlegger and Sweeney 2022).

[21] In the two markets that dropped out of the experiment, the village chief denied the baseline surveys despite the approval from the head of the district. We kept the original treatment assignment and did not re-randomize assignment.

[22] As Appendix Table A1 shows, there were 2,375 households at the census who were formally connected, which is the number we show in Figure 4. As we describe above, attrition and census mismeasurement imply a final sample of 1,985 households with a completed baseline.

[23] We describe the reasons for this attrition in Appendix C. Baseline survey attrition is balanced across treatment and control arms of each experiment (Appendix Table A1). All counts exclude 25 households (8 in T1, 17 in T2) assigned in the two markets where our field team could not operate; none completed a baseline interview.

[24] We do not condition on baseline electricity source when randomizing T1 because it is possible that households may be interested in switching between resellers or sources of electricity. Otherwise, if the extensive margin price instrument is conditioned on baseline status, the instrument would be conditional on unobserved preference shocks.

Balance. A joint F-test across all three experiments shows that we cannot reject the null hypothesis that the treatment and control groups are balanced across all covariates we consider (Appendix Table A3). Appendix Table A3 also shows the pairwise balance tests between each treatment arm and control group on household covariates including demographic variables and baseline electricity consumption across T1, T2, and T3. This balance test is conducted on data collected at baseline, accounting for the attrition from assignment to baseline data collection. We find slight imbalances in the asset index and in the share of households that are in the bottom income quintile in T2, and slight imbalances in pre-period consumption among formal households in T3.

Take-up. We show the take-up rates of the treatments in Appendix Table A4. We find that 50% and 56% of households took up the medium and high extensive subsidies in T1, respectively. Roughly 80% of households in T2 and T3 ever took up the consumption subsidies. Conditional on taking up, we find that the average informal household in T2 redeemed their subsidy 3.7 times (out of 5 months total). Formal households in T3 redeemed their subsidy 9.3 times (prepaid customers can top up multiple times per month). Relative to the total number of prepaid top-ups households made, this is 65% of their total top-ups during the subsidy period.

2.2. Experimental Results

We present the reduced-form results that characterize the demand and supply of informal electricity in this subsection.

2.2.1. Empirical Approach

We present the intent-to-treat effects and the instrumental variables estimates of the elasticities, using experimental assignment to instrument for the relevant prices. We estimate the intent-to-treat effects by estimating variants of the following specification:

$$y_{im} = \beta_0 + \sum_{k=1}^{K} \beta_k \text{Subsidy } k_{im} + \gamma \boldsymbol{X}_{im} + \varepsilon_{im} \tag{1}$$

where we compare treatment arm k to the control arm. Across all specifications, we include baseline household demographics of household size and dwelling size in the vector $\boldsymbol{X}_{im}$ and control for baseline outcomes. We report heteroskedasticity-robust standard errors for T1 and T2 and standard errors clustered at the market level for T3.

We estimate the elasticities of demand and supply by instrumenting for the relevant prices

using the experimental variation. We estimate the following:

$$y_{im} = \beta_0 + \beta_1 \ln(\text{Price})_{im} + \gamma \boldsymbol{X}_{im} + \varepsilon_{im} \tag{2}$$

$$\ln(\text{Price})_{im} = \alpha_0 + \sum_{k=1}^{K} \alpha_k \text{Subsidy } k_{im} + \lambda \boldsymbol{X}_{im} + \varepsilon_{im} \tag{3}$$

where we include the same controls as in the intent-to-treat specification.

2.2.2. Demand for Informal Electricity

Extensive Margin. Subsidizing connection fees for an informal electricity connection (T1) increases the share of households with an informal electricity connection. We show the ITT in Column (1) of Table 3 Panel A. Relative to the control arm's probability of having an informal electricity connection (20.1%), the high connection subsidy increases the probability of having an informal electricity connection by 44.4 percentage points. The medium connection subsidy increases the probability of having an informal electricity connection by 43.4 percentage points. We do not detect any statistically significant differences in the probability of an informal electricity connection between the high and medium subsidy arms ($p = 0.793$).[25] When evaluated at the control group mean probability of an informal electricity connection, we estimate an own-price elasticity for an informal electricity connection of -2.69.

We find that households that connect due to lower connection fees consume less electricity, consistent with the descriptive evidence in Section 1.3. We compare the electricity consumption of households induced to connect by the connection fee subsidy against the electricity consumption of households informally connected in the control group. Column (2) of Panel A of Table 3 shows that households that were induced into connecting by the high and medium subsidies have 31 and 29 percent lower monthly electricity consumption relative to households that were informally connected in the control group, respectively.[26] While we lack the power to detect any differences between the high and medium subsidy arms, we find consistent evidence where the coefficient is more negative in the high subsidy arm.

Intensive Margin. Subsidizing informal households' electricity consumption for five months by an average of 50 percent increases their average monthly electricity consumption by 10.5 percent ($p = 0.064$; Table 3 Panel A Column (4)). This reduced-form effect translates to an estimated own-price elasticity of informal electricity consumption of -0.24.[27]

[25] Take-up is higher in the high-subsidy arm (Appendix Figure A10), although endline connection rates are similar across subsidy arms. This pattern is consistent with more subsequent disconnection in the high-subsidy arm.

[26] We restrict the sample to households that are informally connected at endline and were not connected at baseline.

[27] This implies that the demand for electricity consumption among informally connected households is inelastic, at least in the short run over a period of five months. However, our estimates suggest that households in low-income

Our estimates on the effects of the subsidy on electricity consumption condition on households remaining informally connected at the endline as we cannot measure the consumption of households who have disconnected by endline. We find that over 8% of households in the control group are no longer informally connected at the endline. Relative to the control group, we find that treated households are 3.4 percentage points more likely to remain informally connected at the endline ($p = 0.035$; Table 3 Panel A Column (3)). We find that the subsidy was particularly effective at keeping households with lower consumption at baseline connected (Appendix Figure A11). This treatment effect at the extensive margin would bias the estimated own-price elasticity of electricity consumption toward zero.[28]

Even when prices are equalized between formal and informal households, we find that informal households consume less electricity than formal households. Assuming constant elasticity, our intensive margin estimates imply that lowering the informal marginal price to the utility's marginal price would close only about 9 percent of the gap in log electricity consumption between informal and formal households.[29] This suggests that the large observed consumption differences between formal and informal households are primarily driven by differences in the households' level of demand for electricity.

The results across the extensive and intensive margins suggest that households with lower demand for electricity are more likely to select into the informal electricity market, because it offers an alternative price schedule with a lower connection fee. While lower connection fees increase the share of households that are electrified, the marginal household demands less electricity than the average household. Consistent with this, informal households, even when facing the same marginal price as formal households, still consume far less electricity.

2.2.3. Demand for Formal Electricity

The intensive demand for electricity among formal households is also inelastic. T3 lowers the formal marginal price by 50 percent, but it raises the electricity consumption of formal households by only 4.8 percent (Column (2) of Table 3, Panel B), which implies an own-price elasticity of -0.15. Because we net out the resold amounts of electricity, there may be measurement error, which may be correlated with treatment since the subsidy may increase the amount of electricity resold. We estimate the supply effects in Section 2.2.4.

settings are more elastic than households in high-income settings. For example, Deryugina, MacKay, and Reif (2020) estimate that the own-price elasticity of electricity consumption is -0.094 over six months.

[28] We compute the Lee bounds for the ITT effect and find that the bounds on the difference in monthly electricity consumption between the treated and control groups are 4% and 18%.

[29] The calculation is as follows: $-0.24 \times [\ln(150) - \ln(262)] = 0.13$ log points. The gap in mean log monthly consumption between informal households in the T2 control group (2.35) and formal non-resellers in T3 control markets (3.90) is 1.55 log points (Column (4) of Panels A and B of Table 3). We note that our large price subsidies equalized the marginal prices between the informal sector and the utility. This exercise does not require substantial extrapolation.

Our preferred specification thus restricts to the sample of formal non-resellers (solo sample) to ensure our estimates capture the *demand* for formal electricity consumption. We find similar results where treated households have 6.1% higher electricity consumption during the subsidy period (Column (4) of Table 3 Panel B).[30] This reduced-form effect translates to an estimated own-price elasticity of formal electricity consumption of -0.19.

2.2.4. Supply of Informal Electricity

The subsidies in T3 also act as a market-level marginal cost shock to the informal electricity market because the resellers of informal electricity are themselves formally connected. We use this experimental variation to estimate the supply response of informal electricity at both the extensive and intensive margins. In the results we show below, we add controls for the baseline share of households that are unelectrified and the share of households that are resellers. We also control for the experimentally induced demand shocks: the number of households in each market receiving demand shocks from T1 and T2.

Extensive Margin. Subsidizing the formal households' electricity consumption increases the share of households that resell their electricity connection by 2.5 percentage points among formal non-resellers at baseline (Column (1) of Table 4). This is an increase of over 80% relative to the control group mean of 3.0%. This implies an elasticity of entry with respect to the reseller's marginal price of -2.48.

We do not detect any statistically significant differences in the probability of exit among households that were reselling their electricity connection at baseline (Column (2) of Table 4). We cannot rule out that resellers in treated markets are either 6 percentage points more or less likely to stop reselling by endline compared to resellers in control markets (the 95% confidence interval ranges from -0.066 to 0.060).

Intensive Margin. The supply of informal electricity also expands via baseline resellers serving more buyers. We estimate a statistically significant 12.2 percent increase in the number of buyers for resellers in treated markets relative to resellers in control markets (Table 4 Column (4)), which suggests an intensive margin buyer elasticity of -0.29.

We estimate that the total amount of electricity resold per month rises by 16.1 percent among treated resellers relative to control resellers, but this estimate is not statistically significant at conventional levels (Column (3) of Table 4). We find that the total implied elasticity of supply is -0.36, which is primarily driven by the increase in the number of buyers. However, we cannot rule out that the electricity sold per buyer has increased either given the large confidence intervals in

[30] In Appendix Figure A19, we compare how the subsidy affected *consumption* and *top-up*.

Column (5) in Table 4.

Pass-through. Given the effects of the formal consumption subsidy on the supply of informal electricity, we consider the effects of the formal consumption subsidy on equilibrium prices in the informal electricity market. The pass-through is informative of both the cost structure and the nature of competition in the informal electricity market. If there is constant marginal cost, perfect competition would predict full pass-through of the subsidy. If we reject full pass-through, it could suggest that marginal costs are not constant or that there is market power.

Despite more entry and more buyers per reseller, the formal consumption subsidy does not substantially affect the equilibrium marginal price in the informal market. We reject full pass-through of the formal consumption subsidy onto equilibrium informal marginal prices. We estimate that the average marginal prices in treated and control markets differ by -2.21 FCFA (0.004 USD) per kWh and that the 95% confidence interval rules out price decreases larger than 6.60 FCFA (0.012 USD) per kWh (Figure 5).[31] When we instrument for the reseller's marginal cost using the experimental variation, we find an average pass-through rate of 9.5% across markets, with a 95% confidence interval of $[-0.093, 0.284]$ (Appendix Figure A12).

We consider a suggestive test for market power by estimating the pass-through rate in markets with different levels of competition. The lack of full pass-through is consistent with increasing marginal costs (e.g., not perfectly elastic supply) and/or market power in the informal electricity market. But if the resellers' cost functions do not vary systematically with baseline levels of competition, then variation in pass-through across local markets with different baseline levels of competition can be informative about the presence of market power.

We find *suggestive* evidence that the pass-through rate increases with the share of formal households that are resellers in the market. The right three sets of estimates in Figure 5 present the difference in informal marginal prices at endline across market terciles of the baseline share of formal households that are resellers.[32] At the lowest two terciles, we cannot reject that prices between treated and control markets are the same. In the highest tercile of markets, we find that treated markets had informal prices that were 7.23 FCFA (0.013 USD) lower than control markets. The lower part of Appendix Figure A12 shows that the implied pass-through rate is 36.5% in the most competitive tercile of markets. We reject that the estimated pass-through rates between the top tercile and the lower two terciles are equal at the 10% level.

Incomplete pass-through could also reflect prices that do not respond to a subsidy that lasts only five months. But price stickiness alone does not explain why pass-through rises with competition. Our supply-side results are consistent with a broad class of models of oligopoly competition (e.g.,

[31] We also rule out price increases larger than 2.18 FCFA (0.004 USD) per kWh.

[32] Appendix Table **??** shows that the numbers of treated and control markets are balanced within each tercile.

Cournot or Bertrand) with constant marginal costs, where demand is not "too convex" (Ritz 2024).[33] Our conclusions here rest on the fact that the subsidies toward formal households were randomized at the *market* level rather than at the *individual* level, where individual-level pass-through of cost shocks may exhibit a gradient of pass-through rates that is attenuated, or even of the opposite direction (Muehlegger and Sweeney 2022).

2.3. Summary

The experiment illustrates how the demand and supply of the informal electricity market function. Informally connected households have lower demand for electricity, informal electricity supply responds to changes in utility prices, and resellers may have local market power. These results, however, leave three questions that require more structure. First, they do not show how households choose among all the price schedules available to them, from the utility and from resellers, when these sources also differ in quality (Section 1.3). Second, although the experiment provides evidence of selection, quantifying the degree of selection requires structure that connects each household's choice of source with how much electricity it expects to consume. Third, the experiment shows how resellers respond to one cost shock, but not how entry and pricing in the informal market would adjust in equilibrium under other utility policies, or how much of resellers' markups reflects their costs. We therefore develop an equilibrium model that adds this structure, which lets us quantify the extent to which the rigid price schedule limits electricity access and the consequences of the informal electricity market relaxing this rigidity.

3. Model of Electricity Demand and Supply

We extend the experimental results with a model of electricity demand and supply. We use the model to quantify the value of the informal electricity market and to conduct counterfactual policy analysis. The model allows us to estimate household demand for electricity over all sources of electricity and quantify the degree of selection by linking the household's choice on the extensive and intensive margins. It also separates resellers' markups from their costs of reselling, which lets us quantify market power.

In our model, households demand a source and amount of electricity to consume. We embed a consumer's preference for the amount of electricity in a discrete choice model (Dubin and McFadden 1984) with unobserved product characteristics (Berry, Levinsohn, and Pakes 1995). We incorporate entry into reselling as an additional choice in the demand system to capture the possibility that a household would only choose to be formally electrified if they were able to resell.

[33] The evidence is inconsistent with models of competition where pass-through rates generally do not depend on the intensity of competition (e.g., Salop or Hotelling-type models). Though, differential entry patterns in more competitive markets may also generate the result on pass-through. We do not find evidence that entry is concentrated in more competitive markets, but our test is rather underpowered.

Conditional on choosing to resell, informal resellers compete in a Nash-Bertrand pricing game. Informal prices are determined in equilibrium. We assume that the formal electricity and solar supply is perfectly elastic at observed prices.

3.1. Demand

We model consumer demand over electricity sources by combining a static discrete choice, random coefficients model (Berry, Levinsohn, and Pakes 1995, 2004) with the continuous choice of electricity consumption (Dubin and McFadden 1984; Benetton, Gavazza, and Surico 2025). In our model, households simultaneously choose the source of electricity j and the amount of electricity q to consume given their preferences. We consider the choices of all every household in our sample. The model explains the primary source of electricity for every household in our sample.

Choice set. In each market m, households i simultaneously choose from the sources of electricity available to them $j \in \mathcal{J}_m$. The outside option is to be unelectrified $j = 0$, where the indirect utility of this outside option is normalized to zero.[34] The set of available choices $\mathcal{J}_m$ includes: *Formal, no resale*; *Formal, resale*; *the set of informal resellers*; and *off-grid solar*.

Indirect utility. The indirect utility for each inside source j is given by

$$V_{ijm} = \mu_{ijm} + \delta_{jm} + \eta_{ijm} \tag{4}$$

The term δ_{jm} represents the mean indirect utility from each source of electricity, which is common across households in a market. It is given by

$$\delta_{jm} = \alpha_2 \boldsymbol{X}_{jm} + \xi_{jm} + \omega \pi^E_{jm} \tag{5}$$

where $\boldsymbol{X}_{jm}$ represents a vector of product attributes, such as frequency of outages or voltage. Mean unobserved source indirect utility (ξ_{jm}) is assumed to be known to households but not to the econometrician. For example, this may capture battery capacities that limit electricity usage for off-grid solar, or the hassle of dealing with a particular reseller over another, or perhaps the hassle costs of obtaining a formal electricity connection. The term π^E_{jm} represents the average variable payoff from reselling electricity in market m, which is zero for all sources except when j is an option for reselling. We discuss this further below. η_{ijm} is an idiosyncratic preference shock that is private information to the household and is not observed by the econometrician.

[34] We assume that households may only choose one source of electricity. Households may have multiple sources of electricity. For example, households may have basic solar lanterns in addition to a grid electricity connection in the case of power outages. In these cases, we view our problem as the households choosing their *primary* source of electricity.

The term μ_{ijm} represents the household-specific utility from each source of electricity:

$$\mu_{ijm} = -\alpha_f^i \bar{f}_{ijm} - \alpha_1^i x_i(p_{jm}) + \boldsymbol{\gamma}\, \boldsymbol{Y}_i \times \mathbb{1}(\text{Resell}_{jm}) \tag{6}$$

where $\bar{f}_{ijm}$ is the fixed connection fee for a source j, p_{jm} is the marginal price of electricity, $\mathbb{1}(\text{Resell}_{jm})$ is an indicator for the *Formal, resale* option, and $\boldsymbol{Y}_i$ is a vector of household characteristics that includes, for example, asset index and measures of credit constraints.[35] We specify $x_i(p_{jm})$ as

$$x_i(p_{jm}) = \frac{\exp(\beta_0^i)}{1+\beta_1^i}\,(\alpha_1)^{\beta_1^i} p_{jm}^{\beta_1^i+1} \tag{7}$$

We let the disutility from connection fee, level of (log) demand, and the price elasticity of electricity consumption $\theta_1^i = \{\alpha_f^i, \alpha_1^i, \beta_0^i, \beta_1^i\}$ vary by demographics and be affected by an unobserved preference shock:

$$\theta_1^i = \bar{\theta}_1 + \Pi \boldsymbol{Y}_i + \Sigma \boldsymbol{\nu}_i \tag{8}$$

r where $\boldsymbol{\nu}_i = (\nu_{i,f}, \nu_{i,0}, \nu_{i,1})'$ is a vector of household-specific preference shocks over the three preference parameters that are unobserved to the econometrician. We do not specify a random coefficient for α_1^i. We allow the unobserved components of α_f^i and β_0^i to be correlated (Σ is lower triangular). We do not allow for correlation between other preference shocks.

We allow households to value the fixed connection fee and marginal prices differently. Our approach is similar to Allcott and Wozny (2014), who estimate a wedge between the upfront and ongoing costs.[36] We can interpret the differences between how households value the fixed connection fee and the marginal prices as capturing their discount rate, any liquidity or credit constraints, and the expected connection length. Our approach implies that the relative valuation is constant across the electricity sources that the household may choose. We note that to interpret these as structural parameters, we assume that our counterfactuals do not change the household's discount rates or credit constraints.

We specify a static model of electricity demand.[37] There are two main reasons why this specification is appropriate in our context. First, our research questions do not require the dynamics

[35] We assume that f_{jm} does not vary across households in the formal sector within a market, but it varies across households within a market in the informal sector: $\bar{f}_{ijm} = \tilde{f}_{ijm}(d_{ijm}) + f_{jm}$. We let a household's connection fee vary by their distance to each informal reseller. The connection fees in the informal market consist of two parts: the installation charges that are paid to a third-party electrician, and the "advance" paid to the electricity reseller.

[36] We depart from their approach in two ways. First, by considering two separate coefficients for the upfront and variable costs, we do not make any assumptions on the household's discount rate. Second, we allow for household heterogeneity in the wedge through α_f. We discuss this further in Appendix A.

[37] Appendix A derives Equation 4 from a model in which households weigh the connection fee against the discounted cost of their future electricity consumption, assuming that they expect current prices to persist and that the discount rate and connection length are the same across sources.

of households' connection decisions. For example, our model does not describe the path or the timing of households' transitions between electricity sources. We are instead interested in how households sort across electricity sources under counterfactual policies, which we study by comparing equilibria of the static model. Second, the environment that households face has been stable: formal connection fees and tariffs have not changed since 2020 (Section 1). With stable prices, a household's connection decision reduces to a comparison of the connection fee with the present value of the electricity that it expects to consume. We further discuss the implications of the static model in Appendix A.

Choice probabilities and demand for electricity. We collect the model parameters as $\Theta = (\theta_1^i, \alpha_1, \omega)$ and $\delta_m = (\delta_{\text{Formal, no resale } m}, \delta_{\text{Formal, resale } m}, \delta_{\text{Informal 1 } m}, \ldots, \delta_{\text{Informal } J\, m}, \delta_{\text{Solar } m})$ and the characteristics of each source of electricity $C_{ijm} = \{\bar{f}_{ijm}, p_{jm}, \boldsymbol{X}_{jm}\}$. We write the probability that a household chooses product j' as:

$$\Pr(j'|C_{ijm}, \Theta, \delta_m) = \int_{\boldsymbol{\nu}_i} \Pr(j'|C_{ijm}, \Theta, \delta_m, \boldsymbol{\nu}_i) f(\boldsymbol{\nu}_i) d\boldsymbol{\nu}_i \tag{9}$$

$$= \int_{\boldsymbol{\nu}_i} \frac{\exp(\mu_{ij'm} + \delta_{j'm})}{1 + \sum_{j \in \mathcal{J}_m} \exp(\mu_{ijm} + \delta_{jm})} f(\boldsymbol{\nu}_i) d\boldsymbol{\nu}_i \tag{10}$$

We make two distributional assumptions. In writing Equation 10, we assume that the idiosyncratic preference shock is independently and identically distributed across households and electricity sources with type I extreme value distribution. This assumption, which is common in the discrete choice literature, delivers the choice probabilities in Equation 10. We also assume that the unobserved household-specific preference shocks $\boldsymbol{\nu}_i$ follow a multivariate normal distribution.[38]

The conditional demand for electricity can be derived using Roy's identity, where our parametric assumption on $x_i(p_{jm})$ implies a constant elasticity demand for electricity consumption at the intensive margin:

$$\ln q_{ijm}(\boldsymbol{\nu}_i) = \underbrace{\beta_0^i + \beta_1^i \ln \alpha_1}_{\tilde{\beta}_0^i} + \beta_1^i \ln p_{jm} \tag{11}$$

Equations 9 and 11 define a household's choice of electricity source and consumption given their preferences and product characteristics. Equation 11 provides a natural exclusion restriction: the fixed connection fee $\bar{f}_{ijm}$ does not affect household demand for electricity at the intensive margin. That is, conditional on a choice of electricity source j, the fixed connection cost $\bar{f}_{ijm}$ is sunk. Similarly, source characteristics do not affect consumption conditional on the discrete choice. Appendix A provides the formulas for the various share and quantity elasticities.

[38] We consider the log α_f and log β_1 during estimation to ensure that the estimated α_f^i and β_1^i have the expected signs across households.

Entry into reselling. We incorporate the household's choice of entry into reselling in the informal market through the demand model.[39] The household's entry decision depends on three terms. First, it depends on the average variable resale payoff, which we define as:

$$\pi^E_{jm} = \frac{TN_m}{N_m^{\text{Formal, resale}}} \sum_{k \in \mathcal{R}_m} (p_{km} - mc) q_{km} s_{km} \quad \text{if } j = \text{Formal, resale}, \qquad \pi^E_{jm} = 0 \text{ otherwise} \tag{12}$$

where $\mathcal{R}_m$ denotes the set of informal resellers in market m, $N_m^{\text{Formal, resale}}$ is the number of resellers, N_m is the number of households, s_{km} is the share of households that buy from reseller k, q_{km} is the average monthly quantity per buyer, and T denotes the average connection duration.[40] Second, it depends on the mean unobserved indirect utility of reselling, which can be interpreted as the unobserved fixed costs of reselling (and other unobserved market heterogeneity) when we difference the ξ's of the *Formal, resale* and *Formal, no resale* options $\left(\xi_{\text{Formal, no resale}} - \xi_{\text{Formal, resale}}\right)$. Finally, it depends on the unobserved household-specific preference for reselling $\eta_{i\,\text{Formal, resale}\,m}$. This preference shock is private information and is not observed by other households (or the econometrician).

Our specification assumes that the observed and unobserved components of the resale payoffs (π^E_{jm} and $\xi_{\text{Formal, resale}\,m}$) do not vary across households within a market. Households take these payoffs as given and do not anticipate the effect of their own entry on the shares or prices of other resellers. We allow entry probabilities to vary by observed household characteristics through μ_{ijm}. Our model implies that conditional on a formal connection and on $\boldsymbol{Y}_i$, every household in a market resells with the same probability. A household's decision to resell does not depend on its location (conditional on a formal connection). Conditional on being formally connected, households differ in their entry decision only through the private information $\eta_{i\,\text{Formal, resale}\,m}$, which is assumed to be independently distributed across households and unrelated to observed household characteristics.

Because households take the payoffs as given, we can separately estimate the demand and supply sides of the informal market. We use the fact that we observe the formal marginal price to construct the average variable resale payoff. If households accounted for the effect of their entry on the profits of other resellers, we would need to jointly estimate the supply and demand sides of the informal market.

We also specify a quasi-linear indirect utility function, which implies that there are no income effects from reselling. That is, the profits of reselling do not affect the household's electricity consumption. We assume that the demand and supply problems are separated in Section 3.2, which

[39] Our setting and model of entry relate to retail spatial entry problems (Aguirregabiria and Suzuki 2016). However, households' location choices are sunk in our setting. We treat that as exogenous so households are only considering *whether* and not *where* to enter.

[40] Note that this term is not discounted. We interpret ω as capturing the combination of the discount factor of future profits and the marginal utility of the resale payoff.

also implies that there are no income effects.

Despite these restrictions, the model still allows for flexible entry patterns in several ways. First, by embedding the entry decision into the demand model, we allow for the possibility that a household connects formally only because it is able to resell.[41] Second, the unconditional probability of reselling varies across households through μ_{ijm} beyond observed demographics, which reflects household heterogeneity in the decision to connect to the formal utility.

3.2. Supply

Informal supply. Conditional on choosing to enter as a reseller, households compete in a static Nash-Bertrand pricing game. We assume that the household consumption problem and the production problem are separate (Benjamin 1992). This assumption may be reasonable in our setting, where the flat tariff structure does not create a trade-off for households to choose between their own consumption and supply. As we discuss above, this also implicitly assumes that there are no income effects from reselling. Resellers are differentiated in their distance to each household (which affects the upfront connection fees that the household has to pay) and other observed and unobserved product characteristics such as their willingness to tolerate late or missing payments. Resellers face a constant marginal cost of providing an additional unit of electricity and supplying an additional buyer.[42]

Resellers set f_j and p_j, the fixed connection fee and the marginal price of electricity, to maximize their profits:

$$\Pi_{jm} = \max_{f_{jm}, p_{jm}} \sum_{i \in \mathcal{I}_m} s_{ijm}(\boldsymbol{f}_m, \boldsymbol{p}_m) \left[T q_{im}(p_{jm})(p_{jm} - mc_{jm}) + f_{jm} \right] - c_{jm}(N_m s_{jm}(\boldsymbol{f}_m, \boldsymbol{p}_m)) \tag{13}$$

Let $s_{ijm}(\boldsymbol{f}_m, \boldsymbol{p}_m)$ denote the probability of household i connecting to a reseller j; $s_{jm}(\boldsymbol{f}_m, \boldsymbol{p}_m)$ denotes the market share of reseller j in market m; T denotes the average connection duration; $q_{im}(p_{jm})$ denotes the conditional electricity demand of the buyers that reseller j faces from household i; mc_{jm} denotes the marginal cost of providing an additional unit of electricity; $c_{jm}(N_m s_{jm}(\boldsymbol{f}_m, \boldsymbol{p}_m))$ represents the cost with respect to the number of buyers. We note that the dependence on $\boldsymbol{\nu}_i$ is implicit in the i indices.

[41] An alternative approach would be to specify a separate model of entry among formally connected households that is jointly estimated with the supply model specified in Section 3.2. However, this approach would not allow households to choose to be formally electrified only if they are able to resell.

[42] We assume in Section 3.1 that mc_{jm} is equal to the formal marginal price. We test this using the supply model by comparing the estimated marginal cost per kWh against the formal marginal price.

Reseller j's first-order conditions with respect to its two choice variables are:

(14)

$$[f_{jm}]: \sum_{i \in \mathcal{I}_m} s_{ijm}(\boldsymbol{f}_m, \boldsymbol{p}_m) + \frac{\partial s_{ijm}}{\partial f_{jm}} \left[T q_{im}(p_{jm})(p_{jm} - mc_{jm}) + f_{jm} \right] - \frac{\partial c_{jm}}{\partial s_{jm}} \frac{\partial s_{jm}}{\partial f_{jm}} = 0$$

(15)

$$[p_{jm}]: \sum_{i \in \mathcal{I}_m} \frac{\partial s_{ijm}}{\partial p_{jm}} \left[T q_{im}(p_{jm})(p_{jm} - mc_{jm}) + f_{jm} \right] + s_{ijm}(\boldsymbol{f}_m, \boldsymbol{p}_m) \left[\frac{\partial q_{im}}{\partial p_{jm}} T(p_{jm} - mc_{jm}) + T q_{im}(p_{jm}) \right] - \frac{\partial c_{jm}}{\partial s_{jm}} \frac{\partial s_{jm}}{\partial p_{jm}} = 0$$

Formal supply. We assume that the formal utility supplies electricity (both connections and kWh) perfectly elastically at the observed prices. We believe that this is a reasonable assumption given that this paper focuses on one municipality rather than the whole country. We discuss the implications of the perfectly elastic supply for our counterfactuals in Section 5.

Solar supply. We assume that solar devices are supplied perfectly elastically at the observed prices. We also assume that firms that sell solar devices earn zero profits.

3.3. Equilibrium

In each market m, which households resell, and the prices $\boldsymbol{p}_m$ and connection fees $\boldsymbol{f}_m$ that these resellers set are determined in equilibrium. We impose two additional assumptions under which the number of resellers is sufficient to describe the set of resellers that households face. We assume that households only know the distribution of marginal cost per kWh, marginal cost per buyer, and reseller characteristics in the market, but not the values that they would have as a reseller if they decide to resell. We also assume that households and resellers act as if the expected number of resellers is present in the market. Together with the restrictions in Section 3.1, these assumptions imply that the distribution of the set of resellers depends only on the *number* of resellers.

The equilibrium that we consider is characterized by the number of resellers and the vectors of prices and connection fees such that (1) for each realization of the set of resellers, each reseller's price and connection fee satisfy Equations 14 and 15, given those of the other resellers; (2) each household chooses the source that maximizes its indirect utility, given prices, connection fees, and the resale payoff; and (3) the resale payoff equals the average variable profit of resellers, and the number of resellers equals the number of households times the share of households that choose to resell.

3.4. Welfare

We define the total private surplus in market m as the sum of consumer surplus, informal producer surplus, and utility producer surplus. We compute consumer surplus using the log-sum formula (Small and Rosen 1981). We remove the average variable resale payoff from the consumer surplus calculation to avoid double counting resale profits. We also consider an alternative measure of consumer surplus where we normalize by the mean marginal utility of income rather than the individual-specific marginal utility of income. We compute producer surplus in the informal market by measuring profits from reselling using the specified profit function in Equation 13. We use the standard formula when we add the consumer and producer surplus to compute total private surplus.

We measure producer surplus in the formal market by considering the utility's profits over the same horizon as the informal producers. We make several assumptions on the utility's cost function. First, we assume that the utility has a constant marginal cost per kWh and per electricity connection. Second, we assume that the utility loses 25 FCFA per kWh of electricity sold (La Marina BJ 2025). Finally, we assume that the marginal cost of extending a formal electricity connection is 100,000 FCFA (World Bank 2021b).[43] In the baseline, we do not consider the utility's discounting of the future revenue flows. We consider the sensitivity of our results to the utility's horizon and how the utility discounts future flows of revenue in Appendix Table A5.

4. Model Identification, Estimation, and Results

We estimate the model with the experimental variation. The experiments identify household price sensitivity at the extensive and intensive margins. Given the demand estimates, resellers' profit maximizing behavior identifies their costs. Our model estimates reveal that informal resellers make only modest profits due to the cost incurred per buyer.

4.1. Identification

The experimental price variation informs the identification of the model parameters. We discuss the "primary" sources of variation that intuitively identify a few key parameters in this subsection. We discuss the intuitive identifying variation for the rest of the parameters in Appendix A. The experimental variation identifies the price coefficients. Identification of the coefficients on other non-price characteristics comes from an assumption of their exogeneity to other unobserved

[43] In markets where the average observed connection cost is below 100,000 FCFA, we assume the utility makes a constant profit of 10,000 FCFA. This is because we impute 100,000 FCFA from policy reports that include pole extensions, but some markets may not need any additional extensions.

product characteristics.[44]

Mean taste for connection fee $\overline{\alpha}_f$. This is informed by the average take-up responses to the T1 connection fee subsidies (Table 3).

Unobserved heterogeneity in taste for connection fees Var(σ_{α_f}). Intuitively, the shape of the (aggregate) take-up in response to the T1 connection fee subsidies, conditional on demographics, provides identifying variation. If there is no unobserved heterogeneity, the logit structure fully determines the curvature of take-up as a function of the subsidy.[45]

Covariance between unobserved taste for connection fees and unobserved baseline consumption Cov$(\sigma_{\beta_0}, \sigma_{\alpha_f})$. The average consumption for those induced by treatment and control groups of T1 is informative of the marginal level of electricity consumption for those more/less sensitive to the fixed connection fee.[46]

Mean price elasticity $\overline{\beta}_1$. Average consumption response from the intensive margin treatments (T2 and T3) informs the mean consumption price elasticity (Table 3).

Mean (log) electricity consumption $\tilde{\beta}_0$. Average consumption levels in the control arm mean of T2 and T3 inform the level of electricity consumption.

Utility of resale payoff ω. This is informed by the effect of subsidizing formal electricity consumption (T3) on the probability of entry into reselling among households who did not resell (Table 4).

4.2. Estimation

We estimate the model in two steps. First, we estimate the mean indirect utilities δ_{jm} and the parameters θ_1 that enter household-specific choices. We then use the δ_{jm} to estimate the average effects of product characteristics and recover the mean unobserved indirect utilities ξ_{jm}. We use the modified nested fixed point algorithm for micro-BLP outlined in Conlon and Gortmaker (2024). In our main results, we do not rely on the second step of the estimation to avoid the assumption that non-price product characteristics are exogenous to unobserved product characteristics.

We estimate the first step by the Generalized Method of Moments (GMM). We intentionally specify a parsimonious model such that the moment conditions we use to estimate the model

[44] In the main text, we do not project the mean indirect utility of each source onto non-price characteristics to avoid this assumption.

[45] This attributes imperfect experiment take-up unexplained by demographics to preference heterogeneity.

[46] Note that $\text{Cov}(\sigma_{\beta_1}, \sigma_{\alpha_f}) = 0$ is also relevant here as any potential variation that stems from $\text{Cov}(\sigma_{\beta_1}, \sigma_{\alpha_f})$ would be included in $\text{Cov}(\sigma_{\beta_0}, \sigma_{\alpha_f})$.

are experimentally derived (as we specify in Section 4.1). In the second step, we project the estimated mean indirect utilities δ_{jm} onto the non-price product characteristics to recover the mean unobserved indirect utilities ξ_{jm}. Appendix A provides the formal definition of moments and the objective function and additional estimation and computational details.

We categorize our moment conditions into four categories. The first set of moments is source-by-market market shares—which is used to solve for the mean indirect utilities for any given candidate preference parameters θ_1. This ensures that the model fits observed market shares exactly and reduces the number of parameters to be estimated in the nonlinear step. The second set of moments is the "intent-to-treat" moments of each experiment: treated and control comparisons of connection take-up and consumption. The third set of moments is "complier" moments that compare the consumption of those induced to connect to an informal connection by the experiment to those in the control group. We also interact each of these sets of moments with household demographics—similar in spirit to heterogeneous treatment effects. The fourth set consists of second moments for consumption and connection fees, interacted with the experiment instruments.

We use the estimated demand parameters to invert the marginal cost and per-buyer cost implied by the system of first-order conditions in Equations 14 and 15. We assume a horizon of 2 years, which is the average length of an informal connection in the data.[47]

We compute standard errors from a joint "sandwich" that stacks the linear and nonlinear stages of demand estimation. We compute the standard errors for the marginal cost and per-buyer cost using the delta method. We report conservative standard errors that cluster at the market level to reflect the market-level randomization of T3.

4.3. Results

4.3.1. Parameter Estimates

Table 5 reports the parameter estimates of the equilibrium model obtained from the experimental moments described above.

Demand parameters. We find that the median household has a higher disutility over a dollar of spending on the connection fee compared to spending on monthly electricity consumption (median $\alpha_f = 0.938$, median $\alpha_1 = 0.726$; Panel A of Table 5). This wedge can reflect credit constraints, high discount rates, or uncertainty about how long a connection lasts. Consistent with credit constraints, households that want credit are more sensitive to the connection fee, and wealthier households are less sensitive. Wealthier households are also less sensitive to prices in general and have higher baseline demand for electricity. Consistent with this interpretation, we find that less

[47] This calibration implies that resellers have rational expectations over the connection length of each buyer.

credit constrained and wealthier households have a lower connection fee disutility (Panel B of Table 5 shows the demographic interactions and random coefficients).

We estimate substantial unobserved heterogeneity in the connection fee disutility (α_f), and households that are more sensitive to the connection fee also demand less electricity, even conditional on demographics ($\rho(\tilde{\beta}_0, \log \alpha_f) = -0.86$). This is consistent with the experimental findings in Section 2 in Table 3. Allowing for flexible correlation between the unobserved preference shocks for connection fee disutility and baseline electricity demand allows us to consider the degree of selection. We show the distribution of the preference parameters in Appendix Figure A15.

Entry. We estimate that households value the resale payoff quite substantially ($\omega = 2.86$). This is consistent with the large response we observe in the experimental entry response to the T3 subsidy (Table 4). We do not specify heterogeneity in how households respond to the resale payoff, but we allow for observed heterogeneity in the propensity to resell. We estimate that wealthier households and less credit constrained households are less likely to resell electricity. This is consistent with the flexibility we wanted to capture in the model, where the option of resale can induce the marginal households to connect to formal electricity.

Costs. We estimate that the median marginal cost of electricity is 162 FCFA per kWh (standard error 6.13 FCFA per kWh) and the median per-buyer cost is 40,105 FCFA per buyer (standard error 4,409 FCFA) over two years (Panel C of Table 5). Appendix Figure A16 shows the distribution of the estimated marginal costs and the per-buyer costs.

Our cost estimates are broadly consistent with the role of informal resellers. First, the median estimated marginal cost of electricity is close to the formal marginal prices (162 vs. 150 FCFA per kWh). This is consistent with the idea that informal resellers are purchasing electricity at the formal tariff and reselling it to other households. The slightly higher estimated marginal cost may reflect potential line losses from poorer wiring quality that transmits electricity from informal resellers to buyers.[48] The consistency between the estimated marginal cost and the formal marginal price provides an informal untargeted validation of the estimated model.

Second, we estimate that the median per-buyer cost exceeds the median connection fee that the reseller receives. Over two years, this implies a monthly recurring cost of 1,670 FCFA. This result is consistent with standard theory on two-part tariffs, in which consumer demand heterogeneity can lead firms (that do not price discriminate) to set per-unit prices above marginal cost while lowering entry fees to retain low-demand consumers. Resellers do not have to undertake any particular investments in order to resell electricity, as it is the buyers who pay for the wires, poles, and meters necessary for a connection. The per-buyer cost we estimate can be interpreted as an effort cost to

[48]The estimates imply a median transmission loss of 8%—which is in line with transmission and distribution losses in developing settings which are on the order of 10–20% (World Bank 2024).

collect payments and enforce against non-payment. We decompose the intensive margin price markup in the next subsection.

4.3.2. Model-implied Elasticities and Markup

Elasticities. We use the estimated model to compute the implied own- and cross-price elasticities with respect to both the connection fee (Panel A) and the marginal price (Panel B) in Table 6 across formal and informal sources of electricity.[49] Our model of electricity demand captures flexible substitution patterns across sources of electricity.

We estimate that households are much more elastic to the connection fee than the marginal price (own-connection-fee share elasticities range from -1.96 to -1.1 while own marginal price elasticities range from -0.07 to -0.15). We estimate that resellers are more elastic to connection fees and to marginal prices than formal non-resellers and informal households. This is consistent with the idea that resellers include households that are induced into formal electricity from the option to resell electricity. Consistent with Burgess et al. (2025), we find that households are the most elastic to off-grid solar electricity.

Cross-price elasticities show the substitution patterns. We find that an increase in the formal connection fee would primarily divert households to informal and solar sources of electricity, and very little to the outside option of no electricity.[50] An increase in the informal connection fee would primarily leave households without an electricity connection. An increase in the price of solar would divert households primarily to formal sources of electricity.

We estimate slightly different substitution patterns for a change in the marginal prices compared to connection fees. Given an increase in the formal marginal price, much of the diversion is to an informal electricity connection rather than solar or the outside option. If the marginal prices in the informal sector increase, households are more likely to switch to formal electricity rather than the outside option, unlike the increase in the informal connection fee.

Markups. We decompose the intensive margin markup at the observed quantities and find that for the median reseller, 70 percent of this markup is due to the losses incurred from the per-buyer costs. Thus, the large observed differences in the marginal prices between the formal and informal sectors are mostly due to the fixed costs of reselling electricity. However, we find that there is a rather wide distribution of the share of the observed markup that is due to the per-buyer costs (Appendix Figure A17). This suggests that the median reseller only earns modest profits from

[49] We consider elasticities with respect to *all* informal resellers in this table and report reseller-specific own- and cross-price elasticities in Appendix Figure A18.

[50] This analysis fixes the supply of informal electricity. In the counterfactuals, the supply of informal electricity would also change given a change in connection fees.

reselling—only 1,499 FCFA per month (2 percent of the median household income).

5. Counterfactual Policy Analysis: Rigid Pricing Structure and Electricity Access

We use the estimated model to evaluate counterfactual policy scenarios that allow us to infer the value of the informal electricity market and its policy implications. The informal market substantially expands electricity access and raises total surplus, especially for poorer households. But if the utility were not limited to a single price schedule, a price menu with the same connection fee as the informal market would raise total surplus by more than three times as much, and the informal market would largely disappear.

5.1. Simulation Algorithm

We consider four scenarios. The status quo is the simulated current equilibrium. An informal market ban removes the informal market. The utility menu adds a low-fee schedule (a 30,000 FCFA connection fee and 212 FCFA per kWh) to the utility's current price schedule, and resale remains allowed. The utility menu with the informal market ban adds the same low-fee schedule and bans resale.

To conduct counterfactual policy analysis, we simulate how the equilibrium in the informal market responds to changes in the policy environment. Households choose whether to resell and set their connection fee and marginal prices.

In our simulations, we first introduce a counterfactual policy environment (e.g., the informal market ban). Given the estimated preference parameters, households then choose the sources of electricity that maximize their utility and, in particular, whether to resell electricity. Consistent with the assumptions in Section 3.3, each reseller receives a random draw of its marginal costs and characteristics from the market distribution of estimated cost and characteristics. Given the costs, a household that chose to be a reseller would compete against other resellers by choosing the connection fee and marginal prices (f_{jm}, p_{jm}) by solving the first-order conditions in Equations 14 and 15.

We separately solve for the equilibrium in each market with two nested loops. We initialize the algorithm using the observed values of π_m^E, f_{jm}, and p_{jm}.[51] The outer loop is a fixed point over the average resale payoff, where for a given resale payoff, households choose their source of electricity, which determines the number of resellers in the market. The average resale payoff is a function of the average number of buyers, quantities, and prices in the informal market (Equation 12). These market averages are determined in the inner loop, which jointly solves for the set of connection fees and marginal prices that satisfy the first-order conditions for the set of resellers that entered

[51] If a reseller that we do not observe in the data chooses to enter, it is initialized with the market median prices.

from the outer loop. The outer loop stops when the average resale payoff implied by the inner loop equals the resale payoff that households used to decide whether to resell.

We report the results of all counterfactual scenarios in Table 7. We compare each scenario to the informal market ban. The first row thus compares the status quo to the informal market ban. This enables us to compare the gains from various policy scenarios to the gains from the informal electricity market.[52]

5.2. The Value of the Informal Electricity Market

We consider the informal market ban and find that the informal electricity market meaningfully expands electricity access. We do so by removing the informal electricity market from the households' choice sets (Trajtenberg 1989; Petrin 2002). Electrification rates under the informal market ban would be 59.6 percent, compared to 77.1 percent in the status quo (Figure 6). The increase in the share of electrified households is driven by the informal electricity market electrifying households who would otherwise be unelectrified. We find that 57 percent of baseline informal households would become unelectrified in the counterfactual, while 34 percent would choose to be formally connected and 9 percent would choose to use solar. We find that only 1.6 percent of formal resellers would become unelectrified.

The increase in electrification rates translates into a gain of 9.6 percent in total surplus (Panel A of Table 7). As we describe in Section 3.4, we consider two measures of consumer surplus—the first weights each household's surplus equally with a common marginal utility of income; the second is the standard money-metric measure of consumer surplus. We find a larger percentage increase in consumer surplus when weighting each household's surplus equally (19.4 percent) relative to the standard measure (8 percent). Informal resellers earn 51.8 million FCFA (92,500 USD) in profits over an expected two years of reselling. We find that the utility's losses would rise by 7 percent as the total amount of electricity consumed increases slightly with the informal electricity market (Appendix Figure A20).

Consistent with how market shares of informal electricity change with income in Section 1.3, the informal market appears to mainly benefit less wealthy and lower-income households. The differences in the gains in consumer surplus between the two measures suggest that the informal electricity market is particularly important for households at the bottom of the wealth distribution. Panel B of Table 7 shows that households in the bottom quintile of the wealth distribution would gain 38.6 percent of their surplus from electrification with the informal electricity market. Households in the top quintile would gain only 5.6 percent.

These results suggest that, while the informal electricity market is expanding electricity ac-

[52]The status quo re-solves the model using the estimated parameters and the observed policy environment.

cess, the marginal households it connects consume relatively little electricity. Total electricity consumption would fall by only 2.5 percent under the informal market ban (Appendix Figure A20). The informal households that would become unelectrified consume 13.7 kWh per month. But the informal households that would instead connect formally would more than double their consumption—from 31 to 66 kWh per month, which offsets most of the lost consumption. However, the households that would become unelectrified value the little electricity that they consume highly. Their loss in consumer surplus amounts to roughly 1,700 FCFA per kWh that they no longer consume (5,400 FCFA under the standard measure), about seven to twenty times the price that informal buyers pay.

5.3. Utility Price Menu

We relax the constraint that the utility can only offer one price schedule and find that the gains from the utility offering a price menu exceed the gains from the informal market. We consider various low-fee schedules that the utility could offer that do not incur additional losses. We simulate two scenarios for each low-fee schedule: one in which the informal market is banned and one in which it is allowed. Our main counterfactual policy in Table 7 considers a low-fee schedule that offers the same connection fee as the median informal connection fee (30,000 FCFA) and a marginal price that implies that the utility would not incur any additional losses relative to the status quo (212 FCFA per kWh).[53]

We find that if the utility is able to offer a low-fee schedule that features the same connection fee as the median informal connection fee, the informal market no longer generates any substantial gains (Panel A of Table 7). The low-fee schedule would increase total surplus by 34.6 percent under the utility menu with the informal market ban and 35.4 percent under the utility menu. This suggests that the informal market does not generate substantial gains when the utility is able to offer a price schedule that rivals the informal market's. Consistent with this, the informal market practically unravels as only 1.3 percent of households would be informally electrified (Figure 6).

The availability of a price menu from the formal utility would benefit the less wealthy households the most (Panel B of Table 7). Households in the bottom quintile of the wealth distribution would gain 129 percent in consumer surplus. We find that households in the top quintile of the wealth distribution would also gain 24.6 percent in consumer surplus. This is because nearly all formal households would choose the low-fee schedule rather than the current price schedule.

[53] In our main counterfactuals, we ignore the cost to the utility of paying for each connection upfront and recovering the cost over time (e.g. the utility does not discount). This may be difficult for a utility that already loses money (Section 1.1). Appendix Table A5 shows the sensitivity of the calculation of the marginal prices that ensures that the utility does not incur additional losses. The Ministry of Energy conducts its analysis assuming a 10 year horizon and a 10 percent discount rate, for which at the same connection fee of 30,000 FCFA, the marginal price would be 163 FCFA per kWh. We view our main counterfactuals as a more conservative estimate of the gains from the utility offering a low-fee schedule, as it would require the utility to raise the marginal price to 212 FCFA per kWh to avoid additional losses.

We find that the informal market adds value only when the utility's connection fee is high. Appendix Figure A21 shows the gains in consumer surplus from low-fee schedules with different connection fees, each with the marginal price that keeps the utility's losses at the status quo level. Lower connection fees generate larger gains: consumer surplus increases by 47.8 percent with a connection fee of zero and a marginal price of 281 FCFA per kWh, compared with 16.3 percent with a connection fee of 100,000 FCFA and a marginal price of 164 FCFA per kWh. The informal market adds to these gains only when the connection fee is high. With a connection fee of 100,000 FCFA, consumer surplus increases by 16.3 percent under the utility menu and by 9.9 percent under the utility menu with the informal market ban.

6. Conclusion

Solving the challenge of expanding electricity access will be critical for economic development (Greenstone 2024). Yet, many households in developing countries remain unelectrified despite decades of effort (IEA 2024).

This paper's central contribution is to propose and evaluate a new explanation for this persistent challenge: a rigid price schedule that charges all households the same connection fee and marginal price. We document a large informal electricity market in Abomey-Calavi, Benin, where households with utility connections resell power to their neighbors at lower connection fees and higher marginal prices. This informal market provides a valuable setting to study how the rigid pricing structure of the utility limits electricity access. It completes a "missing" market for an alternative price schedule. Through novel data collection, a large-scale field experiment, and an equilibrium model, we show that the informal market has substantially increased electricity access and household welfare. But a price menu offered by the utility itself would increase electrification and total surplus even more. Altogether, our results suggest that the rigid price schedule of the utility is a key constraint on electricity access.

Our results add a new perspective to the literature on electricity access in developing countries. The predominant explanation for the challenge of expanding electricity access has been that households are not willing to pay the high connection fees set by the utilities (Lee, Miguel, and Wolfram 2020). This paper complements this explanation—we show that while households are not willing to pay the high connection fees, they are willing to pay higher marginal prices for electricity. The latent demand for alternative price schedules indicates the gains from introducing a price menu. Indeed, we document an informal solution that has emerged in Abomey-Calavi, Benin.

While we focus on one city, our findings can inform electrification policies in other settings. Many utilities in sub-Saharan Africa offer households a single price schedule with high connection fees and low marginal prices (Golumbeanu and Barnes 2013). Many utilities "tag" electricity customers by whether they are a household, a small business, or an industrial customer. But they

do not offer different price schedules to induce self-selection among customers with different electricity demand.

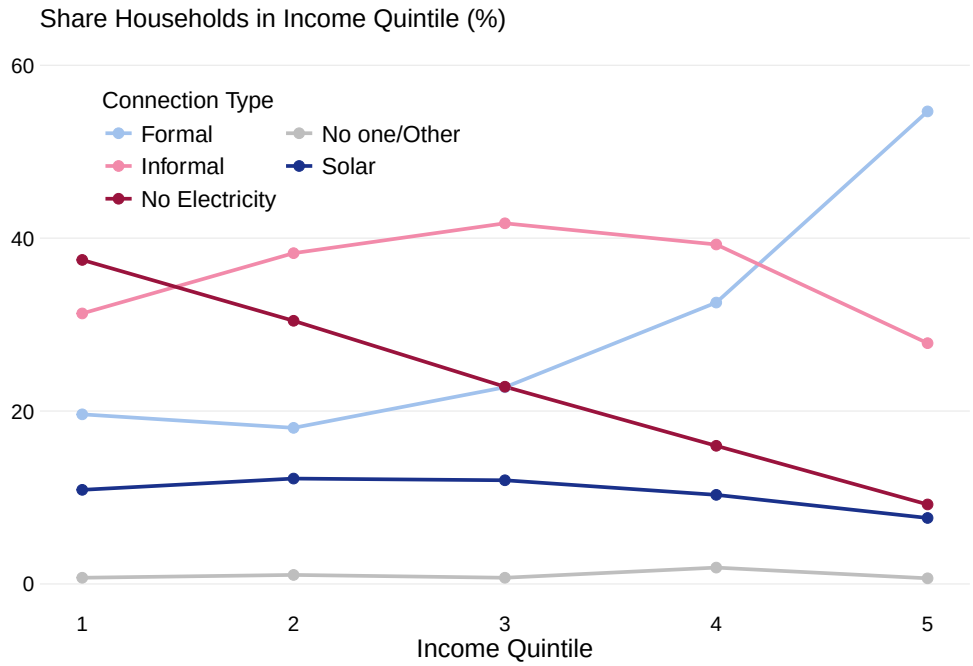
Moreover, the informal electricity market is not unique to Abomey-Calavi, Benin. Informal resale with similar features (low fixed cost, high variable cost) has been documented in other cities across sub-Saharan Africa (Franks and Prasad 2014; Houngbonon, Le Quentrec, and Rubrichi 2021; Mensah 2022; Jacques Fotso, Mvogo, and Bidiasse 2023; Kersey et al. 2025). More generally, while this informal market is *one* organic response to the rigid pricing scheme, it can also manifest in other ways. For example, households may directly steal electricity (Burgess et al. 2020). Our explanation rationalizes these behaviors as responses to the rigid price schedule of the utility.

Our analysis leaves several questions for future research. First, our results do not speak to the constraints that utilities face to offer a price menu. While we may interpret the gains from the counterfactual price menu as a bound on the costs, it would be fruitful for future research to explore the constraints that utilities face in offering a price menu. Second, we consider only the short-run consequences of informal electricity access. Future research could explore the longer-run consequences of informal grid access, including changes in appliance ownership and electricity demand. Finally, we do not separately estimate effects on productivity or spillovers beyond the households served. Positive spillovers could provide an additional rationale for subsidizing electricity consumption or connection fees.

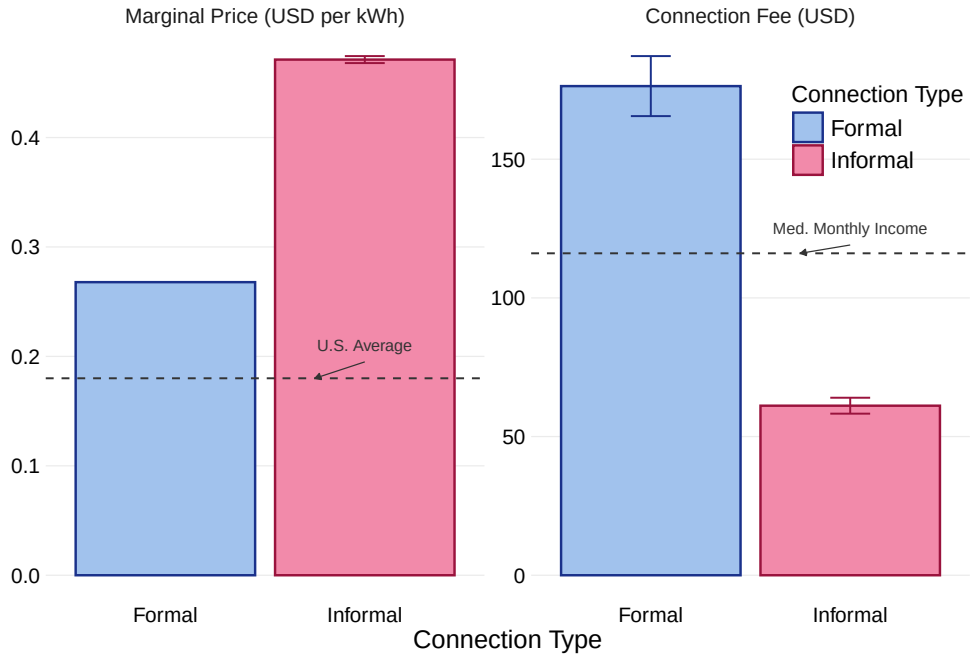
Figures

FIGURE 1. Electricity Sources and Prices in the Census Sample

Panel A. Market Shares of Electricity Sources in Census Sample

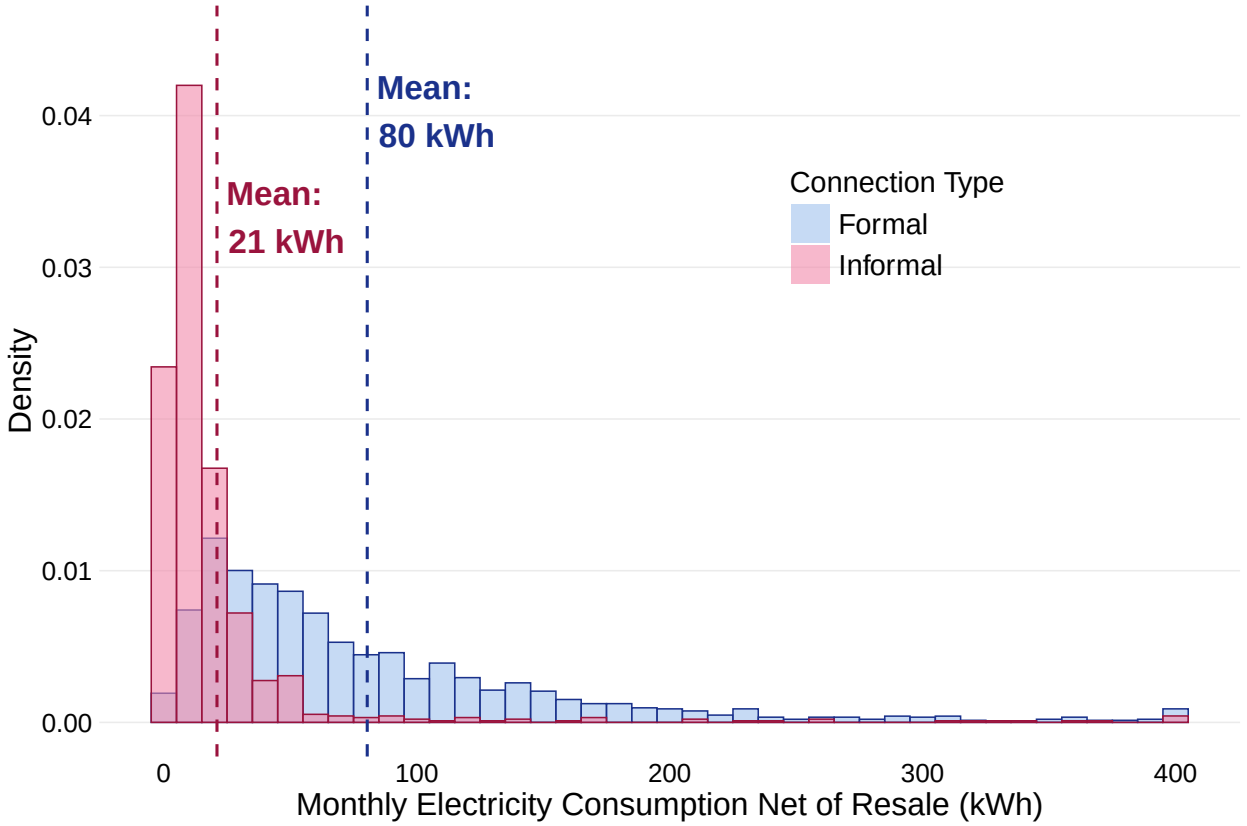


Panel B. Prices for Formal and Informal Electricity Connections



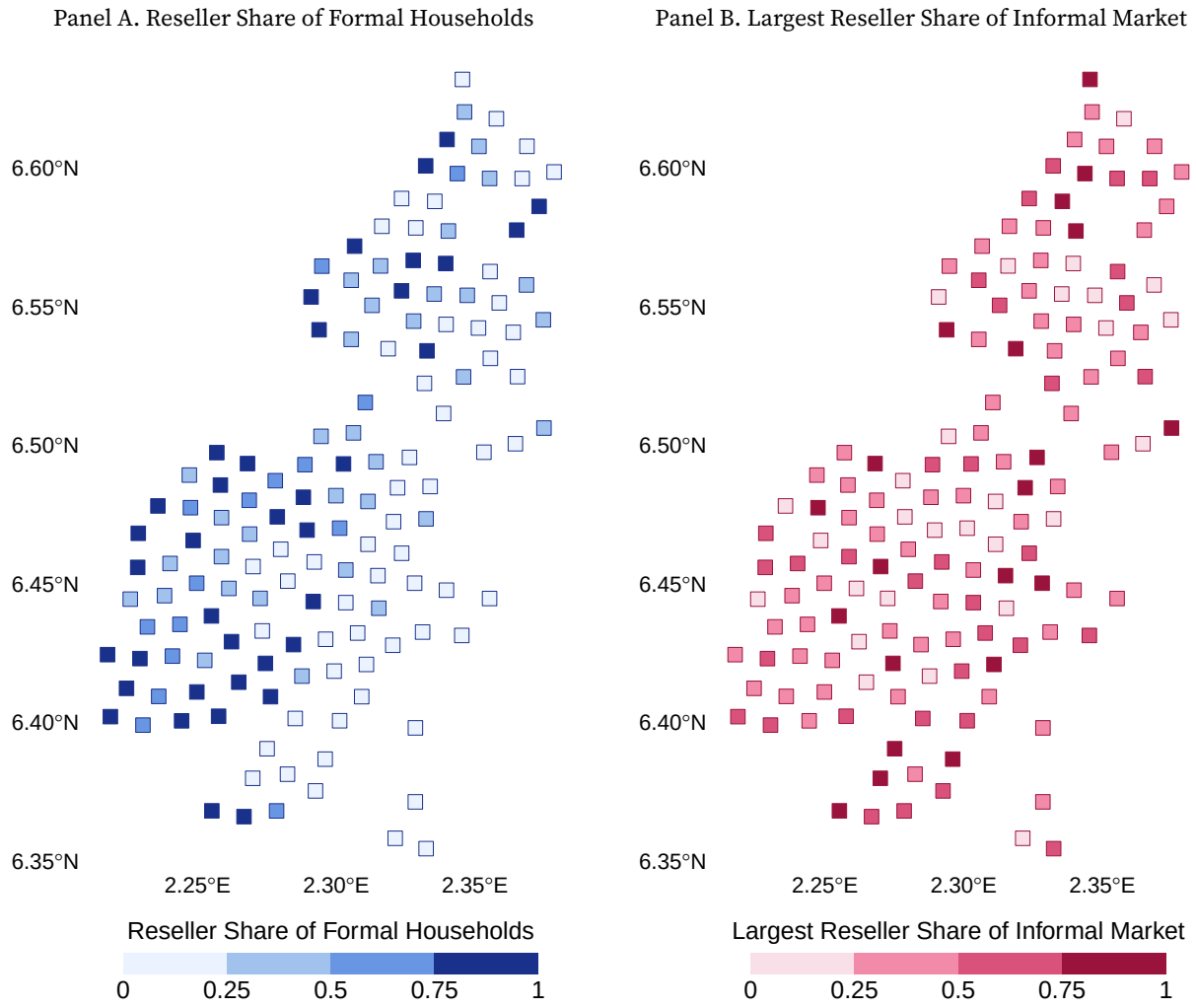
Notes: Panel A shows the market shares of electricity sources across quintiles of self-reported monthly household income in the census sample of 183 markets. Panel B shows the average self-reported connection fees and marginal price in the formal and informal markets from the baseline survey. There is no variation in the marginal price in the formal market because households face a flat tariff of 150 FCFA per kWh (0.27 USD per kWh). We plot the average US tariff and the median monthly income in our census sample as comparisons.

FIGURE 2. Distribution of Monthly Electricity Consumption by Connection Type



Notes: This figure shows the distribution of monthly electricity consumption by connection type in the baseline survey.

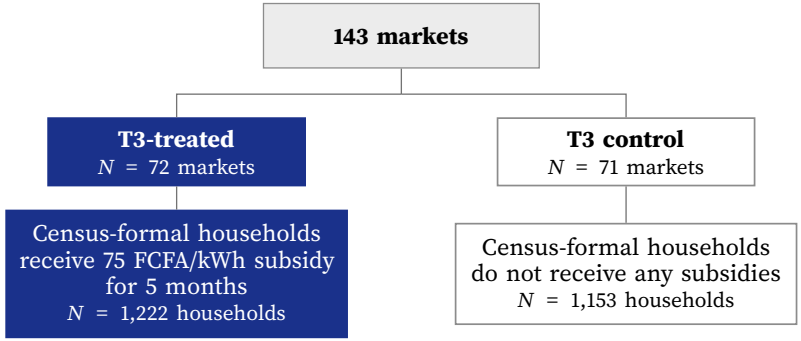
FIGURE 3. Spatial Distribution of Informal Markets



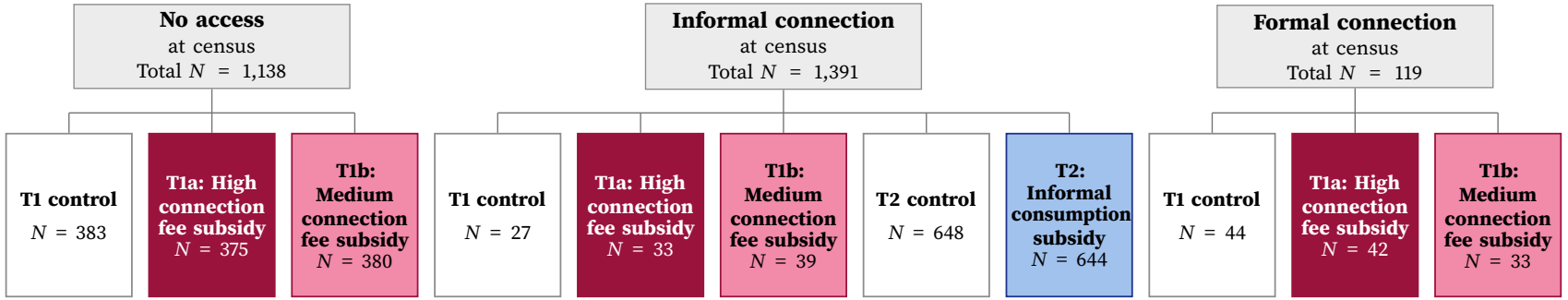
Notes: This figure shows the spatial distribution of informal resellers and informal market concentration across the 143 markets in the experimental sample. Panel A plots the share of formal households that are informal resellers in each local market. Panel B plots the largest reseller's share of informal buyers in each local market. Each square represents a market and its size is exaggerated and its position is jittered for clarity.

FIGURE 4. Experimental Design

Panel A. Market-Level Randomization

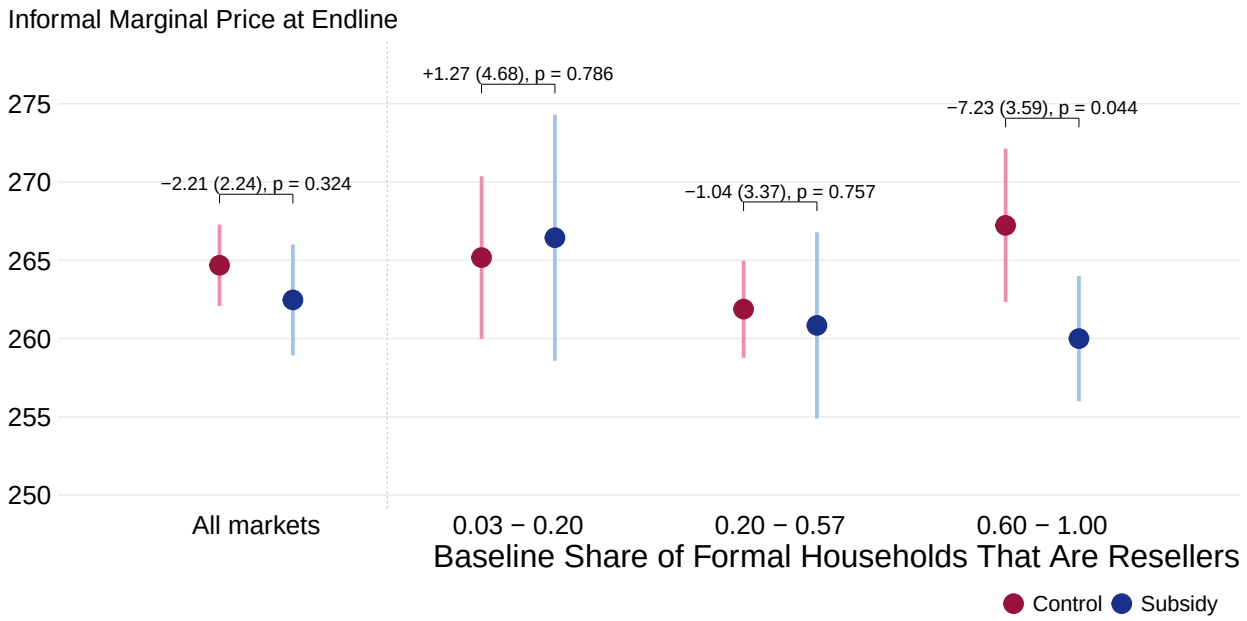


Panel B. Household-Level Randomization



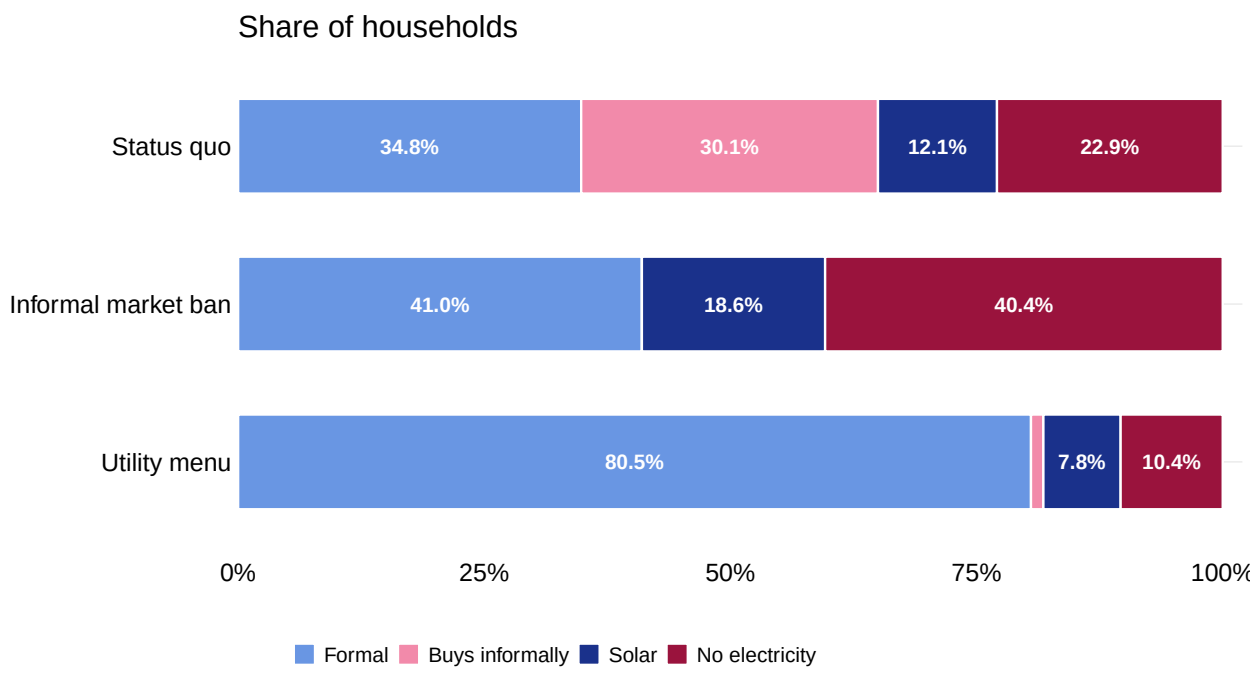
Notes: This figure shows the experiment design as randomized prior to the baseline. Panel A describes the randomization scheme for T3—subsidy for formal electricity consumption among census formally connected households. *All* households that were categorized as formally connected at census (regardless of whether they are reselling or sharing their electricity connection) in treated markets are notified to claim the subsidy—which subsidizes the household's electricity consumption by 75 FCFA per kWh for 5 months. Panel B describes the randomization scheme for T1 and T2—subsidy for informal electricity connection fee and consumption. First, each of the T1 and T2 randomizations is stratified by whether the eligible households live in T3-treated or control markets. As we describe in Section 2.1.1, we construct the eligible sample that consists of households with no electricity access, households that are informally connected, and households that are formally connected. In T1a, households are eligible to receive up to a subsidy of 50,000 FCFA for a new informal electricity connection; the minimum payment is 5,000 FCFA. In T1b, households are eligible to receive up to a subsidy of 35,000 FCFA for a new informal electricity connection; the minimum payment is 12,500 FCFA. T2 is restricted to households that are informally connected at census. Treated households in T2 receive a subsidy for their (informal) electricity consumption of 125 FCFA per kWh for 5 months. Counts are households as assigned, by electricity source at census, within the 143 realized markets.

FIGURE 5. Pass-Through to Informal Prices (T3)



Notes: This figure compares the average informal marginal price by treated and control markets, where treated markets are those whose baseline formal households were eligible to receive the T3 subsidy for formal electricity consumption. The first column shows the average informal marginal price for all informal resellers in treated and control markets. The next three columns show the average informal marginal price in treated and control markets within each tercile of the baseline share of formal households that are resellers. We include controls for the number of households in the market assigned to a connection subsidy, the number of households in the market assigned to an informal consumption subsidy, the household's baseline informal marginal price, and the census share of households in the market without electricity. Standard errors are clustered at the market level.

FIGURE 6. Counterfactual Market Shares



Notes: This figure plots the market shares of electricity sources in the status quo and under the informal market ban and the utility menu. Status quo market shares are derived from solving the equilibrium entry and pricing game given the demand estimates at the observed prices.

Tables

TABLE 1. Households by Electricity Source, Census Sample

Source	N	Share (%)
No Electricity	2,236	21.9%
Informal	3,704	36.3%
Formal	3,077	30.2%
Solar	1,085	10.6%
No One / Other	89	0.9%
Total	10,191	100.0%

Notes: This table shows the distribution of households by electricity source in the census sample. We follow the Multi-Tier Framework (MTF) Survey in assessing electrification status (World Bank 2026b). In particular, some households may have small-scale solar lanterns that are only capable of lighting for a few hours a day. We follow the MTF's convention and consider a household as "unelectrified" if its solar lantern is incapable of charging a phone. Otherwise, a household is electrified if it is connected to the grid via informal or formal means or if its solar lantern can charge at least one phone. If a household reports that it is paying the utility for its electricity, they are considered formally connected to the utility. If a household reports that it is paying its neighbor or landlord for its electricity, they are considered informally connected.

TABLE 2. Non-Price Characteristics of Formal and Informal Electricity Connections

	Formal			Informal				
Characteristic	Mean	SD	Median	Mean	SD	Median	Formal - Informal	p-value
Panel A: Payment Flexibility								
Allow Delayed Payments	0.11	0.31		0.40	0.49		-0.29	0.000
Allow Paying Less	0.10	0.31		0.16	0.37		-0.06	0.025
Allow Paying Late	0.43	0.50		0.60	0.49		-0.17	0.000
No Electricity Due to Nonpayment	0.11	0.31		0.09	0.28		0.02	0.025
Affordability Constraint	0.20	0.40		0.25	0.43		-0.05	0.000
Panel B: Electricity Quality								
% Time Available	0.93	0.15	1.00	0.92	0.19	1.00	0.02	0.226
% Time Available (Peak)	0.91	0.24	1.00	0.87	0.23	1.00	0.04	0.051
% Time Available (Off-Peak)	0.91	0.19	1.00	0.90	0.24	1.00	0.02	0.372
Number of Outages	3.02	3.13	3.00	3.21	3.22	2.00	-0.20	0.394
Outage Duration (hrs)	5.62	9.95	2.00	8.00	12.74	3.00	-2.39	0.003
Average Voltage (V)	215.13	18.55	217.00	207.64	30.44	212.00	7.49	0.000
Weak Power	0.10	0.31		0.18	0.38		-0.07	0.000
Damaged Appliances	0.20	0.40		0.23	0.42		-0.03	0.021
Panel C: Installation Quality								
Circuit Breaker	0.39	0.49		0.16	0.37		0.23	0.000
Exposed Wiring	0.14	0.35		0.18	0.38		-0.04	0.076
Exposed Socket Wiring	0.17	0.38		0.27	0.44		-0.09	0.000
Known Shock Areas	0.03	0.16		0.06	0.24		-0.04	0.000
Injured HH Member	0.01	0.09		0.01	0.11		-0.00	0.331

Notes: This table shows the various characteristics of formal and informal electricity connections across three dimensions: payment flexibility in Panel A, electricity quality in Panel B, and installation quality in Panel C. Appendix B shows how each variable was constructed and phrased in the survey.

TABLE 3. Experimental Estimates of the Demand for Informal Electricity

Panel A: Demand for informal electricity				
	T1		T2	
	𝟙(Informal)	Log Consumption	𝟙(Informal)	Log Consumption
	(1)	(2)	(3)	(4)
𝟙(High Inf. Connection Fee Subsidy)	0.4440***	-0.3672**		
	(0.0342)	(0.1796)		
𝟙(Medium Inf. Connection Fee Subsidy)	0.4344***	-0.3381*		
	(0.0335)	(0.1868)		
𝟙(Inf. Consumption Subsidy)			0.0340**	0.0998*
			(0.0161)	(0.0538)
Controls	Yes	Yes	Yes	Yes
p(High = Medium)	0.793	0.782		
Control mean	0.201	2.279	0.914	2.350
Implied elasticity	-2.69		-0.10	-0.24
Observations	1,031	265	1,088	963
Panel B: Demand for formal electricity				
	Full Sample		Solo Sample	
	𝟙(Formal)	Log Consumption	𝟙(Formal)	Log Consumption
	(1)	(2)	(3)	(4)
𝟙(Formal Per-kWh Subsidy)	0.0053	0.0470*	0.0026	0.0593**
	(0.0049)	(0.0254)	(0.0041)	(0.0296)
Controls	Yes	Yes	Yes	Yes
Control mean	0.980	4.089	0.991	3.900
Implied elasticity	-0.02	-0.15	-0.01	-0.19
Observations	1,217	1,217	777	777

Notes: This table shows experimental estimates of electricity demand from Equation 1. Panel A reports T1 (Columns 1–2) and T2 (Columns 3–4). Panel B reports T3. In both panels, odd columns use an indicator for being connected at endline (informally in Panel A, formally in Panel B), and even columns use log monthly electricity consumption (kWh). In Panel A, Column (2) restricts to households unconnected at baseline and informally connected at endline, and controls for connecting in May or June 2026. In Panel B, Columns (1)–(2) use all formal households matched to a prepaid transaction ("Full Sample"), and Columns (3)–(4) further exclude households that share or resell their connection ("Solo Sample"). Implied elasticities use treatment assignment to instrument for price (Equations 3 and 2). For binary outcomes, we divide the semi-elasticity by the control mean. All regressions control for household size, dwelling size, and the baseline outcome. Consumption regressions add a fixed effect for whether consumption is imputed from payments or recorded from meter readings or prepaid balances. This measurement source is balanced across arms in T2 and T3. Standard errors are heteroskedasticity-robust in Panel A and clustered by market in Panel B. ***, **, * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

TABLE 4. Experimental Estimates of the Supply of Informal Electricity

	Extensive Margin		Intensive Margin		
	𝟙(Entry)	𝟙(Exit)	Log kWh Resold	Log Buyers	Log kWh per Buyer
	(1)	(2)	(3)	(4)	(5)
𝟙(Formal Per-kWh Subsidy)	0.0249**	-0.0030	0.1492	0.1153**	0.0320
	(0.0126)	(0.0319)	(0.0938)	(0.0473)	(0.0860)
Controls	Yes	Yes	Yes	Yes	Yes
RI p-value	0.047	0.940	0.126	0.020	0.734
Control mean	0.030	0.144	3.261	0.693	2.467
Implied elasticity	-2.48	0.07	-0.36	-0.29	-0.06
Observations	1,343	414	329	329	329

Notes: This table shows the reduced-form estimates on the supply of informal electricity from estimating Equation 1. Column (1) restricts the sample to households that were not identified as resellers at baseline. Column (2) restricts the sample to households that were identified as resellers at baseline. Columns (3)–(5) restrict the sample to households that were identified as resellers at baseline and endline (and are not missing the baseline covariates). The dependent variables are: an indicator for whether a household has started reselling in Column (1); an indicator for whether a household has stopped reselling in Column (2); log monthly electricity resold in kWh in Column (3); log number of buyers in Column (4); and the log monthly kWh per buyer in Column (5). We report the implied elasticity from using experimental assignment to instrument for the relevant prices (we estimate Equations 3 and 2). If the outcome is binary, we divide the estimated semi-elasticity by the control mean to derive the implied elasticity. We include controls for the number of households in the market assigned to a connection subsidy, the number of households in the market assigned to an informal consumption subsidy, the census share of households in the market without electricity, the baseline ratio of resellers to formal households in the market, household size, and dwelling size. Columns (3)–(5) additionally control for the baseline value of the outcome and include indicators for whether the kWh resold and the number of buyers were measured from the household's own buyer roster or reconstructed from buyer-side data. We cluster the standard errors at the market level. ***, **, * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

TABLE 5. Model Coefficient Estimates

	Estimate	Std. error
Panel A: Median and mean coefficients		
α_f: median disutility of the connection fee	0.938	(0.201)
$\hat{\beta}_0$: median log demand at 250 FCFA/kWh	2.24	(0.0739)
β_1: median own-price elasticity	−0.604	(0.0891)
α_1: median marginal utility of income	0.726	(0.286)
ω: weight on expected resale profit	2.86	(1.18)
Panel B: Demographic interactions and random coefficients		
$\alpha_1\times$ asset index	−1.73	(0.296)
$\alpha_f\times$ asset index	−0.819	(0.144)
$\alpha_f\times$ wants credit	0.0846	(0.0206)
$\sigma(\log \alpha_f)$	0.823	(0.167)
$\rho(\beta_0, \log \alpha_f)$	−0.860	(0.378)
$\beta_0\times$ asset index	0.730	(0.0293)
$\sigma(\beta_0)$	0.483	(0.256)
$\sigma(\log \lvert\beta_1\rvert)$	0.479	(0.0448)
Formal, resale $\times$ asset index	−0.524	(0.0714)
Formal, resale $\times$ wants credit	0.110	(0.0515)
Panel C: Supply		
Median marginal cost (FCFA per kWh)	162.43	(6.13)
Median per-buyer connection cost (FCFA)	40,105	(4,409)

Notes: This table shows the estimates of the demand model specified in Section 3. Panel A displays the mean and median coefficients from the estimated model. Panel B displays the estimated demographic interactions and random coefficients. Panel C reports the median marginal cost per kWh and per buyer. Standard errors on the median are bootstrapped. We cluster the standard errors at the market level.

TABLE 6. Implied Share Elasticities

	1% increase in the price of:		
	Formal	Informal	Solar
Panel A: Connection fee			
Formal, no resale	−1.152	0.301	0.384
	(0.192)	(0.040)	(0.089)
Formal, resale	−1.674	0.378	0.533
	(0.261)	(0.047)	(0.105)
Informal	0.846	−1.098	0.260
	(0.102)	(0.062)	(0.033)
Solar	0.966	0.188	−1.955
	(0.209)	(0.025)	(0.378)
Outside	0.105	1.126	0.156
	(0.049)	(0.057)	(0.058)
Panel B: Marginal price			
Formal, no resale	−0.074	0.054	
	(0.014)	(0.012)	
Formal, resale	−0.145	0.108	
	(0.031)	(0.026)	
Informal	0.079	−0.100	
	(0.017)	(0.021)	
Solar	0.034	0.015	
	(0.011)	(0.005)	
Outside	0.003	0.038	
	(0.001)	(0.010)	

Notes: This table shows the implied share elasticities with respect to connection fees (Panel A) and marginal price (Panel B). We compute these demand elasticities using the estimated parameters reported in Table 5 and the baseline reported prices summarized in Figure 1 Panel B.

TABLE 7. The Value of Informal Electricity and Effects of Counterfactual Policies

Scenario	Consumer surplus (mean α_1)	Consumer surplus	Producer surplus (informal)	Producer surplus (formal)	Total
Panel A: Gain in total surplus (millions FCFA)					
Status quo	+54.2	+277.2	+51.8	−12.8	+316.1
% change	+19.4%	+8.0%		−7.0%	+9.6%
Utility menu + ban	+204.7	+1,152.3	+0.0	−11.0	+1,141.2
% change	+73.1%	+33.1%		−6.0%	+34.6%
Utility menu	+206.6	+1,165.5	+6.3	−7.2	+1,164.6
% change	+73.8%	+33.5%		−3.9%	+35.4%
Panel B: Gain in consumer surplus per household, by asset quintile (FCFA)					
Scenario	Q1	Q2	Q3	Q4	Q5
Status quo					
Consumer surplus (mean α_1)	+9,753	+8,698	+8,222	+6,807	+3,640
Consumer surplus	+3,724	+8,995	+21,221	+44,132	+112,227
% change	+38.6%	+33.0%	+24.5%	+16.1%	+5.6%
Utility menu + ban					
Consumer surplus (mean α_1)	+32,721	+34,032	+30,508	+27,033	+15,872
Consumer surplus	+12,492	+35,196	+78,743	+175,250	+489,405
% change	+129.6%	+129.0%	+90.9%	+64.0%	+24.6%
Utility menu					
Consumer surplus (mean α_1)	+32,911	+34,282	+30,774	+27,401	+16,057
Consumer surplus	+12,565	+35,455	+79,429	+177,636	+495,100
% change	+130.4%	+130.0%	+91.7%	+64.9%	+24.9%

Notes: This table presents the changes in surplus relative to the informal market ban across different counterfactual scenarios. Panel A reports the change in total surplus across the entire set of households in the census sample in the 142 markets in our analysis sample. The first column reports the change in consumer surplus implied by the log-sum formula (Small and Rosen 1981), but divided by the mean marginal utility of income. The second column reports the change in consumer surplus from the standard log-sum formula (Small and Rosen 1981) with individual-specific marginal utility of income that varies by wealth. The third column reports the change in producer surplus for informal resellers implied by the profit function in Equation 13 over two years, the fourth column reports the change in producer surplus for the electric utility with the assumptions stated in Section 3, and the fifth column reports the change in total surplus. Panel B reports the change in average surplus per household by the household's baseline asset index quintile.

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Appendix A. Model Appendix

This appendix provides additional details on the model and describes the estimation procedure.

A.1. Elasticities

The own and cross-price and connection fee elasticities of market shares for any individual electricity source are given by:

$$\varepsilon^{p}_{kk,m} = \frac{p_{km} \sum_{i \in \mathcal{I}_m} \int \frac{\partial s_{ikm}(\boldsymbol{\nu})}{\partial p_{km}} \, d\Phi(\boldsymbol{\nu})}{\sum_{i \in \mathcal{I}_m} \int s_{ikm}(\boldsymbol{\nu}) \, d\Phi(\boldsymbol{\nu})} \tag{A1}$$

$$\varepsilon^{p}_{\mathrm{I}k,m} = \frac{p_{km} \sum_{i \in \mathcal{I}_m} \int \sum_{j \in \mathcal{J}^{\mathrm{I}}_m \setminus \{k\}} \frac{\partial s_{ijm}(\boldsymbol{\nu})}{\partial p_{km}} \, d\Phi(\boldsymbol{\nu})}{\sum_{i \in \mathcal{I}_m} \int \sum_{j \in \mathcal{J}^{\mathrm{I}}_m \setminus \{k\}} s_{ijm}(\boldsymbol{\nu}) \, d\Phi(\boldsymbol{\nu})} \tag{A2}$$

$$\varepsilon^{f}_{kk,m} = \frac{\sum_{i \in \mathcal{I}_m} \int \bar{f}_{ikm} \frac{\partial s_{ikm}(\boldsymbol{\nu})}{\partial \bar{f}_{ikm}} \, d\Phi(\boldsymbol{\nu})}{\sum_{i \in \mathcal{I}_m} \int s_{ikm}(\boldsymbol{\nu}) \, d\Phi(\boldsymbol{\nu})} \tag{A3}$$

$$\varepsilon^{f}_{\mathrm{I}k,m} = \frac{\sum_{i \in \mathcal{I}_m} \int \sum_{j \in \mathcal{J}^{\mathrm{I}}_m \setminus \{k\}} \bar{f}_{ikm} \frac{\partial s_{ijm}(\boldsymbol{\nu})}{\partial \bar{f}_{ikm}} \, d\Phi(\boldsymbol{\nu})}{\sum_{i \in \mathcal{I}_m} \int \sum_{j \in \mathcal{J}^{\mathrm{I}}_m \setminus \{k\}} s_{ijm}(\boldsymbol{\nu}) \, d\Phi(\boldsymbol{\nu})} \tag{A4}$$

We report elasticities at the group level in Table 6—where formal, informal, and solar each form their own group.

$$\varepsilon^{p}_{gh} = \frac{\sum_m \frac{1}{N_m} \sum_{i \in \mathcal{I}_m} \int \sum_{j \in \mathcal{J}^{g}_m} \sum_{k \in \mathcal{J}^{h}_m} p_{km} \frac{\partial s_{ijm}(\boldsymbol{\nu})}{\partial p_{km}} \, d\Phi(\boldsymbol{\nu})}{\sum_m \frac{1}{N_m} \sum_{i \in \mathcal{I}_m} \int \sum_{j \in \mathcal{J}^{g}_m} s_{ijm}(\boldsymbol{\nu}) \, d\Phi(\boldsymbol{\nu})} \tag{A5}$$

$$\varepsilon^{f}_{gh} = \frac{\sum_m \frac{1}{N_m} \sum_{i \in \mathcal{I}_m} \int \sum_{j \in \mathcal{J}^{g}_m} \sum_{k \in \mathcal{J}^{h}_m} \bar{f}_{ikm} \frac{\partial s_{ijm}(\boldsymbol{\nu})}{\partial \bar{f}_{ikm}} \, d\Phi(\boldsymbol{\nu})}{\sum_m \frac{1}{N_m} \sum_{i \in \mathcal{I}_m} \int \sum_{j \in \mathcal{J}^{g}_m} s_{ijm}(\boldsymbol{\nu}) \, d\Phi(\boldsymbol{\nu})} \tag{A6}$$

The relevant partial derivatives are given below.

$$\frac{\partial s_{ijm}(\boldsymbol{\nu})}{\partial p_{km}} = \begin{cases} -\alpha_1 \, q_{ijm}(\boldsymbol{\nu}) \, s_{ijm}(\boldsymbol{\nu}) \left(1 - s_{ijm}(\boldsymbol{\nu})\right) & \text{if } j = k \\ \alpha_1 \, q_{ikm}(\boldsymbol{\nu}) \, s_{ijm}(\boldsymbol{\nu}) \, s_{ikm}(\boldsymbol{\nu}) & \text{if } j \neq k \end{cases} \tag{A7}$$

$$\frac{\partial s_{ijm}(\boldsymbol{\nu})}{\partial \bar{f}_{ikm}} = \begin{cases} -\alpha^{i}_{f}(\boldsymbol{\nu}) \, s_{ijm}(\boldsymbol{\nu}) \left(1 - s_{ijm}(\boldsymbol{\nu})\right) & \text{if } j = k \\ \alpha^{i}_{f}(\boldsymbol{\nu}) \, s_{ijm}(\boldsymbol{\nu}) \, s_{ikm}(\boldsymbol{\nu}) & \text{if } j \neq k \end{cases} \tag{A8}$$

A.2. Model Discussion

We provide additional discussion of the modeling choices in this subsection.

A.2.1. Interpretation of α_f and α_1

As we discuss in the paper, we allow for separate coefficients on how connection fees and monthly consumption affect the household's indirect utility (Equation 4):

$$V_{ijm} = -\alpha_f^i \bar{f}_{ijm} - \alpha_1 x_i(p_{jm}) + \omega\pi_{jm}^E + \alpha_2 \boldsymbol{X}_{jm} + \xi_{jm} + \eta_{ijm}$$

This specification can be interpreted in a similar way as the model in Allcott and Wozny (2014), which can be written in our context as:

$$V_{ijm} = \alpha_1^i \left(y_i - \gamma_f^i \bar{f}_{ijm} - x_i(p_{jm}) \right) + \omega\pi_{jm}^E + \alpha_2 \boldsymbol{X}_{jm} + \xi_{jm} + \eta_{ijm} \tag{A9}$$

where y_i is household income, and the rest of the variables are as defined in the main text. Within this specification, we can interpret $\alpha_f = \alpha_1 \gamma_f$.

We show that this specification is equivalent to the problem of a household solving the problem by considering the present discounted value of the utility of paying the connection fee and the discounted flow of consumption costs over the expected connection length.

Suppose that household i chooses source j in month $t = 0$ and expects to stay connected for L_i months. The household pays the connection fee $\bar{f}_{ijm}$ once. In each month t, the household receives income y_{it} and pays for its electricity consumption at the price p_{jmt}. Let μ be the marginal utility of one FCFA of income in a month, r_i the household's monthly discount rate, and $\lambda_i \geq 0$ a term that captures liquidity and credit constraints. The indirect utility of source j is

$$V_{ijm} = -\mu(1+\lambda_i)\bar{f}_{ijm} + \mu \sum_{t=0}^{L_i - 1} \frac{y_{it} - x_i(p_{jmt})}{(1+r_i)^t} + \omega\pi_{jm}^E + \alpha_2 \boldsymbol{X}_{jm} + \xi_{jm} + \eta_{ijm} \tag{A10}$$

We make three assumptions. First, we assume that the household's expectation of the prices can be written as $p_{jmt} = g_{it}\, p_{jm}$. That is, the household's expectation of the prices would follow a constant path. Myopic expectations are sufficient. Second, the household's expected connection length, discount rate, and liquidity constraints are the same for every source. Third, the household's income does not depend on the source that it chooses. We believe that all three assumptions are reasonable in our setting, where the utility is reluctant to change prices. The most consequential assumption would be Assumption 3, which assumes a lack of income effects from reselling directly

on electricity consumption. As we find in the main text, the net profits from reselling are small relative to total income.

We consider the case where households are myopic about prices. Under myopic expectations, $D_i = \sum_{t=0}^{L_i-1}(1+r_i)^{-t}$. We define $\bar{y}_i = D_i^{-1}\sum_t (1+r_i)^{-t} y_{it}$ so that the discounted income is $D_i \bar{y}_i$. Factoring out μD_i gives

$$\begin{aligned} V_{ijm} &= \mu D_i \left(\bar{y}_i - \frac{1+\lambda_i}{D_i}\bar{f}_{ijm} - x_i(p_{jm})\right) + \omega\pi^E_{jm} + \alpha_2 \boldsymbol{X}_{jm} + \xi_{jm} + \eta_{ijm} \\ &= \alpha_1^i\left(\bar{y}_i - \gamma_f^i \bar{f}_{ijm} - x_i(p_{jm})\right) + \omega\pi^E_{jm} + \alpha_2 \boldsymbol{X}_{jm} + \xi_{jm} + \eta_{ijm} \end{aligned} \tag{A11}$$

This is Equation A9 with

$$\alpha_1^i = \mu D_i, \qquad \gamma_f^i = \frac{1+\lambda_i}{D_i}, \qquad \alpha_f^i = \alpha_1^i \gamma_f^i = \mu(1+\lambda_i) \tag{A12}$$

Assumptions 1 and 2 make D_i, and hence γ_f^i, the same for every source, as Equation A9 requires. Because the non-price terms occur once, factoring out μD_i does not rescale them or the shock η_{ijm}. Under Assumption 3, the discounted income $\mu D_i \bar{y}_i$ is the same for every option, including the outside option, so it drops out of the choice probabilities and we recover Equation 4.

The coefficient α_1^i is thus the present discounted value of the marginal utility of income over the expected connection, and α_f^i is the utility cost of paying one FCFA upfront. Without liquidity constraints ($\lambda_i = 0$), the household values the connection fee and the discounted flow of consumption costs equally, and $\gamma_f^i = 1/D_i$. Under myopic expectations and without discounting, $\gamma_f^i = 1/L_i$. The inverse $1/\gamma_f^i = D_i/(1+\lambda_i)$ is the number of months of consumption costs that the household weighs against the connection fee.

A.3. Additional Identification

Variance of baseline consumption Var(σ_{β_0}). The cross-sectional dispersion of consumption conditional on demographics among control households is the most informative about this parameter.

Marginal utility of income α_1. α_1 governs how the marginal price affects the household's indirect utility through consumption. Intuitively, comparisons of the consumption between the marginal households in the treated and control groups from the connection fee provide experimental identifying variation. This parameter also relies on the cross-sectional variation in the gap of consumption between the sources of electricity.

Unobserved heterogeneity in the price elasticity σ_{β_1}. The difference in the second moment of log consumption between treated and control households is informative about σ_{β_1}. Intuitively,

this allows the "remainder" of the variation that is not explained by the observable demographic interactions to be matched through σ.

Demographic interactions Π. The interactions with $\tilde{\beta}_0^i$ are informed by how log consumption varies with $\boldsymbol{Y}_i$ among households that choose the same source, across treated and control groups. The interactions with α_f^i are informed by how the take-up response to the connection subsidies varies with $\boldsymbol{Y}_i$.

Non-price characteristics α_2. We estimate the coefficients on ability to tolerate late payments, delivered voltage, and the share of peak hours with power. We regress the mean indirect utilities δ_{jm} from the first step on these characteristics. Identification relies on the assumption that these characteristics are uncorrelated with the unobserved characteristics ξ_{jm}. Cross-market and cross-source variation in market shares and these non-price characteristics thus provides the identifying variation for these coefficients.

Marginal cost per kWh and per-buyer cost. The supply-side parameters are informed by the estimated demand parameters and the assumption of Nash-Bertrand competition.

A.4. Moment Conditions

The first set of moments contains $J \times M$ rows that are the market shares. We match these shares exactly to solve for δ_{jm} for any given guess of the nonlinear parameters θ_1. These do not enter into the GMM objective.

$$S_{jm} - \frac{1}{N_m} \sum_{i \in \mathcal{I}_m} \int s_{ijm}(\boldsymbol{\nu}; \boldsymbol{\delta}_m, \theta)\, d\Phi(\boldsymbol{\nu}) = 0 \qquad \forall j \in \mathcal{J}_m,\ \forall m \tag{A13}$$

Extensive margin moments. The second set of moments contains the reduced-form treatment effects of subsidizing an informal electricity connection. d_{ijm} denotes an indicator that is equal to one if the household selected a particular source of electricity. We consider three different definitions: whether the household chose any electricity at all, whether the household chose an informal source of electricity, and whether the household chose to be electrified via solar. This set of moments restricts the sample to the sample of households that are eligible for T1. We use the instruments $\boldsymbol{Z}_i = \{1, Z_1, Z_2, Z_1 \otimes \boldsymbol{Y}_i, Z_2 \otimes \boldsymbol{Y}_i\}$ where $Z_1 = 1$ and $Z_2 = 1$ if the household was assigned to the high and medium connection subsidy, respectively. Our main specification for $\boldsymbol{Y}_i$ includes the household's baseline asset index and an indicator for whether the household indicated that they

are credit-constrained. There are thus $3 \times 7 = 21$ total moments in this set.

$$\mathbb{E}\left[\left(\sum_{j\in\mathcal{A}} d_{ijm} - \int \sum_{j\in\mathcal{A}} s_{ijm}(\boldsymbol{\nu};\theta)\, d\Phi(\boldsymbol{\nu})\right)\boldsymbol{Z}_i\right] \tag{A14}$$

Intensive margin moments. The third set of moments contains the reduced-form treatment effects of subsidizing the marginal price of electricity on the household's electricity consumption. d_{ijm} denotes an indicator that is equal to one if the household selected a particular source of electricity. We restrict the sample to households that are eligible for T2 and T3 (baseline informal and baseline formal, respectively). We use the instruments $\boldsymbol{Z}_i = \{1, Z_3, Z_4, Z_3 \otimes \boldsymbol{Y}_i, Z_4 \otimes \boldsymbol{Y}_i\}$ where $Z_3 = 1$ and $Z_4 = 1$ if the household was assigned to an informal and formal consumption subsidy for five months, respectively.

$$\mathbb{E}\left[\left(\sum_{j\in\mathcal{A}} d_{ijm} \ln q_i - \frac{\int \sum_{j\in\mathcal{A}} s_{ijm}(\boldsymbol{\nu};\theta) \ln q_{ijm}(p_{jm} - \tau_i)\, d\Phi(\boldsymbol{\nu})}{\int \sum_{j\in\mathcal{A}} s_{ijm}(\boldsymbol{\nu};\theta)\, d\Phi(\boldsymbol{\nu})}\right)\boldsymbol{Z}_i\right] \tag{A15}$$

"First-stage" moments. The fourth set of moments describes the "first stage" of the experiment. We use the set of instruments $\boldsymbol{Z}_i = \{1, Z_1, Z_2\}$ where $Z_1 = 1$ and $Z_2 = 1$ if the household was assigned to the high and medium connection subsidy, respectively. Here, we are implicitly exploiting the relationship between the connection fee and distance (otherwise, there would be no variation in the connection fees within a market).

$$\mathbb{E}\left[\left(\sum_{j\in\mathcal{A}} d_{ijm}\bar{f}_{ijm} - \frac{\int \sum_{j\in\mathcal{A}} s_{ijm}(\boldsymbol{\nu};\theta)\bar{f}_{ijm}\, d\Phi(\boldsymbol{\nu})}{\int \sum_{j\in\mathcal{A}} s_{ijm}(\boldsymbol{\nu};\theta)\, d\Phi(\boldsymbol{\nu})}\right)\boldsymbol{Z}_i\right] \tag{A16}$$

Second moments. The fifth set of moments contains the second moments of consumption and connection fees to capture the dispersion in tastes. For the consumption set of moments (Equation A17), we again use the instruments $\boldsymbol{Z}_i = \{1, Z_3, Z_4\}$ where $Z_3 = 1$ and $Z_4 = 1$ if the household was assigned to an informal and formal consumption subsidy for five months, respectively. For the connection fee set of moments (Equation A18), we use the instruments $\boldsymbol{Z}_i = \{1, Z_1, Z_2\}$ where $Z_1 = 1$ and $Z_2 = 1$ if the household was assigned to the high and medium connection subsidy, respectively. We find that the second moments are critical to getting precise estimates of random coefficients.

$$\mathbb{E}\left[\left(\sum_{j\in\mathcal{A}} d_{ijm}(\ln q_i)^2 - \frac{\int \sum_{j\in\mathcal{A}} s_{ijm}(\boldsymbol{\nu};\theta)\left[\ln q_{ijm}(p_{jm} - \tau_i)\right]^2 d\Phi(\boldsymbol{\nu})}{\int \sum_{j\in\mathcal{A}} s_{ijm}(\boldsymbol{\nu};\theta)\, d\Phi(\boldsymbol{\nu})}\right)\boldsymbol{Z}_i\right] \tag{A17}$$

$$\mathbb{E}\left[\left(\sum_{j\in\mathcal{A}} d_{ijm}\bar{f}_{ijm}^2 - \frac{\int \sum_{j\in\mathcal{A}} s_{ijm}(\boldsymbol{\nu};\theta)\bar{f}_{ijm}^2\, d\Phi(\boldsymbol{\nu})}{\int \sum_{j\in\mathcal{A}} s_{ijm}(\boldsymbol{\nu};\theta)\, d\Phi(\boldsymbol{\nu})}\right)\boldsymbol{Z}_i\right] \tag{A18}$$

A.5. Estimation Details

We first estimate θ_1 along with the mean indirect utilities δ_{jm} using GMM. We describe the procedure below:

(1) Begin with an initial guess of $\tilde{\theta}_1$.

(2) Minimize the GMM objective function

   (a) Use the BLP contraction mapping to solve for δ_{jm} to match the market shares. For any $\tilde{\theta}_1$, we iterate on the contraction until convergence recovers the unique δ_{jm} that rationalizes the observed market shares.

   (b) We stack the set of moments we describe above to form

   $$Q(\tilde{\theta}_1, \delta_{jm}, \boldsymbol{W}) = \boldsymbol{g}(\theta)' \boldsymbol{W} \boldsymbol{g}(\theta) \tag{A19}$$

   with an identity weighting matrix $\boldsymbol{W} = \boldsymbol{I}$.

   (c) We recover the first-step estimate $\hat{\tilde{\theta}}_1 = \text{argmin}_{\tilde{\theta}_1} Q(\tilde{\theta}_1, \delta_{jm}, \boldsymbol{W})$.

(3) Find the optimal two-step estimate $\hat{\theta}_1$.

   (a) Form a new weighting matrix $\boldsymbol{W} = \hat{\boldsymbol{\Omega}}^{-1}$, where $\hat{\boldsymbol{\Omega}}$ is the covariance matrix of the moments at the first-step estimate $\hat{\tilde{\theta}}_1$, clustered at the market level:

   $$\hat{\boldsymbol{\Omega}} = \sum_m \boldsymbol{g}_m(\hat{\tilde{\theta}}_1) \boldsymbol{g}_m(\hat{\tilde{\theta}}_1)'$$

   (b) Repeat the above minimization, starting from $\hat{\tilde{\theta}}_1$, using the objective

   $$Q(\theta_1, \delta_{jm}, \hat{\boldsymbol{\Omega}}^{-1}) = \boldsymbol{g}(\theta)' \hat{\boldsymbol{\Omega}}^{-1} \boldsymbol{g}(\theta)$$

   We recover the two-step estimate $\hat{\theta}_1 = \text{argmin}_{\theta_1} Q(\theta_1, \delta_{jm}, \hat{\boldsymbol{\Omega}}^{-1})$.

We follow the best practices described in Conlon and Gortmaker (2020) and Conlon and Gortmaker (2024). We use tight contraction tolerances of 10^{-10} and a tight convergence tolerance of 10^{-8} for the GMM objective. We use Knitro as the optimizer.

Appendix B. Market Construction and Data Description

B.1. Market Construction

We start from the shapefile of the district of Abomey-Calavi, which is sourced from (GADM 2021). We use this shapefile to cut the population raster from (WorldPop 2026). WorldPop has a roughly 100m $\times$ 100m resolution. We aggregate this up to 377m $\times$ 377m resolution. These become the basis for our markets. We then limit the number of households (we approximate the number of households by dividing population by 4) in each market to be greater than 20 and less than 200 to be eligible in our sample. We do so for cost effectiveness: satellite predictions of population are not perfect, especially at such fine scales.

We then construct strata by estimated households per market. Each stratum is a quartile. The summary is as follows:

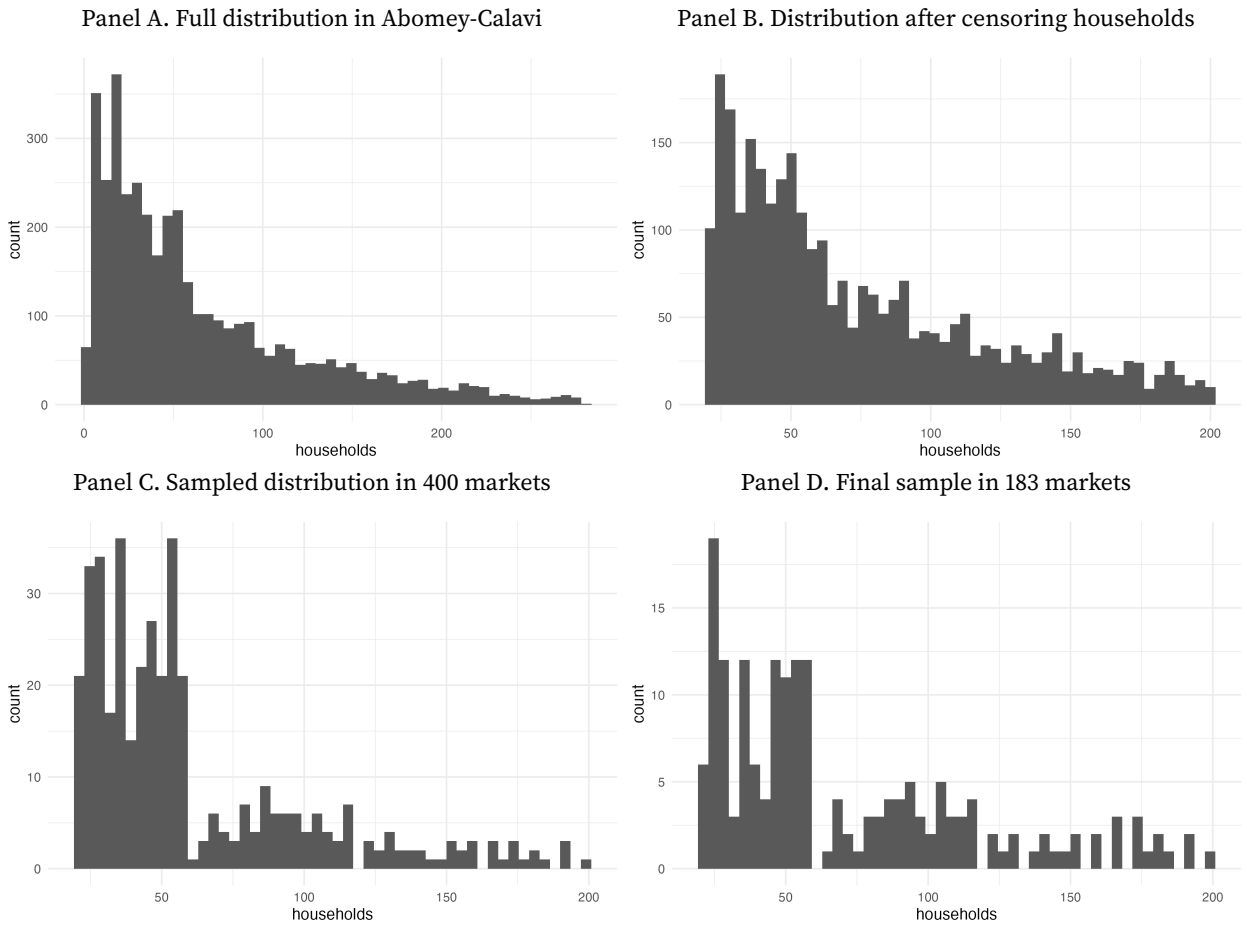
TABLE B1. Distribution of households: Quartiles

Min	21
P25	37
P50	58
Mean	73.77
P75	101
Max	200

Notes: This table summarizes estimated household counts across eligible markets. Household counts are WorldPop population estimates divided by four.

We then sample within each stratum. The proportion is as follows: 35% from Min–P25, 35% from P25–P50, 15% from P50–P75, 15% from P75–Max. Figure B1 below shows how the distribution changes once we filter and sample. We sample **400 markets** that are **350 meters** apart from each other. We then randomly select 183 markets unconditionally from these 400 markets. This stratified sampling produces approximately the same distribution of households across Abomey-Calavi (Panels C and D in Figure B1).

FIGURE B1. Distribution of households across markets

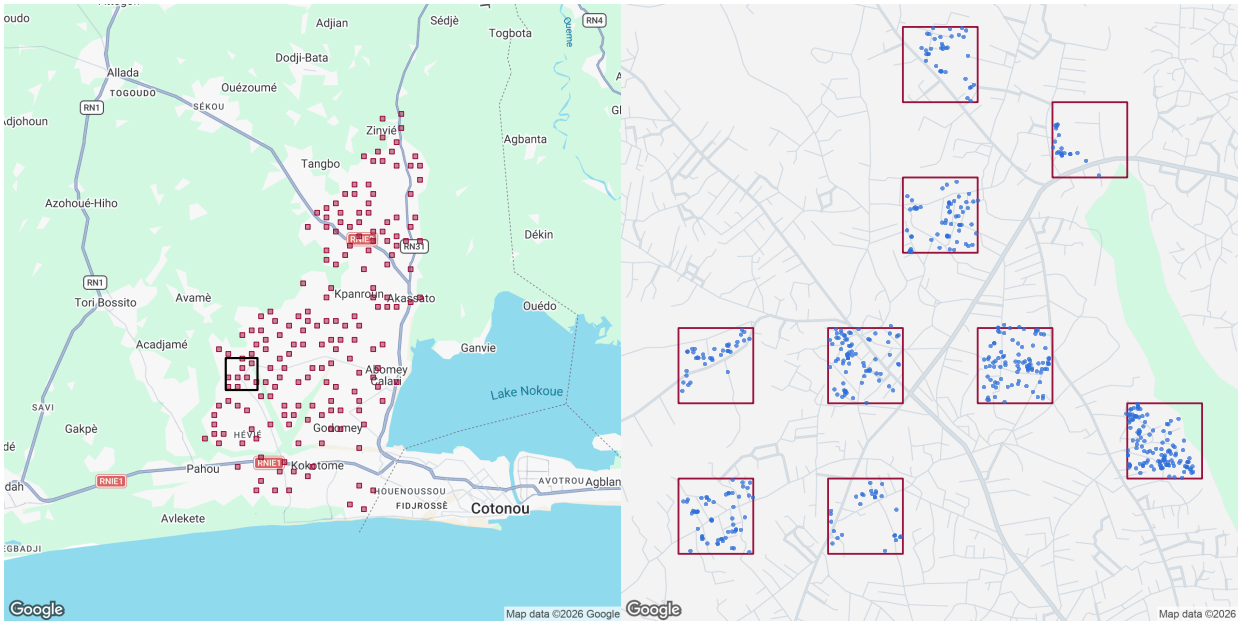


Notes: This figure shows estimated household counts per market before restrictions, after restrictions, among the 400 sampled markets, and in the final census sample of 183 markets.

FIGURE B2. Sampled Markets and Census Household Locations

(a) All 183 sampled markets

(b) Zoom on 9 neighbouring markets: every census household



Notes: Panel (a) shows the 183 sampled markets; the black box marks the area in Panel (b). Panel (b) shows nine neighboring markets and the recorded locations of enumerated households.

B.2. Data Description

B.2.1. Market Shares

We compute the market share of each source of electricity from the census, which enumerates every household in each market. We classify households using the following questions:

(1) "Is your dwelling currently connected to electricity?"

(2) "Who collects your payment for your electricity service?" The options are SBEE (single payment), SBEE (collective payment), a neighbor, a landlord, no one, and other.

(3) "Does your household have a solar lamp torch, solar lantern or solar panels?"

  (a) "Is the solar lamp torch, solar lantern, or solar panel capable of charging mobile phones?"

We define the sources of electricity in market m as follows:

- *Formal, no resale.* The household pays SBEE, with a single or a collective payment, and does not resell electricity.
- *Formal, resale.* The household pays SBEE and resells electricity: we match it to an informal reseller that buyers name in the census or that lists its buyers in the baseline survey.
- *Informal reseller j.* The household pays a neighbor a price per kWh, and we link it to reseller j with the name, nickname, and phone number that it reports. If the neighbor also buys electricity informally, we assign the household to the formal household at the top of the chain.
- *Solar.* The dwelling is not connected formally or informally to the grid, and the household owns a solar device that can charge a mobile phone.
- *Outside option.* The dwelling is not connected to electricity, and the household does not own a solar device that can charge a mobile phone.

B.2.2. Electricity Consumption

We describe how we combine measurements at the census, baseline, and endline to compute electricity consumption for each household.

Informal connections. Informal buyers have a meter that counts their own consumption. In each survey round, enumerators "record the number of kWh that is on the screen of the meter that is counting the respondent's electricity usage" and photograph the meter. Monthly consumption is the difference between the endline reading and the last baseline reading, divided by the number of days between the two readings and multiplied by 30.

If the household changed its meter after the baseline, we divide the endline reading by the number of days since the household changed its electricity meter. If no meter reading is available, we divide the household's electricity spending by its price per kWh, from the questions "In the past month, how much did your household spend on electricity payments (FCFA)?" and "What is the price per kWh that your household pays for electricity?"

Formal connections. We match formally connected households to their SBEE prepaid accounts, which record the date and the kWh of every purchase of credit. A prepaid meter shows the remaining credit, so enumerators ask "What is the balance on your pre-paid meter in kWh? (How much is left?)" We also photograph the prepaid meter with the prepaid balance showing on the screen.

Monthly consumption between the baseline and endline interviews is

$$q_i = \Big(\text{baseline balance+kWh bought between interviews} - \text{endline balance}\Big) \times \frac{30}{\text{days b/w interviews}}$$

If a balance is missing, we use the kWh bought between the two interviews.

A reseller's meter also counts the electricity that its buyers use. In the endline survey, resellers list their buyers and report each buyer's monthly consumption or monthly payment. We subtract the buyers' consumption (assumed to be constant over five months) from the reseller's consumption.

B.2.3. Non-Price Characteristics

We report the English wording of each question used to construct the non-price characteristics in Table **??**.

Panel A: Payment flexibility.

- *Allow Delayed Payments.* "If you had financial difficulties and were unable to pay (or only able to pay a small fraction), would the party that you pay for electricity services still provide electricity for any period of time?" Equal to one if the household answers yes. We code "don't know" as zero.
- *Allow Paying Less.* "In the past 12 months, has your household ever paid less than you were supposed to, and still received electricity from your seller?" Paying nothing counts as paying less. We ask this question only of households that answer yes to the previous question.
- *Allow Paying Late.* "In the past 12 months, has your household ever paid later than you were supposed to, and still received electricity from your seller?" We ask this question only of households that answer yes to *Allow Delayed Payments*.
- *No Electricity Due to Nonpayment.* "In the past 12 months, were there times when your household could not use electricity because . . . " The end of the question depends on the connection: ". . . you could not reload the pre-paid electricity meter?" for prepaid formal connections, ". . . you have not paid SBEE for electricity?" for postpaid formal connections, and ". . . you have not paid your neighbor for electricity?" for informal connections. Equal to one if the household answers yes to the question for its connection.
- *Affordability Constraint.* "In this past month, have you ever decided to not use any of the following appliances because the electricity payment would be too expensive? (1) Lights (2) Fan (3) Television (4) Radio (5) Refrigerator." Enumerators do not record yes for an appliance that the household does not own. Equal to one if the household answers yes.

Panel B: Electricity quality.

- *% Time Available.* We ask households to "select all the hours in which you were home yesterday" and then, out of those hours, to "select all the hours in which electricity is available." The variable is the number of hours with electricity divided by the number of hours at home.
- *% Time Available (Peak).* We restrict *% Time Available* to the evening peak hours from 17:00 to 22:00. We only keep households that were home for at least two of the five peak hours.
- *% Time Available (Off-Peak).* We restrict *% Time Available* to the hours from 06:00 to 17:00 and from 22:00 to 23:00. We exclude the night hours from 23:00 to 06:00. We keep households that were home for at least two off-peak hours.
- *Number of Outages.* "How many electricity interruptions or outages occurred in the past week?"
- *Outage Duration (hrs).* "What is the total duration (in hours) of all the electricity interruptions / outages in the past week?"
- *Average Voltage (V).* With the household's consent, enumerators measure the voltage at a wall socket with a digital multimeter, with no appliance plugged in. We only measure the voltage in dwellings with an available and safe socket.
- *Weak Power.* "In the past twelve months, have there been times when you couldn't power an appliance you wished to use because the electricity was too weak (e.g., low voltage)?"
- *Damaged Appliances.* "In the past 12 months, did any of your appliances get damaged because the voltage was going up and down (e.g., power surges)?"

Panel C: Installation quality. Enumerators record the first three variables during a visual inspection of the dwelling, for households that consent to the inspection.

- *Circuit Breaker.* "Does the dwelling have any circuit breakers?"
- *Exposed Wiring.* "Are any of the visible conductors/wires exposed (without a jacket or connectors) or improperly spliced?" We ask this question only if there are visible wires inside or coming into the dwelling.
- *Exposed Socket Wiring.* "Do any sockets in the room have exposed wiring?"
- *Known Shock Areas.* "Are there any areas of the electrical system in the dwelling that are known to cause electrical shocks?"
- *Injured HH Member.* "In the past year, did any household members get injured from your own electricity connection?"

B.2.4. Credit Constraint

We construct a measure of household credit constraint using two questions from the baseline survey:

(1) "In the past 12 months, have you, or someone in your household, ever tried to borrow money from a commercial bank/lender, moneylender, or someone else outside of your household?"

(2) "Why did you, or others in your household, not attempt to obtain any loans in the past 12 months? Note that this includes any formal or informal loans." [If household did not borrow in the past 12 months]

A household is considered to be credit constrained `wants_credit = 1` is equal to one if the household tried to borrow but the attempt was successful. It is also equal to one if the household did not try to borrow and selected at least one reason related to credit constraints: it does not know any lenders, it believes it would be refused, interest rates are too high, it fears it cannot repay, or it has inadequate collateral. It is equal to zero for all other households, which did not try to borrow because there was no need, it was too much trouble, it did not like to be in debt, or for another reason. The variable is zero otherwise.

Appendix C. Experimental Sampling Details

We construct the experimental sample using the representative sampling frame from the census. We make several restrictions to the sampling frame. This results in 6,095 eligible households in 143 markets.

We first define eligibility by the observed sources of electricity. We exclude households that were unable to articulate their electricity source during the census as the experiments' randomization depended on a characterization of the source of their electricity. Field observations suggest that these households are likely to be engaging in electricity theft. These 89 households make up 0.9% of the total enumerated census households. Households whose informal reseller is their landlord are not eligible to participate in the experiment because they cannot choose their source of electricity. These households face a joint problem of choosing where to live and what source of electricity to use, which presents a different problem compared to the rest of the observed sample. While the characteristics of an informal connection to a landlord and to a neighbor are similar, we do not consider the joint housing choice and electricity source problem in this paper. These 1,603 households make up 15.7% of the census enumerated sampling frame.

We also exclude households for whom we cannot accurately observe electricity consumption from the experimental sample. The experimental sample excludes the 1,085 households (10.6% of the total sampling frame) whose main source of electricity was through solar sources. Households with a solar electricity source do not face a marginal price and are thus ineligible for any subsidies related to the marginal price. While we do not include households with solar sources in the experimental sample, we randomly select 300 households from this sample to survey in the endline (Section 1.2). We also exclude the 441 households (4.3% of the total sampling frame; 21.0% of all informal households connected to a neighbor) who do not face a price per kWh in the informal market.[54] This leaves 6,973 eligible households across 183 markets.

Finally, we restrict the set of markets eligible for the experiment to markets that have at least two households with an informal connection paying a per-kWh price. We further drop one market in which the informal buyers are all located at the corners of the market boundary and two markets in which our field team could not operate. This leaves 143 markets in the experimental sample and 6,095 eligible households.

From the restricted sampling frame, we randomly select 1,138 out of 1,985 households without electricity access and 1,391 out of 1,618 households with an informal electricity connection at census across the 143 markets. We included all eligible households with a formal electricity connection in the survey (2,375 out of the 2,492 households). Treatment status was randomized according

[54] 407 of these households report a payment arrangement other than a per-kWh price and 34 have missing contract information.

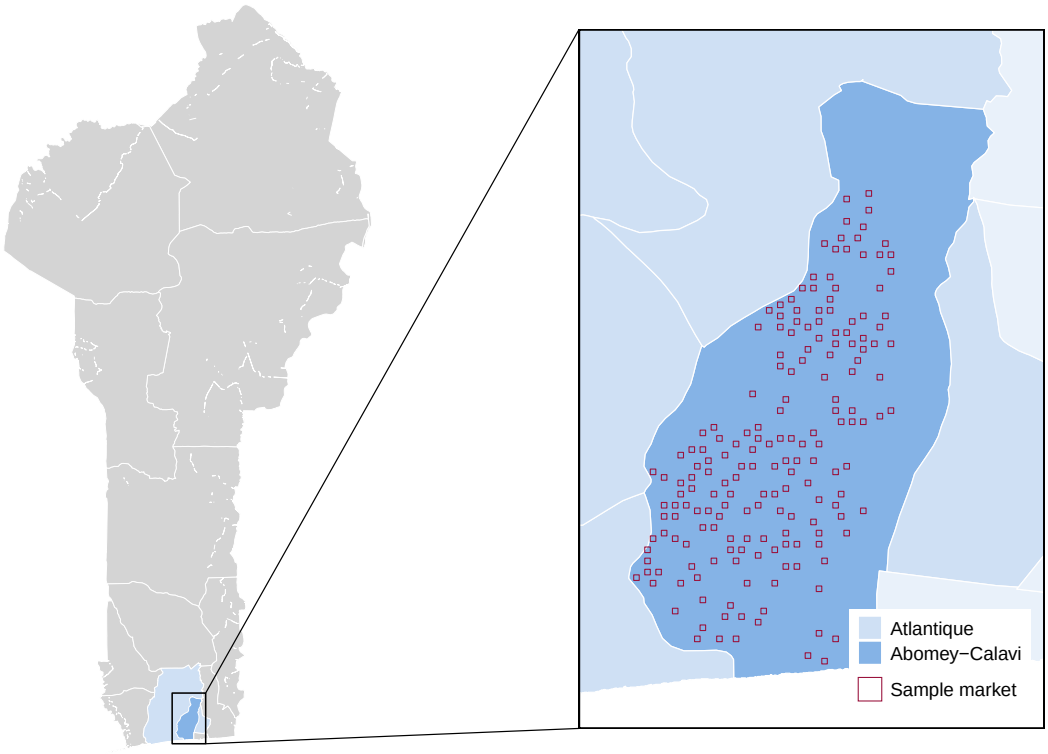
to information provided during the census. We required households to report a working phone number to be eligible during the census.

Our final experimental sample is smaller than the randomly selected sample because a household may become ineligible when we revisit them during the baseline or they may become unavailable. This may be due to measurement error (e.g., the enumerator assigned the wrong source of electricity) or a recent transition of electricity source, since the census took roughly one and a half months. Households may also refuse to participate further in the experiment between the census and the baseline. We randomly selected additional households from the remaining pool to make up for such attrition; for informally connected households, we enrolled all remaining eligible households. Our final experimental sample thus includes 922 households that were not connected to electricity, 1,302 households that were informally connected, and 1,985 households that were formally connected at baseline across 143 markets.

Appendix Table A2 summarizes the household demographics of the final experimental sample compared to the census.

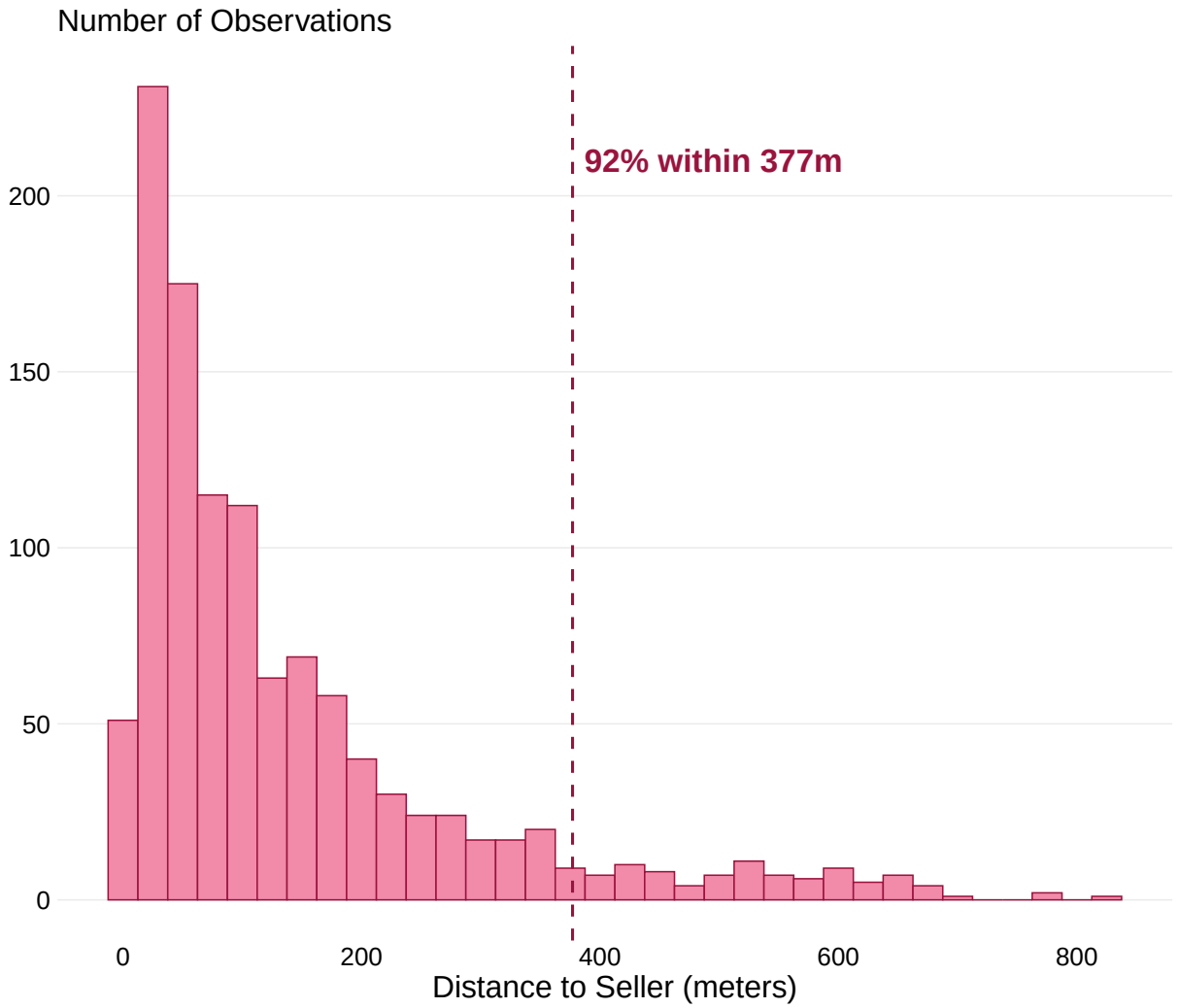
Appendix D. Additional Figures

FIGURE A1. Census Market Locations



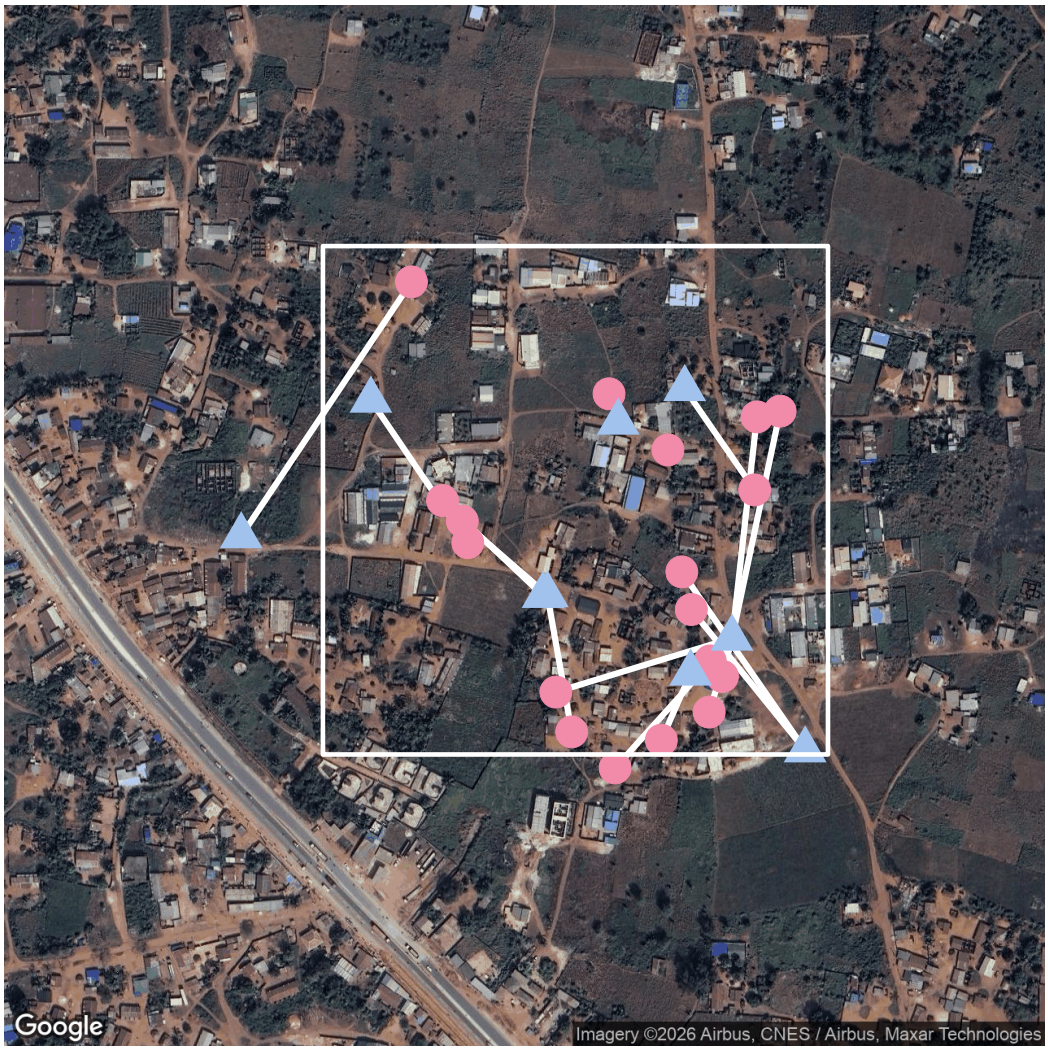
Notes: This figure shows the locations of the 183 markets enumerated in the census across Abomey-Calavi.

FIGURE A2. Distance between Informal Resellers and Buyers



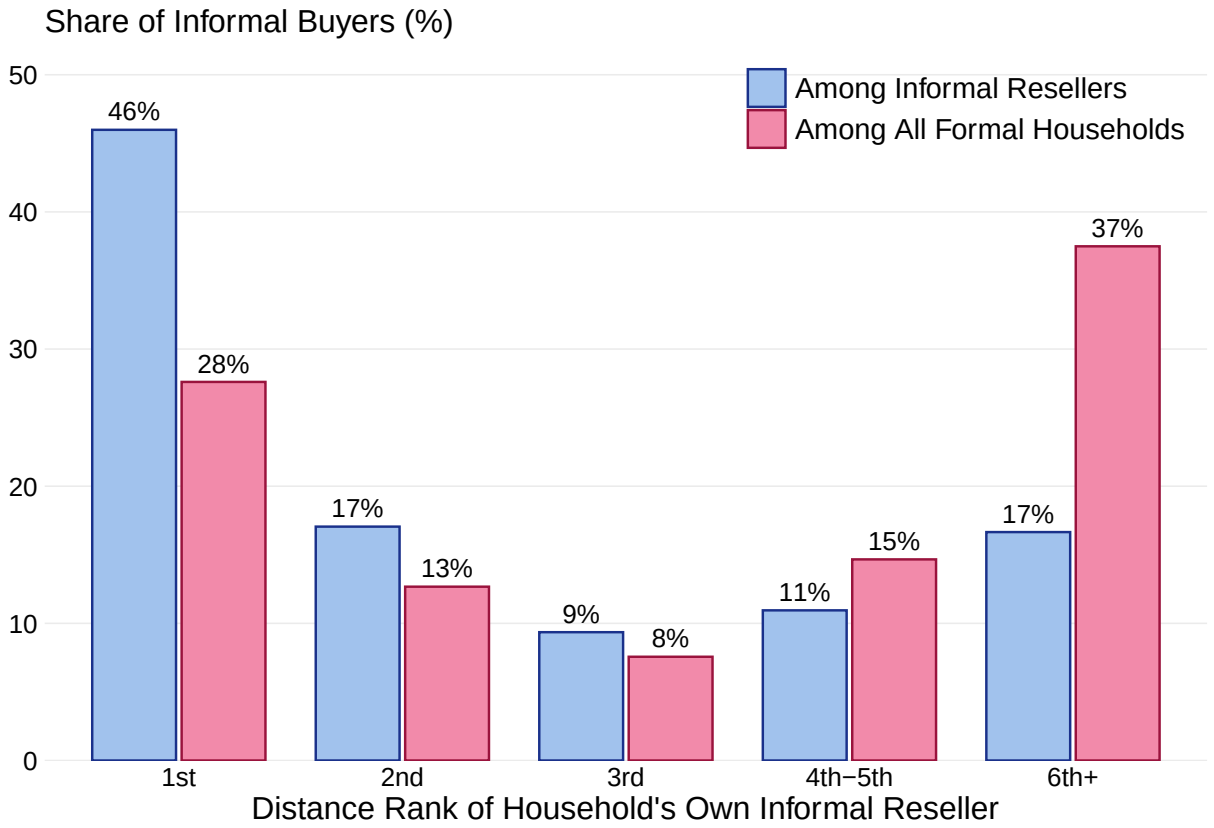
Notes: This figure shows the distribution of distances between informal buyers and their resellers, using recorded GPS coordinates. The dashed line marks 377 meters, the width of a market.

FIGURE A3. Example Buyer and Reseller GPS in Market M459



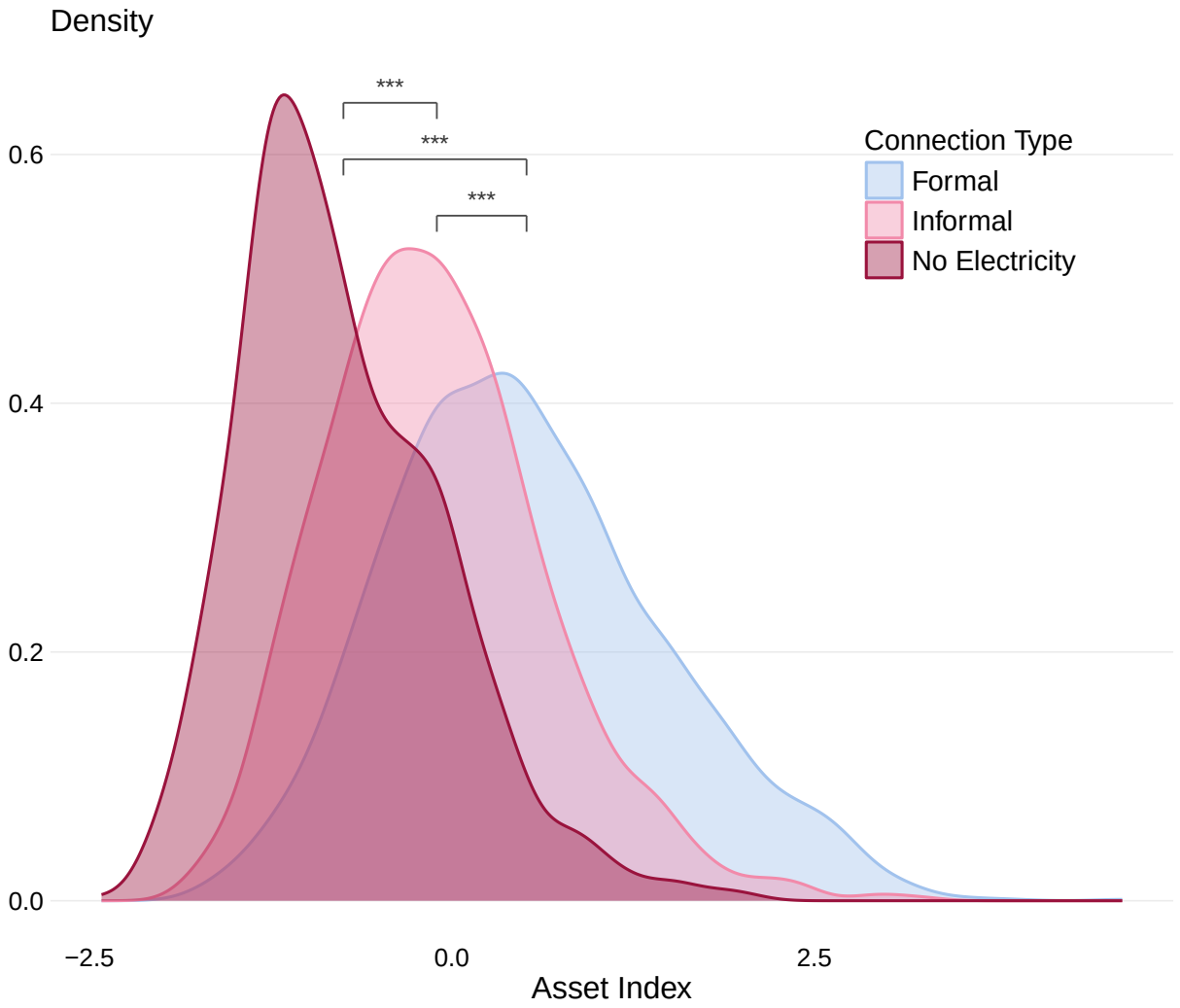
Notes: This figure plots the recorded locations of buyers and resellers in one market. Lines connect matched buyers and resellers; the white square marks the market boundary.

FIGURE A4. Distance Rank of Informal Buyers' Own Reseller



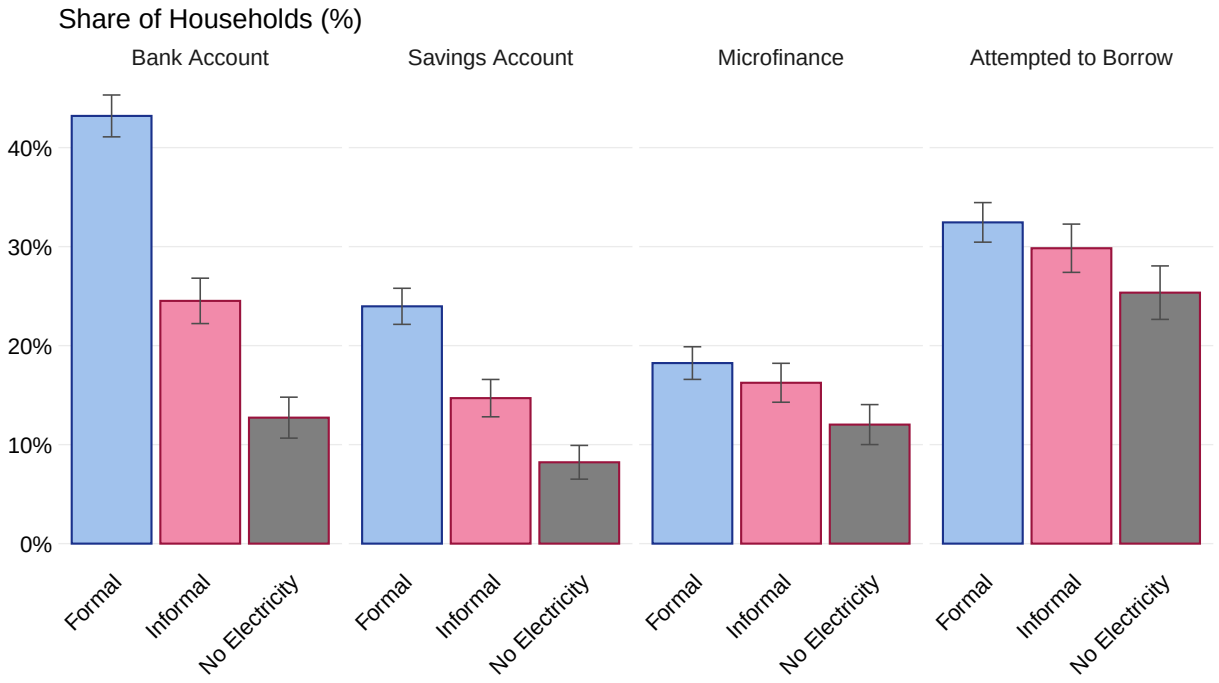
Notes: This figure ranks each census per-kWh informal buyer's own reseller by distance from the buyer, among the other informal resellers in the buyer's market (blue) and among all formal households in the market, resellers included (pink). Rank 1 means no other option lives closer than the buyer's own reseller.

FIGURE A5. Distribution of Asset Index by Electricity Source



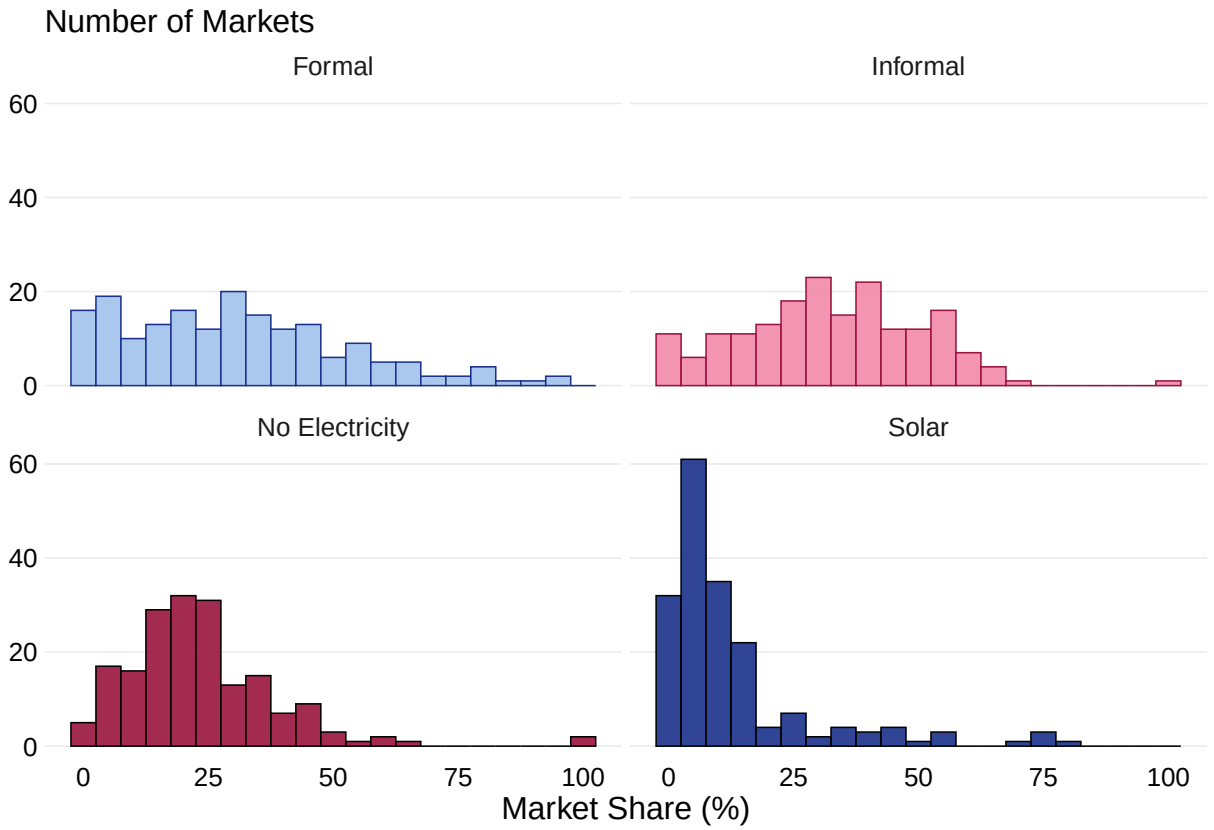
Notes: This figure shows the distribution of the asset index, excluding appliances, by baseline electricity source. Brackets report tests of differences in means; *** denotes $p < 0.01$.

FIGURE A6. Financial Access by Electricity Source



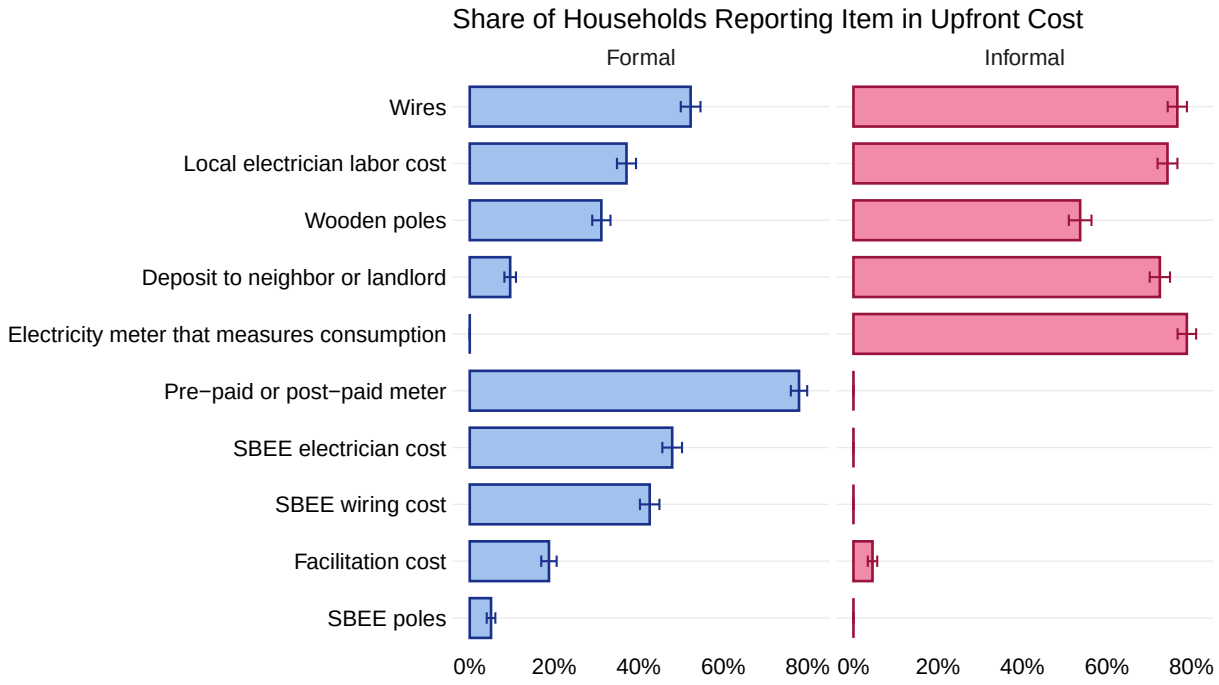
Notes: This figure compares self-reported financial access by electricity source in the baseline survey. Error bars show 95% confidence intervals.

FIGURE A7. Distribution of Market Shares of Electricity Sources by Market



Notes: This figure shows the distribution of each electricity source's household market share across the 183 census markets.

FIGURE A8. Prevalence of Reported Items for Connection



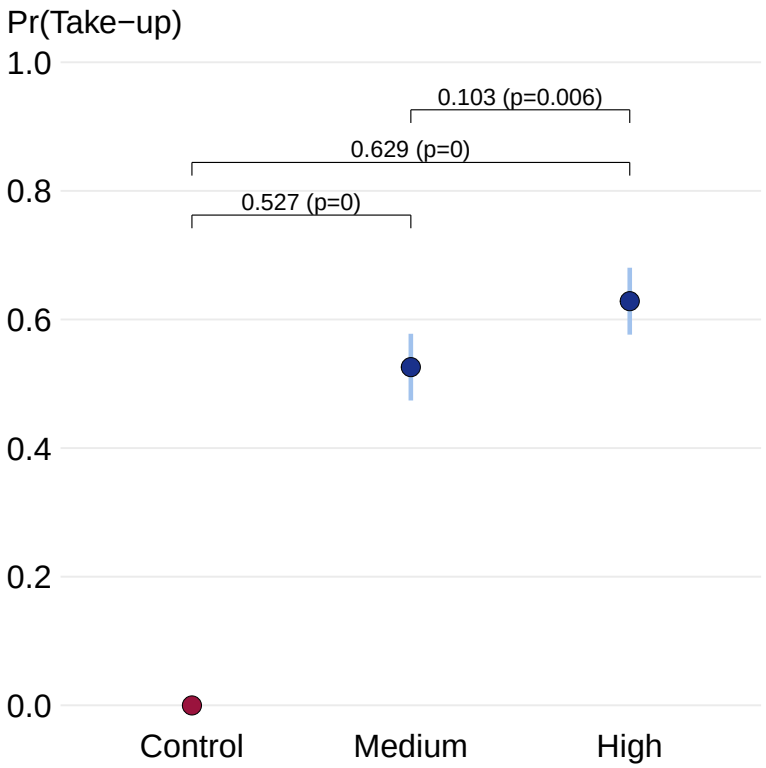
Notes: This figure shows the share of households reporting each item as part of their upfront connection cost, by electricity source. Households may report multiple items. Error bars show 95% confidence intervals.

FIGURE A9. Example of Décompteur (Informal Electricity Meter)



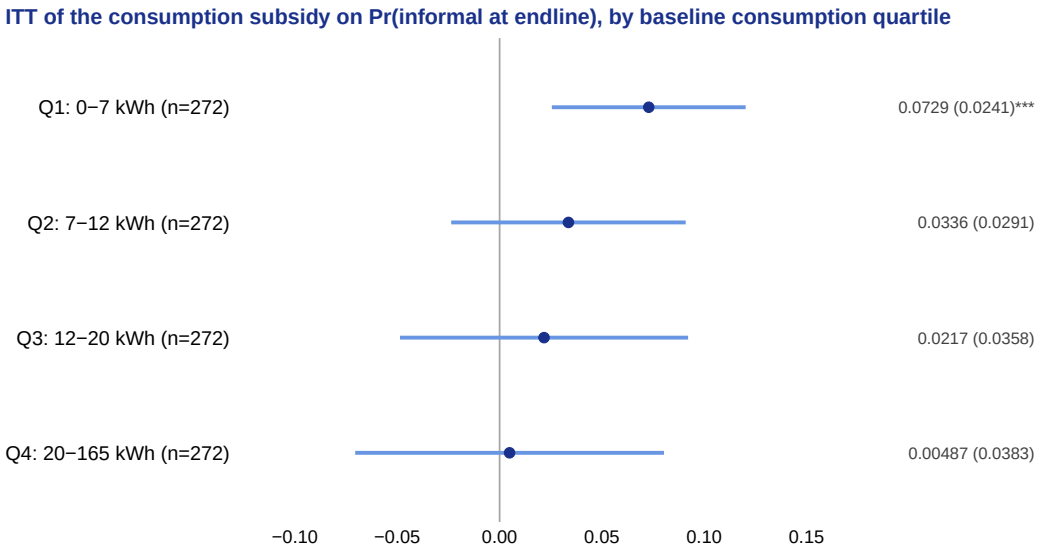
Notes: This photograph shows a meter used to record an informal buyer's electricity consumption.

FIGURE A10. Take-up of the Connection Subsidy (T1)



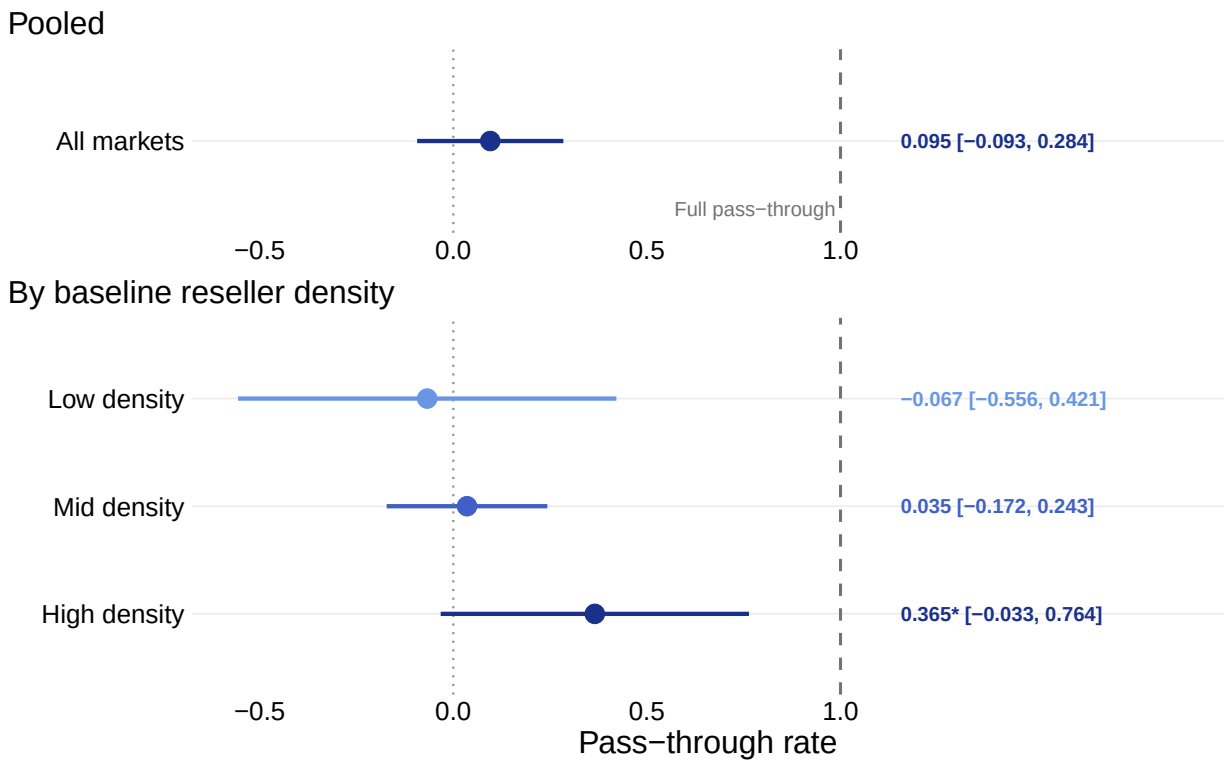
Notes: This figure shows adjusted subsidy take-up by T1 arm among households with endline outcomes and complete controls. We control for household and dwelling size. Error bars show 95% confidence intervals using heteroskedasticity-robust standard errors.

FIGURE A11. Heterogeneous Treatment Effects of the Informal Subsidy (T2)



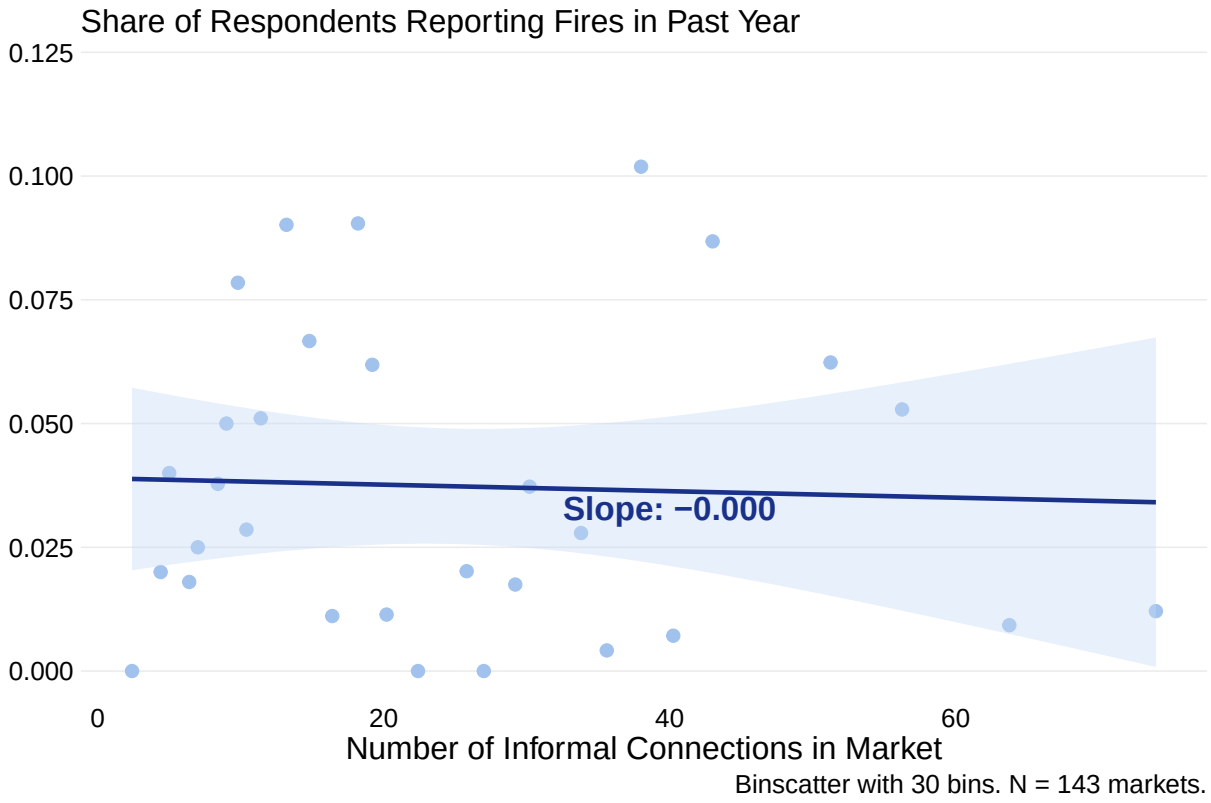
Notes: Panel A compares adjusted informal connection rates at endline by T2 assignment. Panel B reports treatment effects by baseline consumption quartile. Intervals are 95% confidence intervals using heteroskedasticity-robust standard errors.

FIGURE A12. Implied Pass-Through Rate of the Reseller's Marginal Cost (T3)



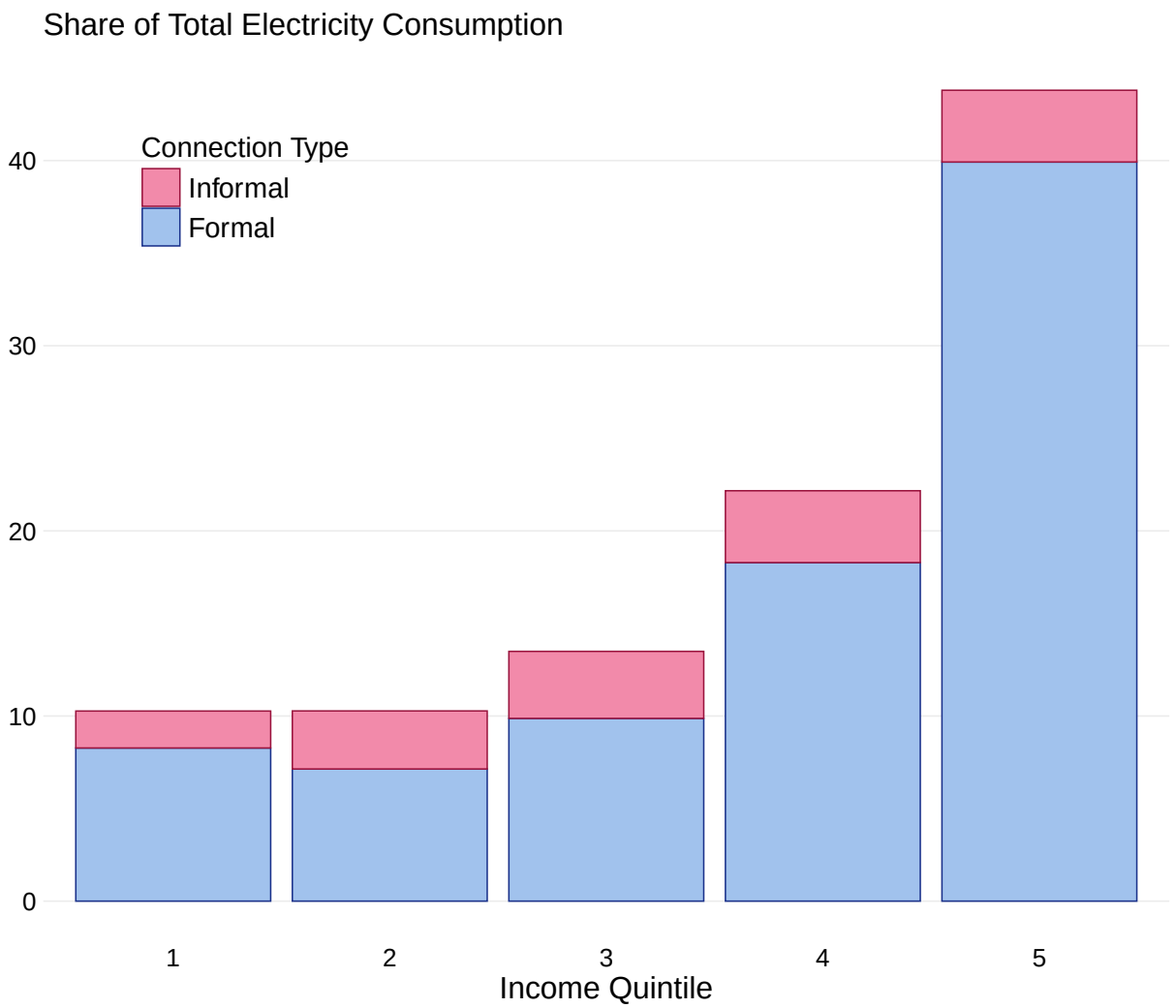
Notes: This figure reports pass-through estimates using T3 assignment to instrument for resellers' marginal cost, pooled and by baseline reseller density. Intervals are 95% confidence intervals with standard errors clustered at the market level.

FIGURE A13. Fires and the Number of Informal Connections in a Market



Notes: This figure plots reported neighborhood fires against the number of informal connections in a market. Points group the 143 markets into 30 bins.

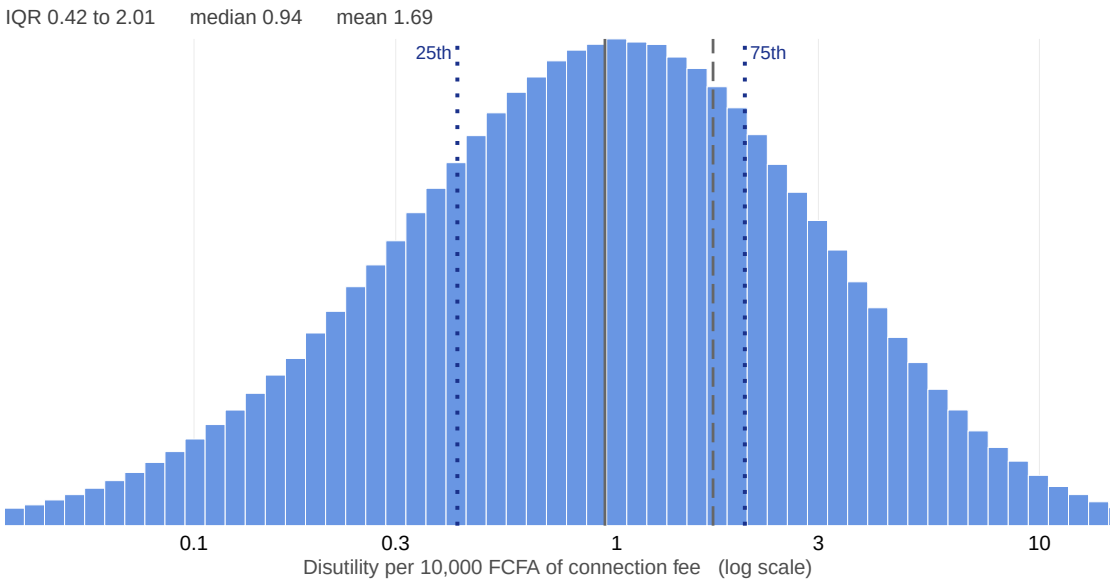
FIGURE A14. Share of Electricity Consumption by Source and Income Quintile



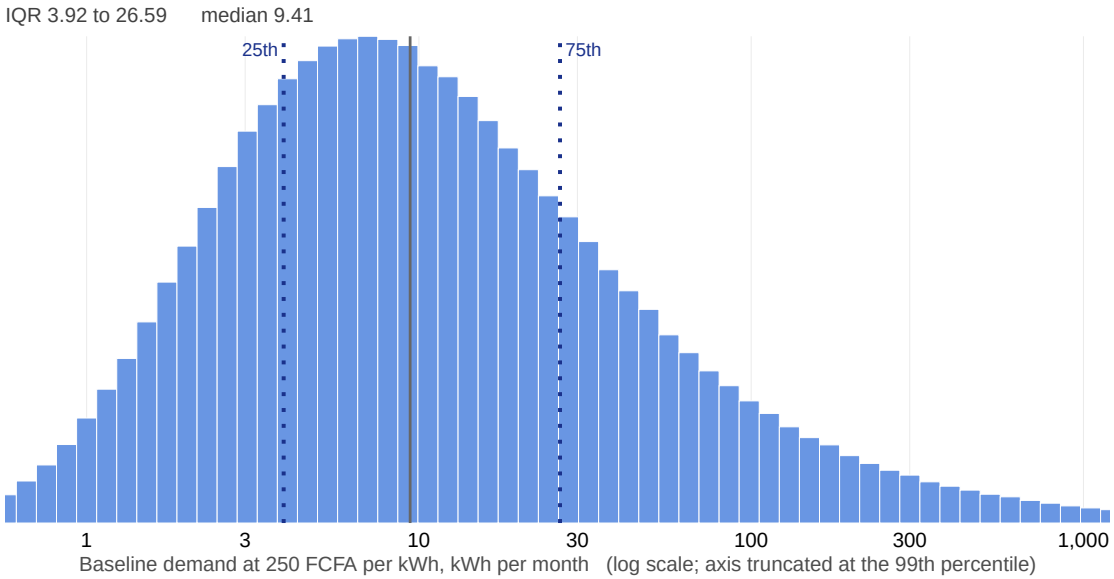
Notes: This figure shows each income quintile and electricity source's share of total formal and informal consumption in the census.

FIGURE A15. Dispersion of Estimated Preference Parameters

Panel A. Disutility of the Connection Fee



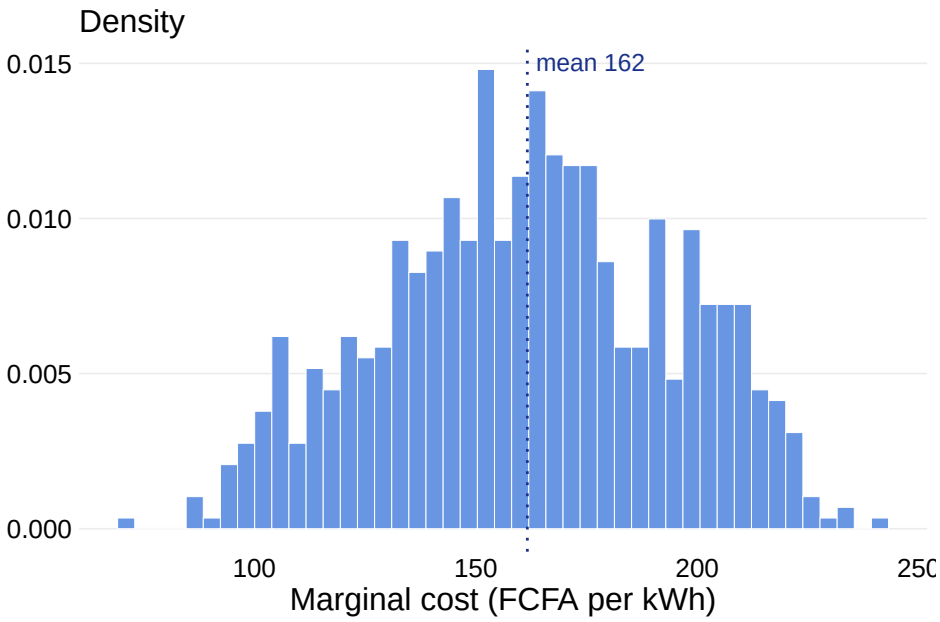
Panel B. Baseline Level of Demand



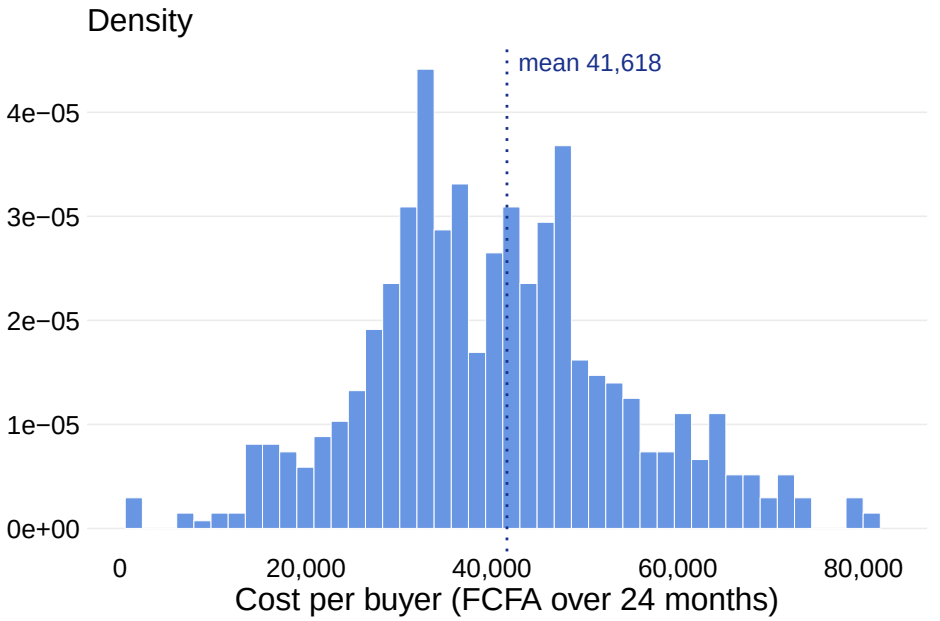
Notes: This figure shows the estimated distributions of connection fee sensitivity and monthly demand at 250 FCFA per kWh, including observed and unobserved heterogeneity. Dashed lines mark the interquartile range; Panel B truncates the axis at the 99th percentile.

FIGURE A16. Recovered Costs of Informal Resellers

Panel A. Marginal Cost

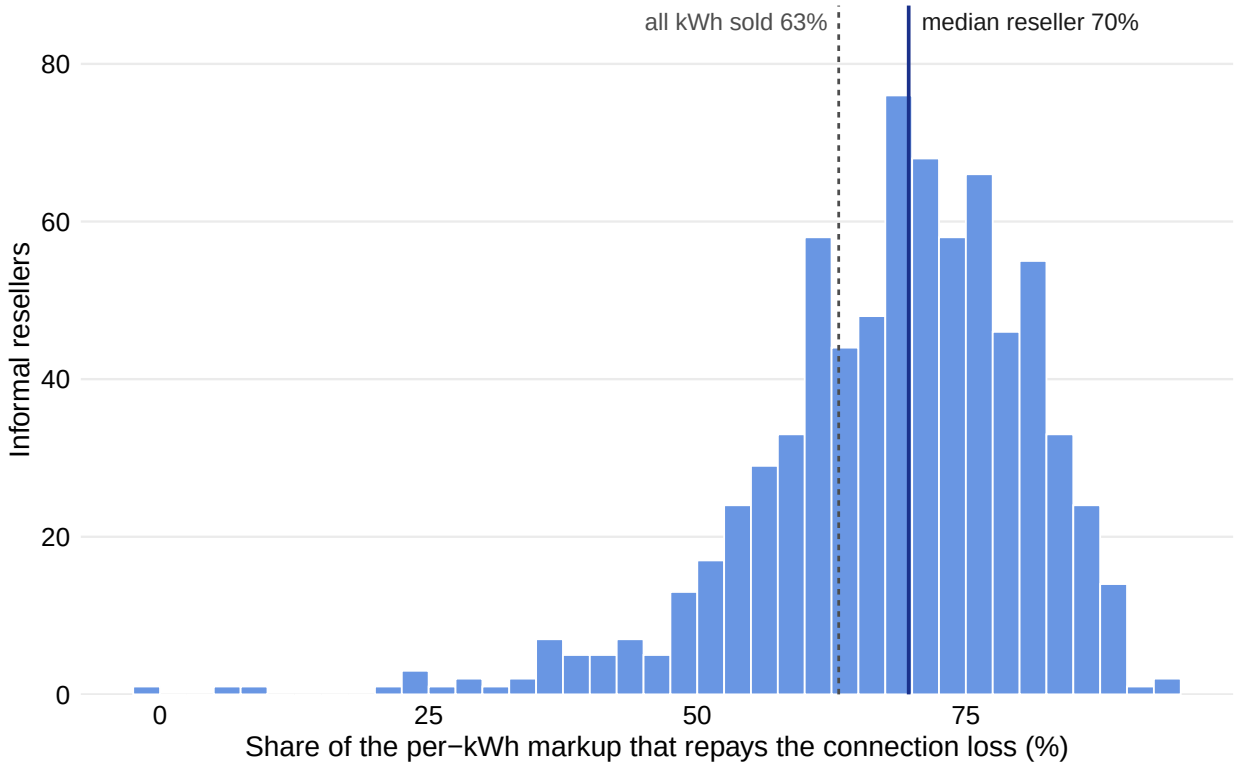


Panel B. Per-Buyer Connection Cost



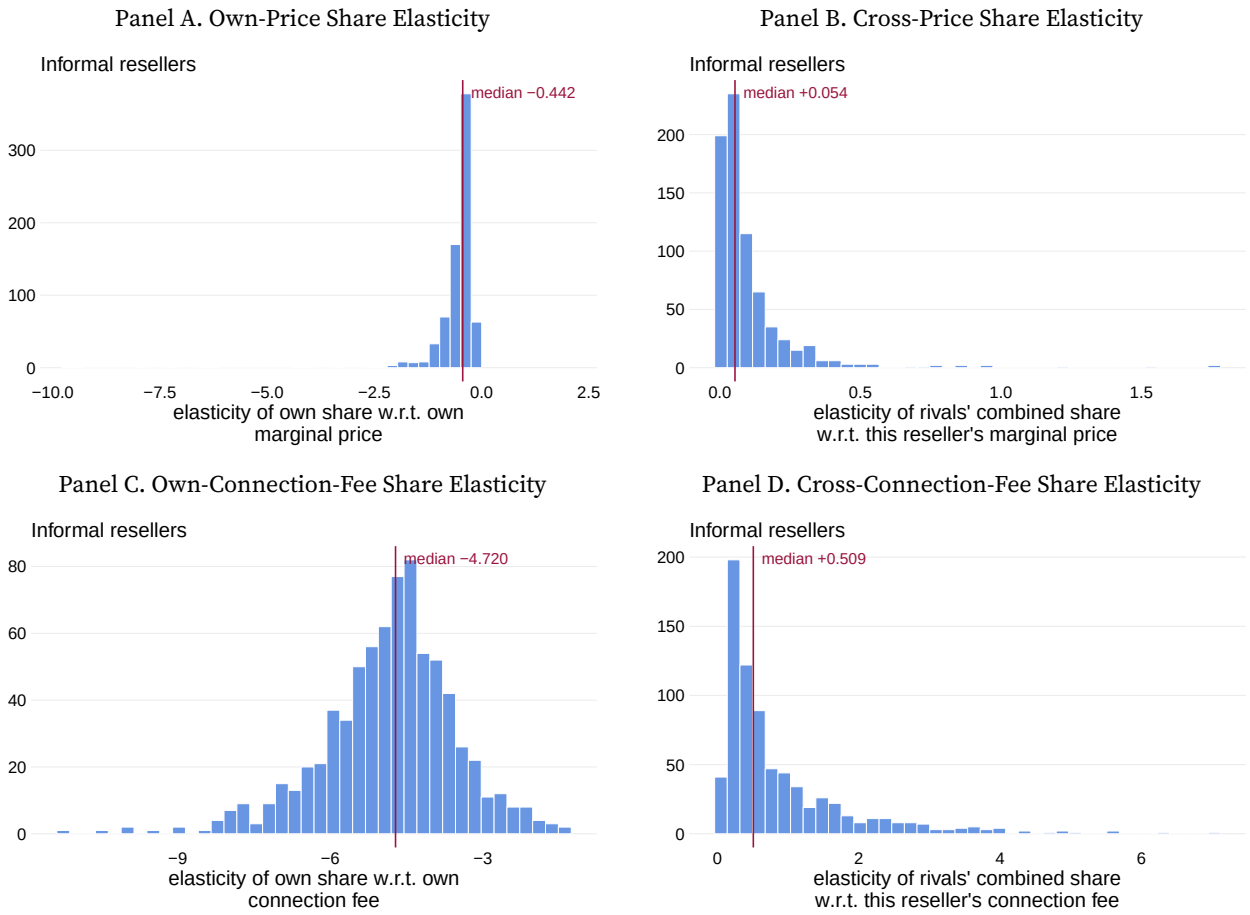
Notes: This figure shows reseller costs recovered from the pricing first-order conditions over a two-year horizon. Per-buyer costs are marginal costs of adding a buyer.

FIGURE A17. Share of the Markup per kWh That Recovers Per-Buyer Costs



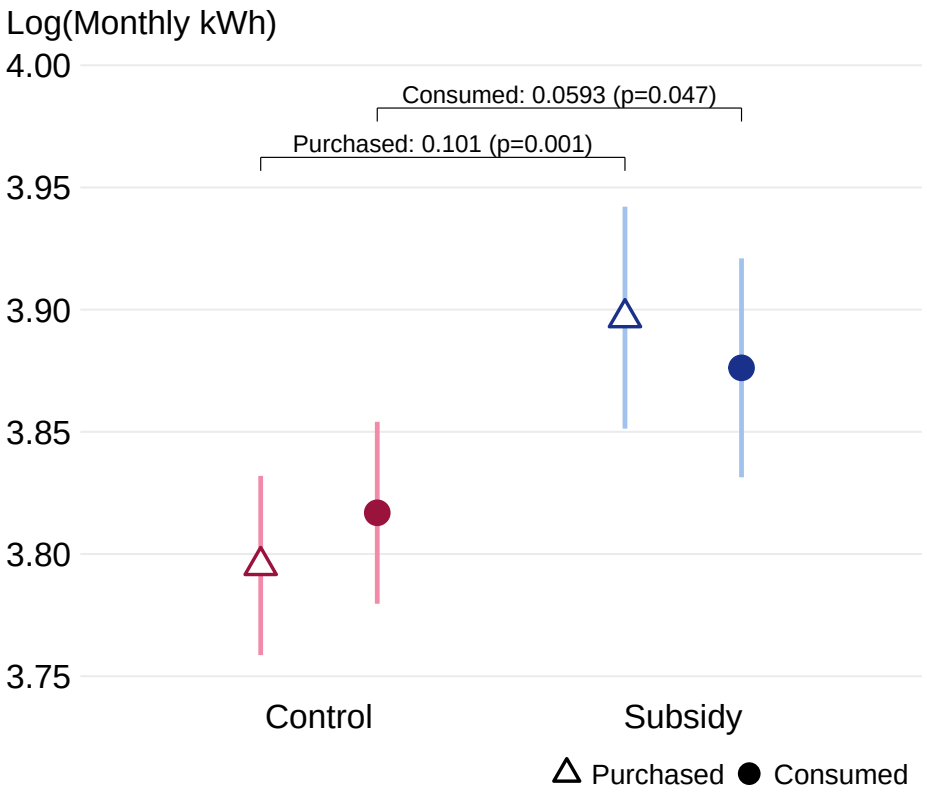
Notes: This figure shows the distribution across informal resellers of the share of the markup per kWh, $p_{jm} - mc_{jm}$, that recovers the per-buyer cost net of the connection fee. For each reseller, this share is $(c'_{jm} - f_{jm})/(T\bar{q}_{jm})$ divided by $p_{jm} - mc_{jm}$, where c'_{jm} is the per-buyer cost, $\bar{q}_{jm}$ is the model-implied monthly consumption of the reseller's average buyer, and T is two years. The solid line marks the median reseller. The dashed line marks the share across all kWh sold.

FIGURE A18. Distribution of Share Elasticities of Informal Resellers



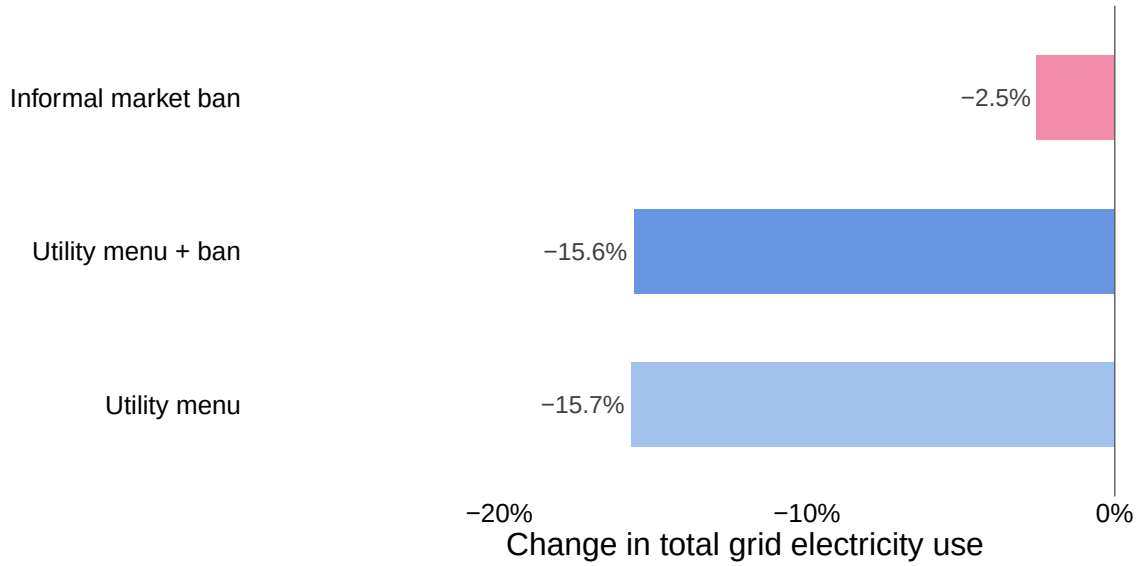
Notes: This figure shows reseller-specific elasticities of household connection shares with respect to a reseller's marginal price and connection fee. Cross-elasticities refer to the combined share of other informal resellers in the market.

FIGURE A19. Effect of T3 on Top-Up



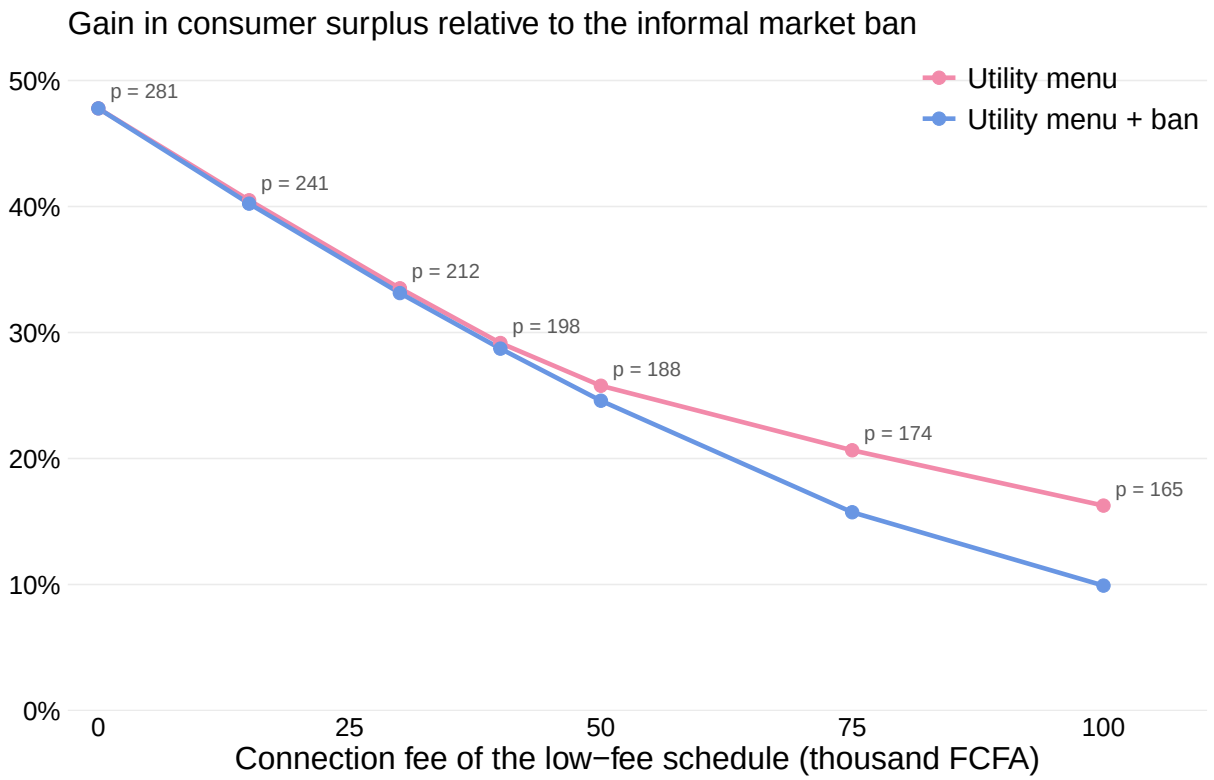
Notes: Panel A compares adjusted log purchases and consumption by T3 assignment among formal households that do not share or resell. Intervals are 95% confidence intervals with standard errors clustered at the market level.

FIGURE A20. Counterfactual Changes in Total Grid Electricity Consumption



Notes: This figure plots the percent change in total monthly grid electricity consumption relative to the status quo in each counterfactual scenario. Grid consumption includes formal and informal consumption and excludes solar.

FIGURE A21. Gains in Consumer Surplus From Low-Fee Schedules, by Connection Fee



Notes: This figure plots the percent gain in consumer surplus relative to the informal market ban for low-fee schedules with different connection fees. For each connection fee, the marginal price (labeled p, in FCFA per kWh) is set so that the utility's producer surplus equals its status quo level. The pink line is the utility menu and the blue line is the utility menu with the informal market ban.

Additional Tables

TABLE A1. Attrition Between Census Assignment and Baseline Recruitment

			Baseline			Endline		
Experiment	Arm	N assigned	N	% of assigned	p-value	N	% of baseline	p-value
Extensive (T1)	Control	454	418	92.1	–	345	82.5	–
	High Extensive Subsidy	450	417	92.7	0.803	338	81.1	0.592
	Medium Extensive Subsidy	452	423	93.6	0.440	360	85.1	0.349
Intensive (T2)	Control	648	596	92.0	–	519	87.1	–
	Subsidy	644	585	90.8	0.488	499	85.3	0.399
Supply (T3)	Control	1,153	998	86.6	–	811	81.3	–
	Subsidy	1,222	1,077	88.1	0.351	919	85.3	0.215

Notes: This table reports the attrition of households from the number of households randomized into treatment and control from the census. Households may drop out from the census to the baseline, then again from the baseline to the endline. The number of households that partcipated in the baseline were the actual number of households that participated in the study. We report baseline recruitment as a share of assigned households and endline response as a share of baseline respondents.

TABLE A2. Demographic Comparison of Census and Experimental Sample

	Full Census		Census (143 Mkts)		Exp. Sample, Unweighted		Exp. Sample, Weighted	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Household Size	4.7	2.5	4.7	2.5	5.1	2.7	5.1	2.7
Room Size	3.5	1.8	3.5	1.8	3.8	2.0	3.7	1.9
Rents Home	0.35	0.48	0.35	0.48	0.30	0.46	0.33	0.47
Years in Dwelling	8.7	11.1	8.8	11.3	10.4	11.8	10.0	11.9
Years in Community	9.4	11.6	9.5	11.8	11.1	12.4	10.7	12.4
Income Quintile 1 (Poorest)	0.24		0.24		0.21		0.22	
Income Quintile 2	0.22		0.22		0.21		0.22	
Income Quintile 3	0.16		0.16		0.15		0.16	
Income Quintile 4	0.27		0.28		0.29		0.28	
Income Quintile 5 (Richest)	0.10		0.10		0.14		0.11	
Wall: Cement/Concrete/Cut Stone	0.84		0.84		0.83		0.82	
Wall: Fired Bricks	0.09		0.10		0.10		0.10	
Wall: Improved Mud Brick	0.01		0.01		0.01		0.01	
Wall: Traditional Stone	0.02		0.02		0.02		0.02	
Wall: Straw/Mud/Clod of Earth	0.02		0.02		0.02		0.02	
Wall: Recycled Materials	0.02		0.02		0.02		0.02	
Floor: Cement/Concrete/Cut Stone	0.76		0.77		0.73		0.76	
Floor: Fired Bricks	0.03		0.03		0.03		0.03	
Floor: Traditional Stone	0.02		0.02		0.02		0.02	
Floor: Straw/Mud/Clod of Earth	0.01		0.01		0.01		0.01	
Floor: Tiles	0.17		0.16		0.20		0.16	
Roof: Cement Slab	0.05		0.05		0.06		0.05	
Roof: Tile	0.03		0.03		0.03		0.02	
Roof: Sheet Metal	0.91		0.92		0.90		0.92	
N	10,191		8,833		4,209		4,209	

Notes: This table compares census characteristics across samples. The weighted column reweights the experimental sample to match electricity-source shares in the 143 census markets. Income quintiles use the full census distribution.

TABLE A3. Randomization Balance, Baseline Characteristics by Treatment Arm

	T1			T2		T3	
	Control Mean (1)	High − Control (2)	Medium − Control (3)	Control Mean (4)	Subsidy − Control (5)	Control Mean (6)	Subsidy − Control (7)
Panel A: Household baseline characteristics							
Household Size	4.86	0.17	0.17	5.20	0.15	5.43	0.01
		(0.18)	(0.18)		(0.15)		(0.21)
Room Size	2.86	0.22**	0.03	3.68	0.00	4.45	-0.08
		(0.11)	(0.11)		(0.11)		(0.17)
Rents Home	0.381	0.028	0.008	0.371	-0.017	0.212	-0.017
		(0.037)	(0.036)		(0.029)		(0.055)
Asset Index	-0.559	0.054	-0.040	-0.146	0.085*	0.520	0.020
		(0.064)	(0.063)		(0.046)		(0.077)
Years in Dwelling	10.70	-0.80	0.66	9.20	-0.72	11.51	-0.06
		(1.02)	(1.09)		(0.62)		(1.01)
Years in Community	11.62	-0.86	0.54	9.94	-1.09*	12.28	-0.40
		(1.04)	(1.11)		(0.64)		(1.07)
Has Savings Account	0.119	0.002	-0.027	0.137	0.011	0.223	0.031
		(0.024)	(0.023)		(0.021)		(0.026)
Attempted to Borrow	0.308	-0.031	-0.048	0.306	-0.010	0.350	-0.048
		(0.034)	(0.034)		(0.028)		(0.048)
Marginal Price (FCFA/kWh)				264.5	-1.2		
					(1.8)		
Monthly Elec. Payment (FCFA)				3,828	259	14,314	-1,064
					(220)		(897)
Monthly Consumption (kWh)				20.84	-1.03		
					(3.00)		
Prepaid Top-ups, 150 Days Pre-Treatment (kWh)						399.7	-53.0*
							(28.1)
Prepaid Top-ups, 150 Days Pre-Treatment (FCFA)						66,357	-7,970*
							(4,347)
Joint *F*-test *p*-value		0.508	0.659		0.245		0.587
Panel B: Market characteristics (one observation per market)							
Share Formal, Resale						0.092	0.001
							(0.010)
Share Informal Buyers						0.230	-0.018
							(0.023)
Share Outside Option						0.425	-0.008
							(0.035)
Share Formal, No Resale						0.253	0.026
							(0.036)
Informal Marginal Price (FCFA/kWh)						260.9	2.8
							(3.8)
Joint *F*-test *p*-value							0.815

Notes: This table compares baseline characteristics between each treatment arm and its control group. Panel A shows balance by household characteristics and Panel B shows balance by market characteristics. Columns (1), (4) and (6) report control means. The other columns report each arm's difference from control, with standard errors in parentheses. Panel B uses one observation per market. Standard errors in Column (7) of Panel A are clustered at the market level. Standard errors are otherwise heteroskedasticity-robust. ***, **, * indicate statistical significance at the 1%, 5%, and 10% levels, respectively.

TABLE A4. Experimental Take-Up

Experiment	Arm	N assigned	N took up	% take-up	N redeemed
Extensive (T1)	High Extensive Subsidy	404	227	56.2	–
	Medium Extensive Subsidy	413	206	49.9	–
Intensive (T2)	Subsidy	581	470	80.9	3.7
Supply (T3)	Subsidy	1,095	868	79.3	9.3

Notes: This table reports take-up among treated households in each experiment's analysis sample. The final column counts subsidy redemptions among households that took up; formal households may redeem multiple times per month.

TABLE A5. Sensitivity of Marginal Price of the Low-Fee Schedule by Horizon and Discount Rate

	Connection fee (thousand FCFA)						
Annual discount rate	0	15	30	40	50	75	100
Panel A: 24-month horizon							
0%	281	241	212	198	187	173	164
5%	300	253	218	202	190	174	164
10%	322	264	224	207	194	176	165
20%	377	292	239	216	200	179	167
30%	454	328	255	227	207	182	169
Panel B: 5-year horizon							
0%	175	170	166	164	162	158	155
5%	179	174	169	166	163	159	156
10%	183	177	171	168	165	160	157
20%	197	187	178	173	168	162	158
30%	215	199	186	179	173	165	160
Panel C: 10-year horizon							
0%	163	161	159	158	157	155	153
5%	166	163	161	159	158	156	154
10%	169	166	163	161	159	157	154
20%	178	173	168	166	163	159	156
30%	191	183	175	171	167	161	158

Notes: This table reports the marginal price (FCFA per kWh) of the low-fee schedule that keeps the utility's producer surplus at its status quo level, for each connection fee and each assumption on the utility's planning horizon and annual discount rate. We simulate the equilibrium model for each scenario to calculate marginal price that do not incur additional loss. The utility earns the connection margin when a household connects. It earns the margin on each kWh every month from one month after connection to the end of the horizon. In each row, the status quo producer surplus uses the same horizon and discount rate. The main counterfactuals use a 24-month horizon and no discounting (first row).