POLICY RESEARCH WORKING PAPER 11019

Agricultural Windfalls and Electrification

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WORLD BANK GROUP
Africa Region
Office of the Chief Economist
January 2025

Abstract

This paper studies how windfalls from agriculture influence demand for electrification in a developing country. Leveraging two decades of administrative data on the universe of electricity grid customers in Rwanda, and plausibly exogenous variations in international coffee prices, we document two key findings: (I) Historical coffee price booms explain about 4% of the increase in electrification rates in Rwanda. (II) Coffee price shocks are also associated with an increase in electricity consumption by connected households. Relaxing liquidity constraints associated with upfront payment of connection fees and increased demand for electrical appliances are likely mechanisms.

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Produced by the Research Support Team

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JEL classification: O13,Q01, Q41, E22, L94
Keywords: Coffee Prices, Agriculture, Electrification, Rwanda

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1 Introduction

More than 560 million people in Sub-Saharan Africa (SSA) lack access to electricity, making the region the last frontier of electrification efforts. Among the connected, consumption of electricity is low by global standards. Rural populations are particularly under-served due to the relatively high cost of extending electric grid infrastructure to communities with low population density spread over a large geographic expanse. Aside from these supply constraints, demand-side constraints are also pervasive: even where the infrastructure is available, demand gaps persist (Blimpo and Cosgrove-Davies, 2019; Blimpo et al., 2020; Lee et al., 2020; Grimm et al., 2020). Factors such as low levels of household income relative to connection and usage cost, unstable incomes, housing quality, and the lack of complementary inputs needed to use electricity productively constrain households' demand for electricity connection (Blimpo and Cosgrove-Davies, 2019). The prevalence of prepaid electricity metering, as in the case of Rwanda, further limits liquidity-constrained households' incentives to connect (Lang, 2020).[1]

In this paper, we investigate the effect of income windfalls on the demand for electrification in a low-income environment. Specifically, we examine the extent to which windfalls from agriculture, via shocks in the price of tradable agricultural products such as coffee, influence demand for modern technologies like electricity. Agriculture is the main source of household income(s) in many developing economies, particularly in SSA. Income from agriculture is often unpredictable. In any production season, household income flows could be disrupted by droughts/floods, crop and animal diseases, and market prices via trade shocks, thereby limiting their ability to pre-commit to costly investments such as paying for electricity connections.Therefore, in such a context, a question that arises and which we seek to answer is the extent to which households' demand for electricity connections and consumption increase when they experience income windfalls from agriculture.[2]

To achieve this goal, we first assemble two decades of unique administrative data on the connection dates of the universe of all grid-connected electricity customers in Rwanda - a country that has made significant progress in electrification over the past two decades - to track the connection rate at the municipality level, otherwise referred to as sectors,[3] between 2000 and 2019. We combine this with historic data on coffee cultivation intensity across municipalities at baseline and exploit plausibly exogenous variations in coffee prices on the international market to identify the effects of coffee price shocks on demand for electrification. In the second part

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[1] There is universal rollout of prepaid electricity meters for residential and non-residential users. Large industries and bulk consumers are the only exceptions.

[2] Answers to these questions could provide useful insights to electrification policy design in developing countries. For instance, can scheduling electrification efforts to coincide with harvesting seasons ensure high take-ups?

[3] The third administrative region

of the paper, we use billing records of the universe of all grid-connected electricity customers in the country from 2011 to 2019 to estimate the effects of coffee price shocks on electricity consumption. To understand the mechanisms, we also use household survey data on electric appliance ownership from the demographic household surveys (DHS) and explore the effects of price shocks on household demand (ownership) for electric appliances.

Our identification strategy is essentially a difference-in-difference design where we compare municipalities based on a predetermined coffee intensity and yearly variations in international coffee prices. Despite being a relatively small country, Rwanda is quite diverse in terms of coffee suitability; hence, not all municipalities grow coffee (see Figure 2). Thus, per our identification strategy, municipalities with high coffee intensity will experience large income shocks when coffee price changes on the international market relative to municipalities with low coffee intensity or non-coffee growing areas (Carrillo, 2020). The identification strategy relies heavily on the assumption that in the absence of coffee price shocks, electrification rates would have evolved along similar patterns between high and low-coffee-intensive municipalities. We provide evidence to support the plausibility of this assumption: (I) Rwandan coffee farmers are essentially price-takers as the country is not a leading producer of coffee and hence shocks to domestic production are unlikely to influence coffee prices on the international market. (II) We rule out concerns of strategic discrimination in favor of coffee-growing areas in the distribution of public infrastructure such as electricity grid network.

Two main findings emerge from the paper. First, coffee price shocks are associated with an increase in demand for electrification for both residential and non-residential uses. A 10% increase in coffee prices is associated with a 1.3% increase in the electrification rate. A counterfactual analysis suggests that the historical increase in coffee prices (between 2000 and 2019)[4] may explain about 4% of the increase in the electrification rate in Rwanda. Second, our results show that a rise in coffee prices leads to a disproportionate increase in electricity consumption in municipalities with high coffee cultivation.

Further, we examine the extent to which value-addition in the coffee value chain via the introduction of coffee mills amplifies the impact of the price shocks on demand for electrification. In an attempt to increase the value of coffee exports from Rwanda, the country embarked on the construction of coffee mills (washers) to improve coffee washing and drying by smallholder farmers, thus moving them away from the traditional methods of coffee washing and drying (Guariso and Verpoorten, 2018; Macchiavello and Morjaria, 2021; Sanin, 2021). Coffee washed in these mills attracts a higher market premium than traditionally (regular) processed coffee

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[4] Real coffee price surged 20% during this period.

(Guariso and Verpoorten, 2018).[5] We leverage the staggered introduction of coffee mills across municipalities to examine the effects of the introduction of coffee mills on demand for electrification. Our findings show a positive association between the introduction of coffee mills and demand for electrification. This provides additional evidence of how income shocks from coffee affect demand for electrification.

In terms of mechanisms, our results point to two potential channels. First, the windfalls associated with price shocks allow (unconnected) households that hitherto were facing liquidity constraints to be able to afford the upfront cost of cost of connection. Secondly, windfalls are associated with an increased demand for electrical appliances, which increases the consumption of electricity by connected households.

Our results are robust to several falsification tests. For instance, we show that the effects are not driven by a mere expansion in grid infrastructure in coffee-intensive municipalities because access to the grid infrastructure in these municipalities is statistically no different from low (non) coffee-intensive municipalities. In addition, conditional on localities with an electricity grid infrastructure, coffee price shocks are associated with increased uptake of electricity, particularly by rural households. Our results also survive a placebo test, in which we randomly assign municipalities to high and low baseline coffee intensity. The findings are consistent with the notion that coffee price shocks induce positive income shocks for households in coffee-intensive municipalities, enabling them to afford connection costs and purchase electricity for consumption.

This paper contributes to two strands of the literature. First, it offers a new perspective to the literature on understanding the demand constraints and drivers of electrification in developing countries. A growing number of studies on (rural) electrification have documented the demand-side constraints to electricity adoption in low-income environments, key among which include the relatively high upfront costs of connection (Golumbeanu and Barnes, 2013; Blimpo and Cosgrove-Davies, 2019; Blimpo et al., 2020; Lee et al., 2020; Grimm et al., 2020). Lee et al. (2020) for instance argues that even for large-scale electrification programs that benefit from economies of scale, the high cost of electricity connections relative to the average income levels of most rural households leads to low demand for grid connection. Lang (2020), also shows that beyond the initial upfront cost, the usage cost (electricity bills) is a major constraint to adoption for liquidity-constrained households. Given the structural rigidities in addressing the critical issue of liquidity constraints, what options exist for developing countries to increase electricity uptake? This study provides novel evidence on how agricultural windfalls can

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[5] A fully washed coffee from the mills sells for an average of \$3 per kg relative to 2\$ for regular coffee in 2007 (Guariso and Verpoorten, 2018).

be leveraged to increase the demand for critical technologies such as electricity for otherwise liquidity-constrained agricultural households. Our findings suggest that (rural) electrification efforts in developing countries can be designed to coincide with the harvesting season of major cash crops like coffee and cocoa: a period where (farm) households experience positive income shocks and may have (temporary) financial resources to make long-term investments like paying for electricity connection.

Secondly, we also contribute to the literature on the socioeconomic impacts of commodity price shocks in developing countries. For years, economists have documented the seemingly negative correlation between resource (mineral and agricultural) endowments and development outcomes, the so-called *resource-curse* thesis (Sachs and Warner, 2001). Since then, a plethora of studies have shown empirical evidence on the underlying channels through which resource abundance undermines economic development. The evidence shows that commodity price shocks are associated with civil conflicts and social unrest (Angrist and Kugler, 2008; Dube and Vargas, 2013; Berman et al., 2017; Ubilava et al., 2022; Hastings and Ubilava, 2023), erosion of institutional quality (Hausmann and Rigobon, 2003; Sala-i Martin and Subramanian, 2013), elevated expectations and associated economic mismanagement (Cust and Mihalyi, 2017; Cust and Mensah, 2020), etc. However, recent evidence using microdata suggests that the impact of commodity price shocks is much more nuanced. For example, Adhvaryu et al. (2019), shows that exposure to positive price shocks of tradable agricultural products like cocoa in early life is associated with a lower probability of experiencing mental health disorders in adulthood, with childhood investments as a likely operative channel. On the other hand, Carrillo (2020) finds that exposure to positive coffee price shocks during school-going ages is associated with lower educational attainment in Colombia due to a high perceived opportunity cost of schooling. We contribute to the ongoing debate on the economic impacts of commodity windfalls by showing how these windfalls influence households' investment decisions on infrastructure like electricity that have the potential to "trigger" other household outcomes.

The rest of the paper proceeds as follows. Section 2 presents a brief description of the context as it relates to electrification and the coffee sector in Rwanda. Section 3 presents a brief description of our conceptual framework. Section 4 presents the data, while Section 5 presents the empirical analysis of the impact of coffee price shocks on demand for electrification. The empirical analysis of how coffee price shocks affect electricity connection, consumption, and purchasing behavior of connected households are presented and discussed in Section 6. We conclude the study in Section 9 with a summary of the main findings

2 Context

2.1 Electricity

About a decade ago, Rwanda was among the countries with the lowest electrification rates in the world. The country has since made significant progress in increasing access to electricity by about threefold, from about 15% in 2013 to 49% in 2021 (Figure 1). Access rates in rural communities also increased from 6% to 38% over the same period. One of the key reasons behind the growth in electrification is the government's massive expansion of grid infrastructure, based on a policy embracing both grid and off-grid solutions, with the latter targeting rural households beyond the reach of the (planned) grid coverage.[6] However, even when the grid is available, connection cost has been a major hindrance to households who want the service. The standard connection fee for households, within 37 meters of a connection source, in 2017 was about $67 (RWF 56,000).[7] However, as shown in Blimpo and Cosgrove-Davies (2019), the total connection cost could range between $78 and $189 depending on the distance to the nearest electricity pole and wiring cost. Given the average income levels in the country, this represents a relatively large share of households' income with implications on demand for connectivity.

To address this challenge and increase the connectivity rate, the government in October 2017, introduced a policy that relaxed the cost requirements for electricity connections. Under the new policy, customers who could not afford the full upfront cost of connection could be connected and pay the connection fees in installments.[8]

A unique feature of the Rwandan electricity services is the universal rollout of prepaid electricity metering for residential and non-residential customers on grid-supplied electricity. A notable exception is the large industries, some of which operate on post-paid meters. Prepaid metering is regarded as an effective instrument for improving the financial viability of utilities in developing countries as it reduces, to a very large extent, the level of non-technical losses (non-payment or low collection of bills) confronting utilities (Jack and Smith, 2015, 2020). However, empirical evidence also suggests that prepaid metering entails unintended consequences: low consumption arising from the associated high marginal price of electricity, resulting in low revenue to the utility (Jack and Smith, 2015, 2020). These features are quite evident in Rwanda.

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[6] https://www.reg.rw/what-we-do/access/

[7] https://www.reg.rw/fileadmin/user_upload/RevisedNewConnectionPolicy__1_-75742.pdf

[8] Specifically, for each purchase of electricity, 50% of the paid amount was used to repay any outstanding connection fees. See: https://www.reg.rw/fileadmin/user_upload/RevisedNewConnectionPolicy__1_-75742.pdf and https://documents1.worldbank.org/curated/en/819241600653622828/pdf/Rwanda-Energy-Access-and-Quality-Improvement-Project.pdf

2.2 Coffee Sector in Rwanda

Coffee was first introduced in Rwanda in the early 1900s, during the colonial period, by the German missionaries. Cultivation of the crop expanded to many parts of the country and became a major revenue source for the colonial government.[9] At the time of independence, in 1962, the coffee sector accounted for nearly 55% of Rwanda's exports. However, following the collapse of the international coffee market in the 1980s and the subsequent decline of global coffee prices, Rwanda's coffee sector experienced a significant decline. This was further exacerbated by the civil war in the 1990s, as coffee trees were left unattended to, and access to input and output markets was severely constrained (Guariso and Verpoorten, 2018). The sector was steadily revived after the civil war when the new government introduced policy reforms in the sector. Some of the landmark policies in the sector include the introduction of coffee mills (washing stations) to increase the value of coffee exports, and the formation of farmer cooperatives.[10]

The importance of the coffee sector for the Rwandan economy cannot be overemphasized. Aside from being a major foreign exchange earner for the country, it employs thousands of people throughout the value chain (cultivation, washing, milling, and transportation). In 2018 for instance, more than 400,000 smallholder farmers were actively engaged in coffee farming, with approximately 90 million coffee trees grown in more than 88 percent of municipalities in the country. Figure 2 shows the intensity of coffee cultivation across the country. Coffee also accounted for nearly a quarter of Rwanda's total agricultural exports in 2017 (Macchiavello and Morjaria, 2022).

3 Conceptual Framework

Standard economic theory suggests that in the absence of income constraints, a representative household will decide to connect to electricity if the expected benefits from consumption exceed the associated connection and usage costs.[11] However, in many low-income environments, households face severe income and liquidity constraints, thereby limiting their adoption decisions even when the expected marginal utility of connection exceeds the associated marginal costs.

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[9] Coffee farming was made compulsory by the Belgian colonial administrators, and a law prohibiting the uprooting of coffee trees was introduced in the 1930s (Guariso et al., 2011).

[10] According to the 2015 Rwanda National Coffee Census, there were more than 400 coffee cooperatives and 1,538 non-cooperative coffee associations in the country. The main variety of coffee grown in Rwanda is *Coffea arabica*, accounting for more than 90% of the total coffee produced in the country (Guariso et al., 2011).

[11] Connection costs are in practice fixed costs that a customer incurs "once in a lifetime" conditional on the building in situ. However, usage costs are variable cost based on the quantity (kWh) of electricity consumed at the respective tariff rates.

For some households, income levels are often too low relative to connection and usage costs. For others, it is not an issue of low income per se, but the mismatch between income flows and expenditures as incomes are often unpredictable and irregular.[12] In addition, credit markets are underdeveloped, and households face severe challenges accessing credit to smoothen consumption. The combined effect of these factors is a major constraint to households' demand for modern technologies such as electricity. In this section, we present a simple framework to guide our understanding of how income shocks (*transitory* vs. *permanent*) influence electricity adoption decisions of households in low-income environments, as in the context of this study. For simplicity and without loss of generalization, we consider the case of positive income shocks.

In the case of households where income constraints are strictly binding (i.e., expected aggregate income is lower than the sum of upfront connection and usage costs associated with future consumption), a *permanent* income shock matters more than a *transitory* income shock for their electricity adoption decisions. Even if a *transitory* income shock is enough to cover the fixed cost of connection, the mere fact that the household may not be able to afford the cost of future consumption is a disincentive to adoption, all else equal.

On the other hand, for liquidity constrained households, both *permanent* and *transitory* income shocks can influence their adoption decisions. For an unconnected households, *transitory* income shocks, for instance, resulting from an expected commodity price boom, can enable them pay for the upfront cost of connection, with the expectation that future income flows can support the usage cost once connected. Similarly, for connected households, a transitory income shock can be expended to: (i) make a one-time purchase of electricity, particularly for those on prepaid meters, as a store of value; and/or (ii) finance the purchase of electrical appliances. The effect of a *permanent* income shock is likely to be similar, albeit with relatively high magnitudes.

To this end, we explore how windfalls from commodity price shocks affect the electricity uptake and consumption decisions of liquidity constrained households using data from Rwanda.

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[12] This is particularly true for agricultural households

4 Data

4.1 Data Description

Electricity Data

The main datasets for this analysis are the municipality-level electricity connection rates between 2000 and 2019 and customer-level quarterly electricity consumption and purchases between 2011 and 2019. These datasets were obtained from a unique database on the billing records of the (near) universe of electricity customers in Rwanda between 2011 to 2019 provided by the Energy Utility Corporation Limited (EUCL)[13] and the Rwanda Utilities Regulatory Authority (RURA).

The database contains detailed information on customer class, date of connection, date and time of electricity purchases, quantity (kWh) of electricity purchases, amount (RWF) of purchases, tax amount of the purchase, medium of purchase (online payment, mobile money, vendor, or at utility office), location or point of connection, municipality, and district. Customers are classified into residential, nonresidential (commercial buildings and stalls, hotels, small industries, medium industries), and public works/buildings (health centers, schools, water storage and pump stations, broadcasters). For the purpose of this study, we focus exclusively on residential and non-residential customers. An important feature of the dataset worth highlighting is that all customers in the dataset use prepaid meters, with large and heavy industries the only exceptions who are allowed to use postpaid meters. Our data exclude these customers (i.e. large and heavy industries). In all, the raw data contains over 300 million customer-event observations.

The panel data on the municipality-level electricity connection rates was constructed as follows. First, using detailed information on the location, date, and time of connection for each customer, we compute the incremental (new) (residential, and non-residential customers) electricity connections per year for each of the 416 municipalities between 2000 and 2019.[14] Second, we scale the connections by the number of people in each municipality, to adjust for population differences across municipalities. Hence our final panel tracks the number of new

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[13] The main distributor.

[14] Essentially, our dataset on electricity connection rate is a retrospective panel constructed using the administrative data on the time of connection. One potential limitation of our dataset is that it may under-estimate the connection rates if for instance some customers who were connected between 2000 and 2010 but were disconnected before 2011, when our dataset starts. However, we do not anticipate this to be a major issue in the context of Rwanda, due to the universal rollout of prepaid meters, hence non-payment of electricity bills which is the main driver of disconnection is almost zero.

electricity connections per 1000 people.[15] Figure 3 shows the temporal trends in electrification at the municipality level.

Next, to understand consumption patterns, we use data on electricity purchases to construct customer-level panel data on electricity consumption (purchases). Specifically, for each quarter-year, we aggregate the data on the frequency of electricity purchases, quantity (kWh) of electricity, quantity (kWh) per transaction, and amount (monetary value in RWF) of electricity purchased. Further, we complement our analysis with spatial data showing the location of the universe of all electricity transformers, as well as the geographic footprints of low and medium-voltage grid lines in Rwanda.[16] This data is used to examine whether coffee-growing municipalities are disproportionately favored in the rollout of grid infrastructure.

Coffee Data

To measure the intensity of coffee cultivation at baseline, we rely on data compiled by Guariso and Verpoorten (2018) from the 1999 Rwandan Coffee Census. The data contains detailed information on the coffee-growing municipalities, including the number of coffee trees in several age groups ($<= 3, 3-10, 10-30$, and ≥ 30 years) per municipality. Using these data, for each municipality, we compute the total number of coffee trees per km^2 in 1999 as the sum of all coffee trees in each municipality divided by the land area (km^2). We use this as our measure of coffee intensity at baseline, reflecting the intensity of coffee cultivation per unit of land area across municipalities. Figure 2 shows the spatial variations in coffee intensity across municipalities in Rwanda.

We complement our analysis with data on coffee prices from the World Bank Commodity Price database.[17] Two main varieties of coffee (*Arabica* and *Robusta*) are traded globally. However, *Coffea Arabica* is the main variety cultivated in Rwanda, accounting for nearly 98% of total coffee production in the country (Guariso et al., 2011). As a result, data on the real annual price (constant 2010) of *Arabica coffee* is used in the study.

Demographic and Health Surveys (DHS)

To complement the above, we draw on household survey data on access to electricity and ownership of electrical appliances such as television, mobile phones, refrigerators, and radio sets. The DHS data is a nationally representative (repeated cross-section) survey of households that

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[15] The population data was sourced from the NASA Socioeconomic Data and Applications Center (SEDAC) https://ciesin.columbia.edu/

[16] Data can be accessed via https://nsdi-rla.hub.arcgis.com/search?collection=Dataset

[17] https://thedocs.worldbank.org/en/doc/5d903e848db1d1b83e0ec8f744e55570-0350012021/related/CMO-Historical-Data-Annual.xlsx

provides useful information on household attributes including, but not limited to, health, demographics, assets, employment, etc. The 2005, 2010, 2014, and 2019 rounds of the survey are used in the analysis.

Complementary Data

In addition to the above, we use data on baseline controls such as the average elevation in the municipality, size (area) of a municipality, distance from the municipality centroid to a major city, border, and major road (Guariso and Verpoorten, 2018). We include for these variables interacted with time trends in our regressions to control underlying correlates of electrification.

4.2 Descriptive Statistics and Evidence

Table 1 presents the summary statistics of key variables used in the analysis. Starting with electricity connections, the number of residential connections per municipality is on average 6.2 per 1000 people. Conditional on connection, the average household consumes 69 kWh of electricity per quarter and purchases electricity about 9 times over the same period. The intensity of coffee cultivation is also high, albeit with significant variations across municipalities. On average, there are about 3119 coffee trees per municipality at baseline (1999). The real price of coffee during the study period (2000-2018) ranged between \$1.8 and \$5.4 per kilogram (kg) with an average of \$3.1 per kg.

To demonstrate the economic importance of coffee in the study area, we show in Table A.1 in the Appendix, the relationship between coffee price shocks and employment.[18] The results (column 3) indicate that a 1% increase in the coffee price shocks is associated with a 0.05% increase in the probability of employment.[19]

5 How Do Coffee Price Shocks Affect Electrification Rates?

We begin the empirical analysis by assessing the effect of coffee price shocks on demand for electrification. The section begins with a description of the identification strategy; we then discuss the baseline results and present a series of robustness checks to ascertain the validity of our baseline results.

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[18] The first-order effect of exposure to the coffee price shocks is income. However, we are constrained by the lack of survey measures on household at the municipality level as the Rwandan Integrated Household Living Conditions Survey (EICV) available only identifies households at the district level. Therefore, we rely on the DHS data and show that coffee price shocks are associated with increased labor market participation in Rwanda.

[19] 0.0349/0.7528=0.046

5.1 Empirical Strategy

To causally estimate the effects of coffee price shocks on demand for electrification, we exploit plausibly exogenous variations in international coffee prices interacted with coffee intensity at baseline across municipalities.[20] Given that our outcome variable, the number of electricity connections (per 1000 people), is count data, we use the Poisson quasi-maximum likelihood (QML) to estimate the effects of coffee price shocks on demand for electricity connections (Wooldridge, 2010; Azoulay et al., 2019; Truffa and Wong, 2022).[21] Our empirical model is specified as:

$$\mathbb{E}(Y_{srt}|X_{st}) = exp\left(\phi \cdot \text{CoffeeIntensity}_{sr} \times \text{lnPrice}_t + \mathbf{X}_{\mathbf{st}}^{'}\alpha + \theta_s + \delta_t + \lambda_p t + \epsilon_{st}\right) \tag{1}$$

where Y_{srt} denotes the number of new (electricity) connections in municipality s, province r, and year t; Coffee Intensity represents the number (1000) of coffee trees per km^2 per municipality at baseline (1999); lnPrice represents the log of the (real) international price of coffee (per kg) in year t. To absorb potential correlates of electrification at the municipality level, we include an exhaustive list of time-invariant controls interacted with time trends represented by $\mathbf{X}_{\mathbf{st}}^{'}$. These controls include average elevation in the municipality, and distance from the municipality centroid to a major city, border, and major road. Elevation is particularly important in the context of electrification in Rwanda, as prior studies have shown that elevation is negatively correlated with expansion in electrification due to the relatively high cost of grid extension in mountainous and rugged terrains (Dinkelman, 2011). Similarly, the distance measures would help absorb the effects of proximity to urban or transport infrastructure that correlates with the rollout of electrification. θ_s represents municipality fixed effects to absorb municipality-specific time-invariant correlates of electrification; meanwhile, year fixed effects, δ_t, are also included to absorb temporal shocks common to all municipalities (e.g., changes in national electrification policies). In addition, we include province-specific time trends,$\lambda_p t$, to account for omitted variables that may be correlated with the concentration of coffee production and trends in electrification across the five provinces in Rwanda (Dube and Vargas, 2013). Finally, we cluster the standard errors at the municipality level to account for the correlation in standard errors over time.

Our identification strategy essentially explores whether changes in coffee prices affect de-

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[20] This is the third level administrative unit in Rwanda.

[21] For example, 31% of our municipality-year observations have zero connections. One of the main advantages of the Poisson QML estimator is that it can be used to estimate a model with zero-inflated (a non-negative) outcome variable in the case of this paper, and also consistent in the presence of high-dimensional fixed effects (Correia et al., 2020).

mand for electrification disproportionately in municipalities that produce more coffee. A price shock will influence demand for electricity through an income effect in two ways. One is simply through higher income from current production. The other is through a supply response - more coffee being produced as a result of higher prices which leads to more income, thus reinforcing the income effect. The income effect through a supply response will confound our identification strategy. Therefore, we fix supply, by using coffee intensity (in 1999) before our sample period. This rules out reverse causality between coffee intensity and electrification because there is no coffee supply response and coffee price variations are exogenous. In other words, we assume coffee producers in Rwanda to be price takers. That is, observed changes in international coffee prices are unlikely to be due to local production shocks (e.g., lack of supply response) in Rwanda. Per this approach, temporal variations in demand stem from yearly variations in coffee prices on the international market, which to a large extent is exogenous to Rwanda's coffee output, given that the country is not a major producer of the commodity. Our coefficient of interest is $\hat{\phi}$, which measures the effects of coffee price changes on electricity connection rates. To visually examine the correlation between coffee prices and electrification in Rwanda, we chart the trends in these variables during our sample period in Figure 4. The figure shows a relatively strong correlation between variations in international coffee prices and the number of electricity connections during the sample period, which underscores the motivation behind the study.

5.2 Results

Table 2 presents the baseline results on the effects of coffee price shocks on electricity connection rates at the municipality level. Columns 1-3 present results on total electricity connections, while in columns 3-5 and 7-9, we focus on residential and non-residential connection rates respectively. For each outcome, we estimate three variant specifications, albeit, our preferred specifications are columns 3, 6, and 9 where we control for the full set of covariates and fixed effects.

Starting with columns 1-3, the results show that increases in coffee prices are associated with increased electrification rates. The effects are both statistically and economically significant. Specifically, given the average coffee intensity of 3.12, the results in column 3 suggest that a 10% increase in coffee prices is associated with a 1.3% increase in the electrification rate.[22] We find similar results in columns 4-6 and 7-9 where we disaggregate the effects into residential and non-residential connections respectively. The results indicate that, for the average munic-

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[22] $(\exp(\hat{\beta}\times \log(1.1)\times 3.12)-1)\times 100=(\exp(.043\times\log(1.1)\times 3.12)-1)\times 100=1.287$

ipality, a 10% increase in coffee prices is associated with a 1.2% (column 6) and 2% (column 9) increase in residential and non-residential connections respectively.

To put the results into perspective, between 2000 and 2019, coffee prices increased by 20% (0.182 log points), from $2.41% to $2.89 (constant 2019) per kg. Given the average coffee intensity at the municipality level, this price increase translates into a 2.5% increase in the electrification rate in the country (column 3).[23] Overall, the results herein show a positive effect of coffee price increases on demand for electrification.

Next, we explore the relative contribution of coffee price shocks over the period 2000 and 2019 in explaining variations in electrification rates across districts in Rwanda. To this end, we adopt the approach of Berman et al. (2017) and predict the changes in electrification rates associated with the increase in coffee prices between 2000 and 2019. In other words, we compute the counterfactual share of electrification rates that would not have occurred if coffee prices had remained at the same levels as in 2000.[24] The results, as shown in Figure 5, reveal significant variations in the relative contribution of coffee price increases over the period on electrification rates across districts.[25] In leading coffee-producing districts such as Nyamasheke, Rutsiro, Kamonyi, and Rusizi, the predicted increase in electrification rates are 14.7%, 9.8%, 9.2%, and 7.6% respectively. Meanwhile, in low coffee-producing districts like Burera, Kirehe, and Musanze, the predicted coffee-induced connection rates are negligible (≈ 0). Averaging across districts, we find that the historical increase in coffee prices contributed on average 4.2% of the observed district-level increase in electrification rates.

5.3 Robustness Checks

This section presents a series of robustness tests to ascertain the validity of our baseline results.[26]

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[23] $(\exp(.043\times0.182\times3.12)-1)\times100=2.47$

[24] The following steps were used. First, we estimate the baseline specification as shown in equation 1 and predict the electrification rates at the municipality level at the observed prices. Second, for each municipality and year, we compare the predicted electrification rates for the observed prices with a counterfactual prediction when prices are set to their 2000 level. Third, we sum the electrification rates across all municipalities and years in each district. Five, we compute the ratio of the difference between the predicted electrification rates at observed prices and the counterfactual prices over the total number of connections in each district between 2001 and 2019.

[25] Second administrative region

[26] Ideally, we would like to check the robustness of our baseline estimates to spatial clustering of the standard errors. However, the current techniques for estimating Conley (1999) spatially correlated standard errors for Poisson models are only available for cross-sectional data, hence limiting its application for our panel data. See for instance https://cran.r-project.org/web/packages/conleyreg/conleyreg.pdf

5.3.1 Sensitivity checks

Placebo test: Coffee or Geographic Effects?

There is a concern that coffee municipalities could in principle be different from non-coffee-producing municipalities and therefore induce variations in electrification outcomes independent of the income shocks from coffee price booms. In other words, our baseline differences in the coffee intensity across municipalities could be picking up structural differences across municipalities, other than coffee cultivation per se, therefore affecting our estimated impacts. For instance, coffee cultivation is well suited for slopes as it avoids water stagnation. At the same time high elevation and slopes increase the cost of grid expansion, thereby leading to lower expansion of the infrastructure in such areas. Technically, our battery of municipal and provincial fixed effects should absorb these spatial differences.[27]

Nonetheless, we address this concern using a randomized inference approach (Athey and Imbens, 2017). Specifically, we perform a placebo test by randomly assigning coffee intensity measures across municipalities while holding coffee price(s) constant. Essentially, we randomly assign municipalities to high and low baseline coffee intensity and re-estimate our baseline equation (1) 1000 times to examine the empirical distribution of the coefficients.

Figure 6 presents the empirical distribution of the coefficients from the placebo tests compared to the baseline estimates in Table 2. If the effect of coffee price shocks on electrification that we observed was driven by some geographic differences other than coffee, then our baseline estimate from Table 2 should be somewhere in the middle of the empirical distribution of the placebo effects. However, as shown in Figure 6, in all cases, the average placebo estimates are centered around zero and significantly lower than the baseline estimates. Specifically, none of the random draw yields estimates larger than the baseline results of the effects of the coffee price shocks on electricity connections. This evidence provides support to our identification strategy and that only the actual differences in coffee intensity at baseline drive our results.

Leave-one-out

Given the heterogeneity in coffee cultivation in Rwanda, an obvious question that may arise is to what extent are the results representative, or driven by a particular set of locations? To address this concern, we conduct a "leave-one-out" exercise where we iteratively estimate the

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[27] Moreover, the differences in elevation work in our favor as coffee price shocks should have muted impacts on electricity uptake in coffee-intensive municipalities due to the associated high cost of grid expansion–implying that our estimates are somewhat a lower bound. Nonetheless, we find no evidence of (strategic) discrimination in the grid infrastructure rollout between high-and-low coffee-intensive municipalities.

baseline specification, while excluding observations from one district at a time.[28] The results in Figure 7 show that the results are not necessarily sensitive to a particular set of districts. In other words, regardless of which district is omitted, the results survive: remaining positive, and statistically significant.

Alternative measure of coffee intensity

We also present additional estimates using a dummy measure of the coffee intensity as opposed to the continuous measure in the main results (see Table A.2 in the Appendix). Specifically, we generate an indicator variable, Coffee Producer, set equal to 1 if the number of coffee trees at baseline (1999) is greater than zero and 0 if otherwise.

The results are qualitatively similar to baseline estimates. A 10% increase in coffee prices is associated with a 4.4% increase in the total electrification rate (column 3).[29] The corresponding increase in residential and non-residential connection rates are 4.5% (column 6) and 3.9% (column 9) respectively. Overall, the results show the robustness of our results to the measure of coffee intensity at baseline.

5.3.2 Demand-side vs supply-side effects

So far, our working hypothesis is that coffee price shocks induce demand for electrification, particularly, among households. However, given that our outcome variable, the number of (new) electricity connections, is an equilibrium outcome of demand and supply of electricity infrastructure, to what extent can we argue that the observed results are purely a demand-side effect and not a supply-side effect? For instance, over the past ten years, the Rwanda government has embarked on a massive expansion of electrification infrastructure, which could influence the rate of electrification in the country. Thus to what extent can we disentangle these supply-side effects from the demand-side effects? Admittedly, disentangling the supply and demand side effects is an empirical challenge.

In this section, we present some evidence that lends support to our hypothesis that the estimated effects reflect the demand-induced effects of income shocks from coffee cultivation. Specifically, we adopt two strategies that examine the association between: (i) coffee price shocks and electricity uptake (i.e., electricity adoption conditional on infrastructure availabil-

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[28] For the sake of brevity and without loss of generality, we conduct this exercise by dropping observations at the district level instead of the municipality level, due to the relatively large number of municipalities (416) compared to districts (30). Recall that municipalities are subdivisions of districts, hence by dropping districts we are dropping multiple municipalities at a time.

[29] $(\exp(\hat{\beta}\times \log(1.1))-1)\times 100=(\exp(.454\times\log(1.1))-1)\times 100=4.4\%$

ity), and (ii) coffee intensity and roll-out of electricity infrastructure.

Coffee Price Shocks and Electricity Uptake

If the baseline estimates of the increase in electricity connections are driven by an expansion in electricity infrastructure, and not necessarily due to increased households' demand for electricity connection as a result of income shocks associated with coffee price shocks, then the correlation between the price shock and connection should disappear when we condition on communities for which the infrastructure is already available.

To test this hypothesis, we leverage the DHS data and restrict the sample to communities (enumeration areas) with at least one household connected to electricity. Using this sample, we explore the association between coffee price shocks and the probability of a household being connected to electricity. The results in Table 4 show a positive association between coffee price shocks and the probability of households connecting to electricity in communities for which the infrastructure is available, though the coefficients are not statistically significant for the full sample which includes urban residents. However, the effect is even stronger and statistically significant when we restrict the sample to rural communities which happen to be: (i) the last mile of electrification efforts; and (ii) where coffee cultivation and processing occur. These results provide suggestive evidence in support of our hypothesis, that income shocks from coffee increase demand for electricity connection, as households that hitherto could not afford to, for instance, pay connection fees can now afford to do so. This is important to emphasize because, aside from the cost of expanding grid infrastructure to communities, often borne by the government or power utility, households are also required to make some upfront payments before being connected. Such costs usually cover registration fees, wiring costs, cost of electric meters, electric pole(s), etc.[30] These connection fees can be costly, especially for low-income households. In Rwanda for instance, estimates from Blimpo and Cosgrove-Davies (2019) suggest that the total cost of electricity connection can range between \$78 and \$189 (9%-27% of GDP per capita) depending on whether the household requires an extra electric pole. Thus, for credit-constrained households, income shocks from agriculture such as coffee production can play an important role in securing electricity connections.

Coffee Intensity and Roll-out of Electricity Infrastructure

Another concern is that perhaps given that coffee is an important source of foreign exchange earnings and revenue for the Rwandan government, the state could favor coffee-intensive mu-

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[30] In most countries, households located beyond a 30-meter radius from an existing pole are required to pay for an extra pole to extend the electric line to their premises (Blimpo and Cosgrove-Davies, 2019).

nicipalities in the roll-out of public infrastructure such as electricity. If so, then perhaps our estimated impacts are driven by coffee-induced supply shocks. To test this assumption, we compile granular spatial (cross-sectional) data on the geographic footprints of key electricity grid infrastructure such as (i) location of all electricity transformers;[31] and (ii) transmission and distribution lines and explore the correlation between these grid infrastructure and coffee intensity at the municipality level.

Figure 8 shows the intensity of these grid infrastructures across municipalities, while Table 5 shows the association between coffee intensity and the availability of grid infrastructure in Rwanda. Starting with the grid network, we do not find a statistically significant association between coffee intensity and the length of the grid network in the municipality (columns 1-2). Adjusting for scale effects, we find a negative and significant association between grid density and coffee cultivation. The association with the number and density of transformers are also negative, albeit largely statistically insignificant. These results contradict the conjecture of favoritism for coffee-growing areas in the rollout of electricity infrastructure. In fact, our results suggest the opposite: coffee-intensive municipalities have lower availability of the electricity grid infrastructure. Hence our baseline results of a positive impact of coffee price shocks on demand for electricity connections are likely driven by a demand shock induced by the coffee price shocks.

To summarize, if our baseline results are driven primarily by an expansion in electricity grid infrastructure then: (i) coffee price shocks should not drive electricity uptake in communities where the grid infrastructure is present; and (ii) roll out of electricity infrastructure should be heavily skewed in favor of municipalities with high coffee intensity. The foregoing analysis provides strong evidence to counter these claims.

6 Coffee Price Shocks and Electricity Consumption

Having established the causal effect of coffee price shock on the demand for electricity connections, we explore the extent to which the price shock influences the consumption of connected households. To this end, we explore two sets of outcomes: (i) consumption (kWh and expenditure), and (ii) electricity purchasing behavior (frequency of purchase and kWh per purchase). We estimate the effect of coffee price shocks on these outcomes using the following specification:

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[31] Transformers are equipment that breaks down high-voltage electricity into medium/low voltage for distribution to end users

$$lnY_{isqt} = \phi \cdot \text{CoffeeIntensity}_s \times \text{lnPrice}_t + \mathbf{X}_{\mathbf{st}}^{'} \alpha + \theta_i + \delta_{qt} + \epsilon_{isqt} \tag{2}$$

where Y_{isqt} is the outcome of household (customer) i in municipality s in quarter q of year t. θ_i, and δ_{qt} represent household and year-quarter fixed effects respectively. All else remains as previously defined. Standard errors are clustered at the municipality level.

6.1 Results

Effect on Electricity Consumption and Expenditure

Table 6 presents the results on the effects of coffee price shocks on households' expenditure and quantity consumed. Columns 1-3 use the full sample, while columns 4 and 5 focus on rural and urban sub-samples respectively. Starting with expenditure on electricity, the results show a positive effect of the price shock on expenditure on electricity consumption. A 10% increase in coffee prices is associated with a 1.3% increase in household expenditure on electricity (column 3).[32] The effect appears to be largely driven by an increase in expenditure by rural households (column 4) as the effect on expenditure by urban households is negative and statistically insignificant. Similar results are obtained in panel B when focusing on the quantity of electricity consumed, although the demand elasticity appears low. The quantity (Kwh) purchased by households increases by 0.16% for every 10% increase in coffee price. Overall, the results herein show a positive increase in electricity demand by connected households following an increase in coffee prices.

Effect on Household Purchasing Behavior

Recall that the context of our study is a low-income environment where all electricity customers are on prepaid meters.[33] Hence, households face a binding constraint: household consumption/purchases are contingent on income or availability of liquidity at any given point in time. As a result, we observe a relatively high frequency of electricity purchases, averaging 3 per month. The quantity (kWh) per purchase is also low, about 10 kWh, per transaction. On the basis of this, we ask: how do income shocks from coffee influence the purchasing behavior of households?

In Table 7, we examine the effect of coffee price shocks on the frequency of purchase and quantity (kWh) per purchase. For each outcome, we estimate the full sample as well as the urban-rural sub-samples. We find that coffee price shocks are associated with a reduction in the

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[32] $(0.0429 \times 3.12) \times 10\%$

[33] The only exception is large industrial customers. These are not included in our datasets

frequency of electricity purchases per quarter and an increase in quantity (kWh) per purchase. Once again, the results pertain largely to rural households than urban households.

7 Role of Value-Addition: The Case of Rwanda Coffee Mills

Beyond the effects of coffee price shocks on the demand for electricity along the extensive and intensive margins, we also examine how income shocks associated with value-addition to agricultural commodities influence households' demand for electrification. While value-addition can take several forms, ranging from basic packaging to the development of refined products, it is associated with high prices relative to selling commodities in their raw (unprocessed) form.

To this end, we examine the effects of a program that increased the value-addition of Rwandan coffee on the demand for electrification. In the early 2000s, the Rwandan government embarked on a program of building coffee mills (washers) increasing from 5 in 2002 to 312 in 2018 as shown in Figure A.1. The goal of this program was to improve the washing and drying of coffee in the country using modern methods as opposed to the traditional methods, which often led to poor quality beans (Macchiavello and Morjaria, 2021; Sanin, 2021). Coffee processed in these mills attract high market premiums [40%] than those processed through traditional methods by farmers (Macchiavello and Morjaria, 2015). Thus, the introduction of the coffee mills, arguably induced a *permanent* income shock to the beneficiary farmers.

We exploit the staggered rollout of the coffee mills across municipalities to examine the association between the introduction of the coffee mills and the demand for electrification (Sanin, 2021; Dabalen et al., 2024).[34] Specifically, we estimate the follow specification:

$$\mathbb{E}(Y_{srt}|X_{st}) = exp\left(\beta \cdot \text{CoffeeMills}_{st} + \mathbf{X}_{\mathbf{st}}^{'}\alpha + \theta_s + \delta_t + \epsilon_{st}\right) \tag{3}$$

where CoffeeMills_{st} measure the intensity (number) of coffee mills operational in a given municipality s in year t. $\mathbf{X}_{\mathbf{st}}^{'}$ is a vector of baseline characteristics such as coffee intensity and elevation interacted with time trends. By controlling for baseline coffee intensity interacted with time trends, we are essentially partialling out the direct effect of coffee cultivation on the electrification rate independent of the effect of the coffee mills. All else remain as previously defined. Therefore conditional on the fixed effects, β measures the association between the intensity of coffee mills and the electrification rates across municipalities.

The results in Table 8 show a positive association between the number of coffee mills operating in a municipality and the demand for electricity connections. The effects are quantita-

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[34] It is important to emphasize that these coffee mills are largely "diesel-powered", hence limiting concerns on reverse causality between the presence of electricity and the mills.

tively and statistically significant for total, residential, and non-residential connections. These provide suggestive evidence that income shocks from the increased coffee value associated with processing of coffee beans in the mills are associated with increased demand for electricity connections.

8 Mechanism

Having documented the effects of coffee price shocks on demand for electricity along the extensive and intensive margins, we proceed to provide evidence on two plausible mechanisms underlying these impacts.

8.1 Relaxing Liquidity Constraints

In line with our conceptual framework, we argue that the effects of windfalls from commodity price booms on demand for electrification operate largely through relaxing liquidity constraints of households. A positive price shock offers unconnected households an opportunity to connect to the grid by leveraging windfalls from commodity price shocks to pay connection fees..

To test this hypothesis, we leverage the 2017 Rwanda grid connection policy that removed the mandatory requirement of upfront payment of connection charges as a natural experiment in Rwanda. In 2017, the government introduced a decree that offered amortized payment of electricity connection fees, allowing households regardless of their income level to connect and pay the connection fees in installments. Under the new policy, customers who could not afford to pay the lump sum connection fees could choose from two payment options: (i) a down payment of any amount and payment of the remaining balance in installment basis; or (ii) payment in installments with a zero down payment.[35]

Thus, if the main channel through which coffee price shocks affect electricity uptake is the ability of households to pay the upfront connection fees, then we should see muted or low impacts of the price shock after the removal of the upfront payment of connection fees. To this end, we estimate the following tripple difference-in-difference specification:

$$\begin{aligned}\mathbb{E}(Y_{srt}|X_{st}) = exp(&\phi \cdot \text{CoffeeIntensity}_{sr} \times \text{lnPrice}_t + \beta \cdot \text{CoffeeIntensity}_{sr} \times \text{lnPrice}_t \times \text{Policy}_t \\ + \quad &\psi \cdot \text{CoffeeIntensity}_{sr} \times \text{Policy}_t + \quad \mathbf{X}_{\mathbf{st}}^{'}\alpha + \theta_s + \delta_t + \lambda_p t + \epsilon_{st})\end{aligned} \tag{4}$$

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[35] For each option, 50% of the amount paid for electricity purchases by the customer is deducted towards the payment of the connection fees. See https://www.reg.rw/fileadmin/user_upload/RevisedNewConnectionPolicy__1_-75742.pdf

where $Policy$ is a dummy defined equal to 1 for the period 2017-2019 when the policy was in effect and 0 otherwise. All else remain as previously defined. The parameter of interest is β which measures the differential impact of coffee price shocks on demand for electricity connections between high and low coffee-intensive municipalities before and after the policy.

The results shown in Table 9 provide suggestive evidence in support of our hypothesis. We find no statistically significant impact of coffee price shock after the removal of the upfront payment of connection fees. Coffee price shocks are associated with increased electricity connections only when customers were required to pay connection fees prior to connection.

8.2 Demand for Appliances

To understand the channels through which coffee price shocks affect electricity consumption, we also examine households' response to the windfall via demand for electrical appliances. Electricity consumption is a derived demand through the usage of electric appliances. Hence, on the extensive margin, demand for electric appliances by connected households is a channel through which the income shocks from coffee production affect electricity consumption. We use the DHS data to explore this relationship in Table 10.

In columns 1-2, the outcome variable is an appliance index constructed as the share of the following appliance set (mobile phone, radio, TV, and refrigerator (fridge)) owned by households). The index is equal to 1 for households that own four appliances and 0 for households that own none of the appliances. The outcome variables in columns 3-10 are dummy variables set equal to 1 if the household owns the respective appliance and 0 if otherwise. Also, since we do not observe the time of appliance purchase, our price shock is constructed using the interaction of the baseline coffee intensity and coffee prices in the previous year instead of contemporaneous prices.[36]

The results in columns 1-2 of Table 10 show a positive association between coffee price shocks and households' ownership of electrical appliances, which are statistically and economically significant. Similarly, we find a positive and statistically significant effect on the ownership of mobile phones and radio. The effects on the ownership of television and refrigerator are also positive, although statistically insignificant. Overall, the results herein provide suggestive evidence of a positive association between coffee price shocks and demand for electrical appliances, which could explain the observed increase in demand for electricity following increases in the price of coffee.

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[36] Given the importance of electricity access in the usage of these appliances, we restrict our sample to households with electricity connection.

9 Concluding Remarks

This paper investigates the extent to which income windfalls associated with commodity price shocks influence demand for modern infrastructure such as electricity in low-income environments. We explore this using unique administrative data on electricity connection rates and consumption of residential and non-residential customers in Rwanda, a country where coffee cultivation is a major source of income for households.

Exploiting exogenous variations in international coffee prices, we document two key findings: (I) Historical coffee price booms may explain 4% of the increase in electrification rates in Rwanda. (II) Coffee price shocks are also associated with an increase in electricity consumption of connected households. In addition, we show that increasing value-addition to the commodity (coffee) also enhances demand for electrification. We provide suggestive evidence showing that (i) relaxing households' liquidity constraints related to the payment of upfront connection fees, and (ii) increased in demand for electrical appliances are likely mechanisms through which windfalls from coffee price shocks affect demand for electrification.

Many households in developing countries are unable to access essential infrastructure such as electricity because of liquidity constraints. Thin or missing credit markets and insecure livelihoods with low earnings often make it difficult for such households to afford high fixed costs of electricity connections. The findings of our paper highlight a potential avenue for utilities to leverage periods of income windfalls (in our case from commodity price shocks) in increasing demand for such services with relatively minor costs in marketing. Our results are consistent with similar conclusions for insurance take-up for liquidity-constrained households (Casaburi and Willis, 2018).

References

Adhvaryu, A., Fenske, J., and Nyshadham, A. (2019). Early life circumstance and adult mental health. *Journal of Political Economy*, 127(4):1516–1549.

Angrist, J. D. and Kugler, A. D. (2008). Rural windfall or a new resource curse? coca, income, and civil conflict in colombia. *The Review of Economics and Statistics*, 90(2):191–215.

Athey, S. and Imbens, G. W. (2017). The econometrics of randomized experiments. In *Handbook of economic field experiments*, volume 1, pages 73–140. Elsevier.

Azoulay, P., Fons-Rosen, C., and Zivin, J. S. G. (2019). Does science advance one funeral at a time? *American Economic Review*, 109(8):2889–2920.

Berman, N., Couttenier, M., Rohner, D., and Thoenig, M. (2017). This mine is mine! how minerals fuel conflicts in africa. *American Economic Review*, 107(6):1564–1610.

Blimpo, M. P. and Cosgrove-Davies, M. (2019). *Electricity access in Sub-Saharan Africa: Uptake, reliability, and complementary factors for economic impact*. World Bank Publications.

Blimpo, M. P., Postepska, A., and Xu, Y. (2020). Why is household electricity uptake low in sub-saharan africa? *World Development*, 133:105002.

Carrillo, B. (2020). Present bias and underinvestment in education? long-run effects of childhood exposure to booms in colombia. *Journal of Labor Economics*, 38(4):1127–1265.

Casaburi, L. and Willis, J. (2018). Time versus state in insurance: Experimental evidence from contract farming in kenya. *American Economic Review*, 108(12):3778–3813.

Conley, T. G. (1999). GMM estimation with cross sectional dependence. *Journal of Econometrics*, 92(1):1–45.

Correia, S., Guimarães, P., and Zylkin, T. (2020). Fast poisson estimation with high-dimensional fixed effects. *The Stata Journal*, 20(1):95–115.

Cust, J. and Mensah, J. T. (2020). Natural resource discoveries, citizen expectations and household decisions. Technical report.

Cust, J. F. and Mihalyi, D. (2017). Evidence for a presource curse? oil discoveries, elevated expectations, and growth disappointments. Technical Report 8140.

Dabalen, A., Mensah, J. T., and Nsabimana, A. (2024). Local economic shocks and human capital accumulation.

Dinkelman, T. (2011). The effects of rural electrification on employment: New evidence from South Africa. *American Economic Review*, 101(7):3078–3108.

Dube, O. and Vargas, J. F. (2013). Commodity price shocks and civil conflict: Evidence from colombia. *Review of Economic studies*, 80(4):1384–1421.

Golumbeanu, R. and Barnes, D. F. (2013). Connection charges and electricity access in sub-saharan africa. *World Bank Policy Research Working Paper*, (6511).

Grimm, M., Lenz, L., Peters, J., and Sievert, M. (2020). Demand for off-grid solar electricity: Experimental evidence from rwanda. *Journal of the Association of Environmental and Resource Economists*, 7(3):417–454.

Guariso, A., Ngabitsinze, C., and Verpoorten, M. (2011). The Rwandan coffee sector: Out of the ordinary. *L'Afrique des grands lacs: Annuaire*, 2012:397–426.

Guariso, A. and Verpoorten, M. (2018). Aid, trade and the post-war recovery of the rwandan coffee sector. *Journal of eastern African studies*, 12(3):552–574.

Hastings, J. and Ubilava, D. (2023). Agricultural shocks and social conflict in southeast asia. *arXiv preprint arXiv:2304.10027*.

Hausmann, R. and Rigobon, R. (2003). An alternative interpretation of the'resource curse': Theory and policy implications. Technical report.

Jack, B. K. and Smith, G. (2015). Pay as you go: Prepaid metering and electricity expenditures in south africa. *American Economic Review*, 105(5):237–241.

Jack, K. and Smith, G. (2020). Charging ahead: Prepaid metering, electricity use, and utility revenue. *American Economic Journal: Applied Economics*, 12(2):134–168.

Lang, M. E. (2020). The role of market frictions in demand for prepaid electricity. Technical report.

Lee, K., Miguel, E., and Wolfram, C. (2020). Experimental evidence on the economics of rural electrification. *Journal of Political Economy*, 128(4):1523–1565.

Macchiavello, R. and Morjaria, A. (2015). Fully washed coffee exports in rwanda: Market structure and policy implications. *International Growth Centre, Policy Brief.*

Macchiavello, R. and Morjaria, A. (2021). Competition and relational contracts in the rwanda coffee chain. *The Quarterly Journal of Economics*, 136(2):1089–1143.

Macchiavello, R. and Morjaria, A. (2022). Acquisitions, management, and efficiency in rwanda's coffee industry. Technical report, National Bureau of Economic Research.

Sachs, J. D. and Warner, A. M. (2001). The curse of natural resources. *European economic review*, 45(4-6):827–838.

Sala-i Martin, X. and Subramanian, A. (2013). Addressing the natural resource curse: An illustration from nigeria. *Journal of African Economies*, 22(4):570–615.

Sanin, D. (2021). Paid work for women and domestic violence: Evidence from the rwandan coffee mills. Technical report, Technical report, Working Paper.

Truffa, F. and Wong, A. (2022). Undergraduate gender diversity and direction of scientific research. Technical report.

Ubilava, D., Hastings, J. V., and Atalay, K. (2022). Agricultural windfalls and the seasonality of political violence in africa. *American Journal of Agricultural Economics*.

Wooldridge, J. M. (2010). *Econometric analysis of cross section and panel data*. MIT press.

10 Figures

Figure 1: Trends in Electricity Access in Rwanda

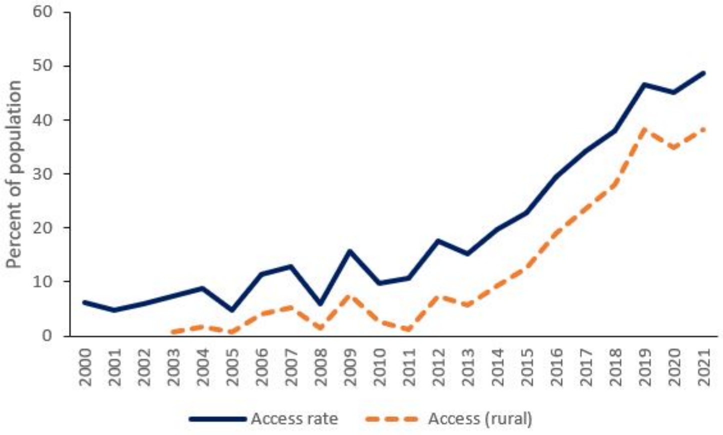
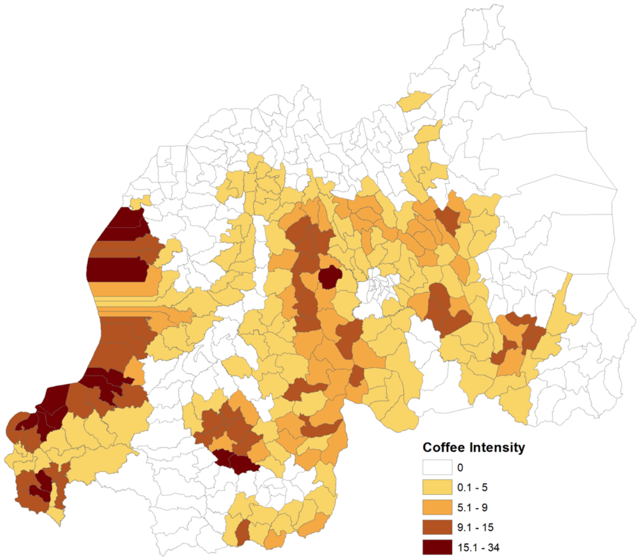
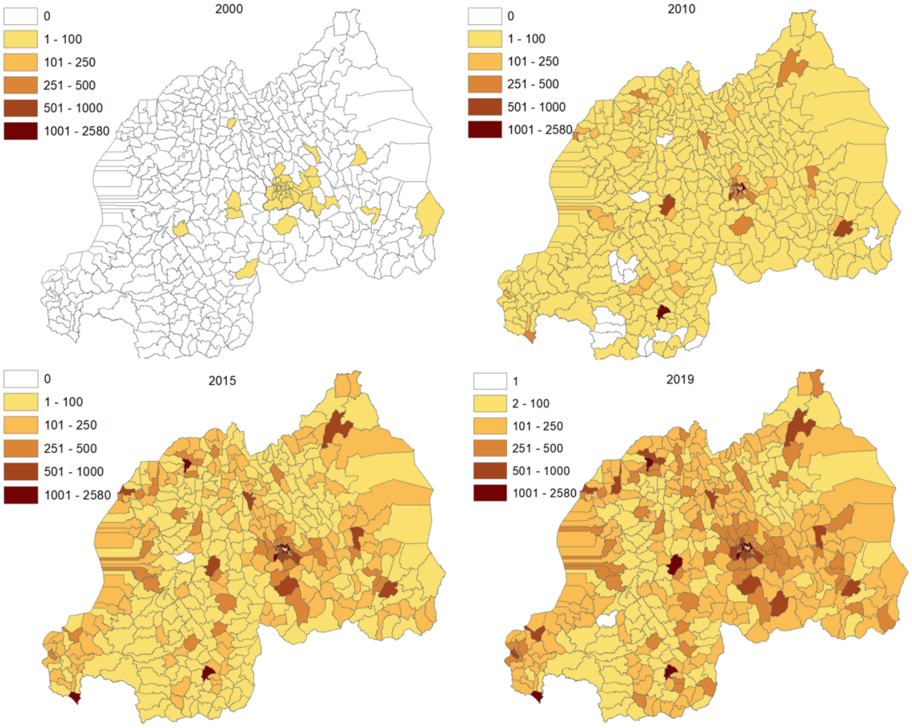


Figure 2: Distribution of Coffee Intensity across Sectors in Rwanda



Notes: This figure shows the number of coffee trees (1000) per km^2 across municipalities.

Figure 3: Trends in Electrification at Subnational Level



Notes: This figure shows the total number of electricity connections per 1000 people across time.

Figure 4: Trends in Coffee Prices and Electricity Connections in Rwanda

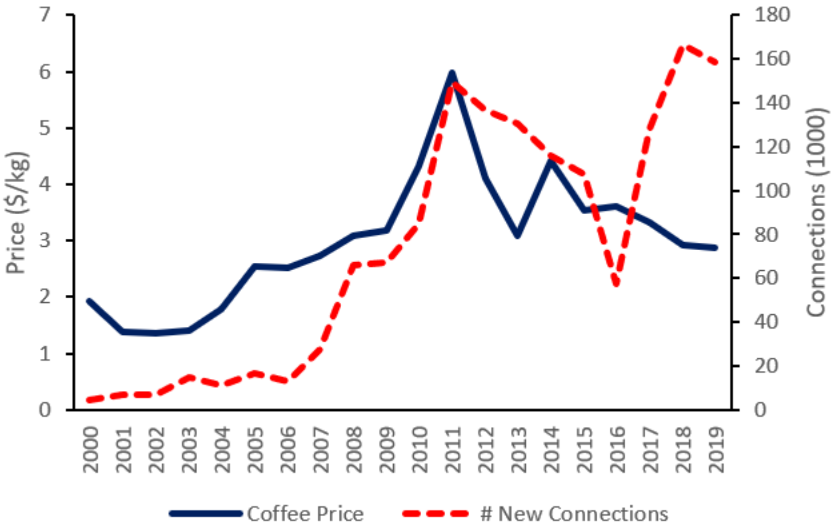
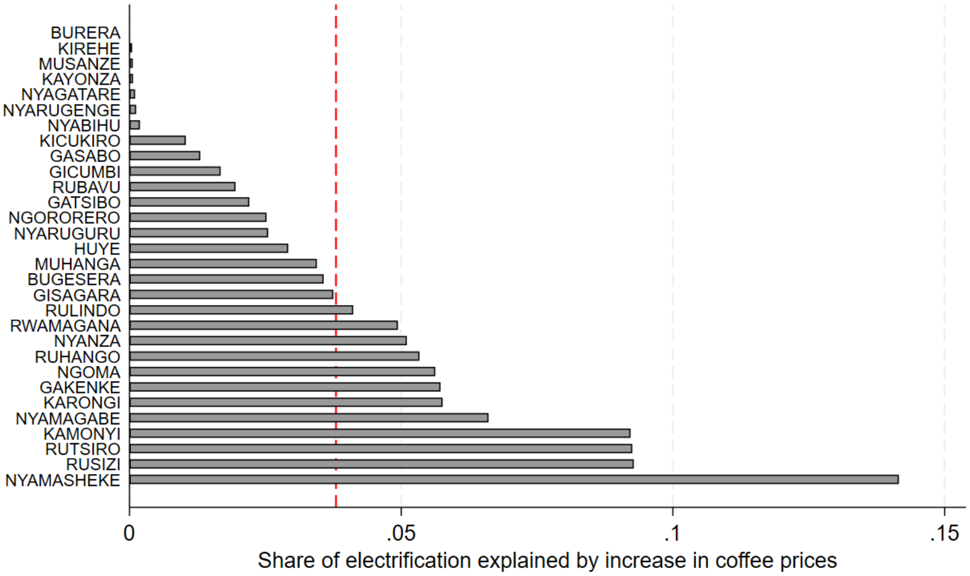
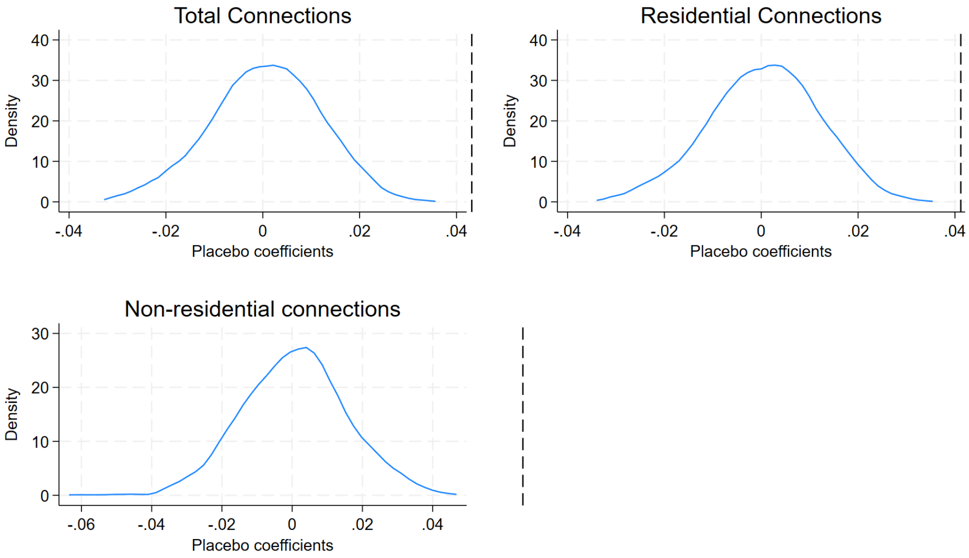


Figure 5: Contribution of Rising Coffee Prices to Electrification in Rwanda



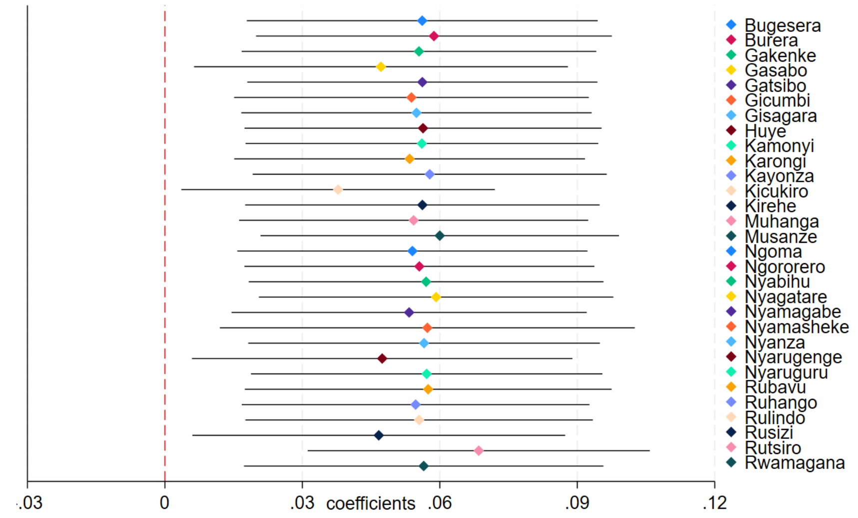
Notes: This figure shows for each Rwandan district, the increase in electrification rates associated with an increase in coffee prices relative to a counterfactual scenario if coffee prices had remained the same as their 2000 level over the entire period.

Figure 6: Placebo Test



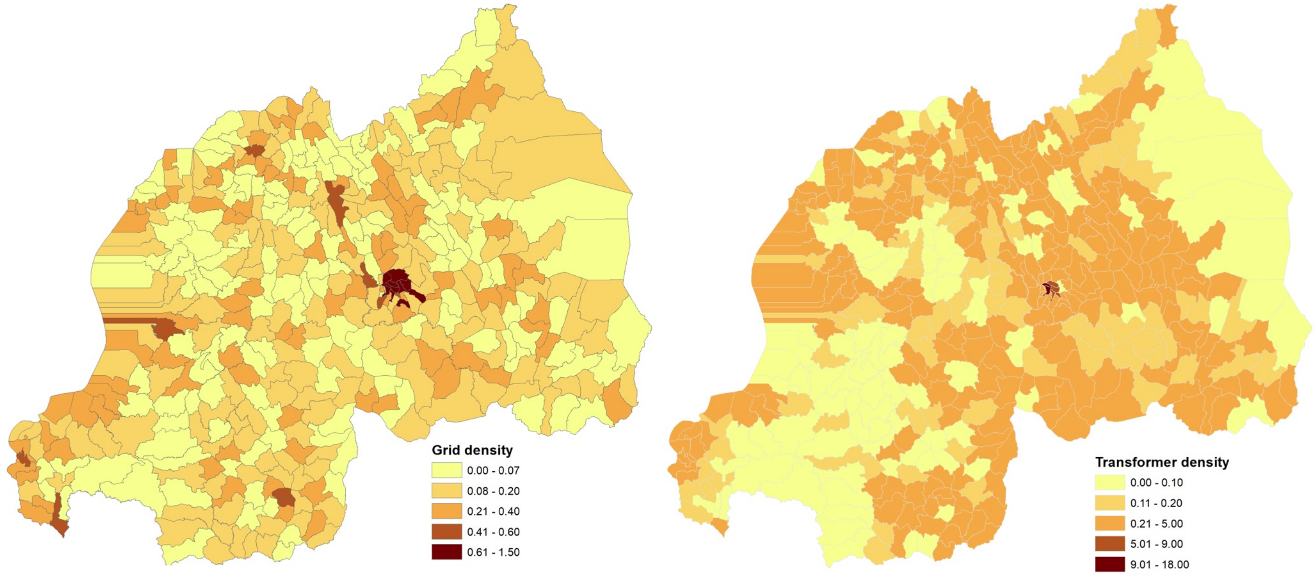
Notes: This figure shows a density plot of the coefficient estimates from 1000 simulations using random assignment of baseline coffee intensity. The left and right panels show the density plots total connections and residential connections respectively. The vertical line represents the baseline estimates in Table 2 (columns 3 and 6).

Figure 7: Leave-one-out Results: Coffee Price Shocks and Electrification



Notes: This figure shows parameter estimates and their 90% confidence interval of the effects of coffee price shocks on electrification while iteratively dropping one district at a time. Each estimate is obtained from a separate regression and is based on estimating the specification in Column 3 of Table 2

Figure 8: Spatial Distribution Electricity Grid Infrastructure in Rwanda



Notes: The left panel shows the density of electric grid infrastructure across municipalities. The right panel shows the number of transformers per sq km across municipalities

11 Tables

Table 1: Summary Statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
Electricity Connections					
Total Connections per 1000 people	6.811	15.48	0	263.418	8320
Residential Connections per 1000 people	6.195	14.101	0	251.834	8320
Nonresidential Connections per 1000 people	0.616	1.82	0	57.226	8320
Coffee Intensity (1000 trees) per sq km (in 1999)	3.119	4.74	0	33.543	8320
Coffee Price per kg (real 2010)	3.083	0.896	1.78	5.38	8320
Distance to major city	23.85	16.833	0.544	91.796	8320
Distance to the border	22.943	14.368	0.434	51.991	8320
Distance to a major road	7.001	6.253	0.008	39.156	8320
Average elevation (meters)	1743.729	301.439	986.808	2913.02	8320
Electricity consumption					
Qty (kWh) of electricity purchased per quarter	68.712	92.732	0.1	362.6	15206429
Frequency of electricity purchases per quarter	8.575	8.851	1	34	15206429
Avg. Qty (kWh) per transaction	9.818	19.585	0.033	362.6	15206429
Expenditure (RWF) on electricity (real 2019) per quarter	15564.62	21924.625	16.741	85315.406	15202325
Urban	0.379	0.485	0	1	15205401
DHS data					
Age of HH	42.521	14.202	15	95	46284
No. of HH members	4.793	2.037	1	22	46288
Female HHH (0/1)	0.311	0.463	0	1	46288
Appliance Index (%)	0.274	0.242	0	1	46281
Owns a radio	0.53	0.499	0	1	46267
Owns a TV	0.089	0.285	0	1	46231
Owns a mobile phone	0.457	0.498	0	1	46241
Owns a fridge	0.02	0.141	0	1	46257

Table 2: Coffee Price Shocks and Electricity Connections

	Dep. var: # of New Connections per 1000 people								
	All			Residential			Non Residential		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Coffee Intensity X Coffee Price (log)	0.055***	0.036**	0.043**	0.052***	0.033*	0.041**	0.080***	0.064***	0.066***
	(0.019)	(0.017)	(0.018)	(0.020)	(0.018)	(0.019)	(0.023)	(0.021)	(0.021)
Baseline Ctrls X Trend	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province X linear trends	No	No	Yes	No	No	Yes	No	No	Yes
Observations	8320	8320	8320	8320	8320	8320	8320	8320	8320

Notes: Poisson estimations. This table presents estimates of the effect of coffee price shocks on the demand for electricity connections. The dependent variable is the number of yearly electricity connections per 1000 people. Coffee Intensity X Coffee Price is the interaction between the coffee intensity (measured as the number of coffee trees (1000) per sq. km in the municipality at baseline (1999)) and the international price of coffee (real 2010 dollars). Baseline controls include elevation, distance from the municipality centroid to the nearest: (i) major road network, border, and main city all interacted with time trends. Columns 1-2 focus on electricity connection by all customers, while columns 3-4 and 5-6 focus on electricity connections by residential and non-residential users respectively. Standard errors clustered at the municipality level in parenthesis.
* Significant at 10 percent level ** Significant at 5 percent level *** Significant at 1 percent level

Table 3: Robustness Checks: Coffee Price Shocks and Electricity Connections

	Dep. var: # of New Connections per 1000 people								
	All			Residential			Non Residential		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Coffee Intensity X Coffee Price (log)	0.092***	0.072***	0.048***	0.090***	0.070***	0.047***	0.103***	0.081***	0.056***
	(0.024)	(0.019)	(0.017)	(0.025)	(0.020)	(0.017)	(0.027)	(0.022)	(0.020)
X Policy	0.040***	0.037***	0.005	0.041***	0.038***	0.005	0.027*	0.020	-0.013
	(0.012)	(0.009)	(0.010)	(0.012)	(0.010)	(0.010)	(0.016)	(0.013)	(0.014)
Baseline Ctrls X Trend	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province X linear trends	No	No	Yes	No	No	Yes	No	No	Yes
Observations	8320	8320	8320	8320	8320	8320	8320	8320	8320

Notes: Poisson estimations. This table presents estimates of the mediating role of the removal of upfront connection fees on the effect of coffee price shocks on the demand for electricity connections. Essentially we exclude the period when the option of paying connection fees by installment was introduced. The dependent variable is the number of yearly electricity connections per 1000 people. Coffee Intensity X Coffee Price (log) is the interaction between the coffee intensity (measured as the number of coffee trees (100s) per sq. km in the municipality at baseline (1999)) and the log international price of coffee (real 2010 dollars). Baseline controls include elevation, distance from the municipality centroid to the nearest: (i) major road network, border, and main city all interacted with time trends. Columns 1-2 focus on electricity connection by all customers, while columns 3-4 and 5-6 focus on electricity connections by residential and non-residential users respectively. Standard errors clustered at the municipality level in parenthesis.

* Significant at 10 percent level ** Significant at 5 percent level *** Significant at 1 percent level

Table 4: Coffee Price Shocks and Electricity Uptake

	Dep var: Household Connected to Electricity (0/1)					
	All			Rural		
	(1)	(2)	(3)	(4)	(5)	(6)
Coffee Intensity X Coffee Price (log)	0.0392 (0.0365)	0.0390 (0.0371)	0.0389 (0.0360)	0.0776*** (0.0277)	0.0762*** (0.0269)	0.0670*** (0.0146)
HH Controls	No	Yes	Yes	No	Yes	Yes
Baseline Ctrls X Trend	Yes	Yes	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Province X trends	No	No	Yes	No	No	Yes
Mean dep. var	0.3966	0.3967	0.3967	0.2720	0.2720	0.2720
R-squared	0.3277	0.3358	0.3359	0.2264	0.2377	0.2388
Observations	29250	29242	29242	19282	19276	19276

Notes: OLS estimations. This table presents estimates of the effect of coffee price shocks on the probability of a household being connected to electricity in a community where the electricity infrastructure is already available. The dependent variable is a dummy variable equal to 1 if the household is connected to the electricity grid and 0 if otherwise. Coffee Intensity X Coffee Price is the interaction between the coffee intensity (measured as the number of coffee trees (1000) per sq. km in the municipality at baseline (1999)) and the international price of coffee (real 2010 dollars). Household controls include gender and age of household head, household size. Baseline (Municipality level) controls include, elevation, population density, distance from the municipality centroid to nearest: (i) major road network, border, and main city all interacted with time trends. Standard errors clustered at the municipality level in parenthesis.

* Significant at 10 percent level ** Significant at 5 percent level *** Significant at 1 percent level

Table 5: Coffee Intensity and Distribution of Electricity Infrastructure

	(1)	(2)	(3)	(4)
	Grid network (km)		Grid Density(km/km^2)	
Coffee Intensity	0.1099	-0.3042	-0.0127	-0.0414*
	(0.3010)	(0.2648)	(0.0218)	(0.0238)
R-squared	0.3369	0.4558	0.6384	0.6384
	No. of Transformers		Density of transformers (per km^2)	
Coffee Intensity	-0.1132	-0.2264	-0.0124	-0.0237**
	(0.1255)	(0.1385)	(0.0093)	(0.0112)
R-squared	0.2337	0.2944	0.3671	0.4057
Baseline Ctrls	No	Yes	No	Yes
District FE	Yes	Yes	Yes	Yes
Observations	416	416	416	416

Notes: OLS estimations. This table presents estimates of the relationship between coffee intensity (at baseline) and the distribution of electricity grid infrastructure at the municipality level. Coffee Intensity is measured as the number of coffee trees (1000) per sq. km in the municipality at baseline (1999). Baseline controls include elevation, and distance from the municipality centroid to the nearest: (i) major road network, border, and main city. Standard errors clustered at the municipality level in parenthesis
* Significant at 10 percent level ** Significant at 5 percent level *** Significant at 1 percent level

Table 6: Effects of Coffee Price Shocks on Electricity Consumption and Expenditure

	All			Rural	Urban
	(1)	(2)	(3)	(4)	(5)
	Panel A: Expenditure on Electricity (log)				
Coffee Intensity X Coffee Price (log)	0.0566***	0.0429***	0.0431***	0.0349***	-0.0137
	(0.0086)	(0.0070)	(0.0071)	(0.0071)	(0.0193)
R-squared	0.7904	0.7933	0.7919	0.7508	0.7650
Observations	15099101	15099101	15099101	9353117	5744784
	Panel B: Qty (kWh) of Electricity Purchased (log)				
Coffee Intensity X Coffee Price (log)	0.0072***	0.0051**	0.0052**	0.0064***	-0.0114
	(0.0027)	(0.0024)	(0.0024)	(0.0024)	(0.0085)
R-squared	0.8122	0.8124	0.8122	0.7733	0.7640
Observations	15101545	15101545	15101545	9354001	5746344
Baseline Ctrls X Trends	No	Yes	Yes	Yes	Yes
HH FE	Yes	Yes	Yes	Yes	Yes
Year-Quarter FE	Yes	Yes	No	Yes	Yes
Quarter	No	No	Yes	No	No
Year FE	No	No	Yes	No	No

Notes: This table presents estimates of the effect of coffee price shocks on the consumption of electricity. Coffee Intensity X Coffee Price (ihs) is the interaction between the coffee intensity (measured as the number of coffee trees (1000) per sq. km in the sector at baseline (1999)) and the log of the international price of coffee (real 2010 dollars). Baseline controls include elevation, distance from the sector centroid to the nearest: (i) major road network, border, and main city, all interacted with time trends. Columns 1-2 and 3-4 focus on connection by residential and non-residential users respectively, while columns 5-6 focus on both residential and nonresidential users. Standard errors clustered at municipality level in parenthesis.
* Significant at 10 percent level ** Significant at 5 percent level *** Significant at 1 percent level

Table 7: Effects of Coffee Price Shocks on Purchasing Behavior

	Frequency of Purchases (log)				Qty (kWh) per Purchase (log)			
	All		Rural	Urban	All		Rural	Urban
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Coffee Intensity X Coffee Price (log)	-0.0108***	-0.0053*	-0.0013	-0.0068	0.0180***	0.0105***	0.0077***	-0.0046
	(0.0034)	(0.0030)	(0.0032)	(0.0125)	(0.0037)	(0.0030)	(0.0029)	(0.0087)
Controls	No	Yes	Yes	Yes	No	Yes	Yes	Yes
HH FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.6678	0.6687	0.6487	0.6159	0.7518	0.7540	0.7189	0.7445
Observations	15101545	15101545	9354001	5746344	15101545	15101545	9354001	5746344

Notes: This table presents estimates of the effect of coffee price shocks on the consumption of electricity. Coffee Intensity X Coffee Price (log) is the interaction between the coffee intensity (measured as the number of coffee trees (1000) per sq. km in the sector at baseline (1999)) and the log international price of coffee (real 2010 dollars). Baseline controls include elevation, distance from the sector centroid to the nearest: (i) major road network, border, and main city all interacted with time trends. Columns 1-2 and 3-4 focus on connection by residential and non-residential users respectively, while columns 5-6 focus on both residential and nonresidential users. Standard errors clustered at the municipality level in parenthesis.
* Significant at 10 percent level ** Significant at 5 percent level *** Significant at 1 percent level

Table 8: Introduction of Coffee Mills and Electrification

	Dep. var: # of New Connections per 1000 people					
	All		Residential		Non-Residential	
	(1)	(2)	(3)	(4)	(5)	(6)
# of Coffee Mills Operating	0.172**	0.163**	0.170**	0.161**	0.169**	0.169**
	(0.075)	(0.076)	(0.076)	(0.077)	(0.083)	(0.083)
Baseline Controls FE	No	Yes	No	Yes	No	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Baseline Coffee Intensity X Nonlinear trends	Yes	Yes	Yes	Yes	Yes	Yes
Observations	8320	8320	8320	8320	8320	8320

Notes: Poisson estimations. The Table shows the results on the association between the intensity of coffee mills operational in a municipality and the number of electricity connections. The dependent variable is the number of yearly electricity connections per 1000 people. # of Coffee Mills Operating is the number of coffee mills operational in a given municipality and time. Baseline controls include elevation and coffee intensity all interacted with time trends. Columns 1-2 focus on electricity connection by all customers, while columns 3-4 and 5-6 focus on electricity connections by residential and non-residential users respectively. Standard errors clustered at the municipality level in parenthesis.
* Significant at 10 percent level ** Significant at 5 percent level *** Significant at 1 percent level

Table 9: Coffee Price Shocks and Electrification: The Role of Connection Fees Payments

	Dep. var: # of New Connections per 1000 people								
	All			Residential			Non Residential		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Coffee Intensity X Coffee Price (log)	0.094***	0.074***	0.042**	0.092***	0.072***	0.040**	0.106***	0.084***	0.054**
	(0.026)	(0.021)	(0.017)	(0.027)	(0.021)	(0.018)	(0.030)	(0.024)	(0.022)
X Policy	0.018	0.012	0.096	0.018	0.012	0.096	-0.052	-0.045	0.037
	(0.068)	(0.063)	(0.069)	(0.066)	(0.062)	(0.067)	(0.106)	(0.103)	(0.118)
Coffee Intensity X Policy	0.026	0.028	-0.104	0.026	0.029	-0.104	0.088	0.074	-0.055
	(0.085)	(0.077)	(0.082)	(0.083)	(0.076)	(0.081)	(0.130)	(0.123)	(0.141)
Baseline Ctrls X Trend	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province X linear trends	No	No	Yes	No	No	Yes	No	No	Yes
Observations	8320	8320	8320	8320	8320	8320	8320	8320	8320

Notes: Poisson estimations. This table presents estimates of the mediating role of the removal of upfront connection fees on the effect of coffee price shocks on the demand for electricity connections. The dependent variable is the number of yearly electricity connections per 1000 people. Coffee Intensity X Coffee Price (log) is the interaction between the coffee intensity (measured as the number of coffee trees (100s) per sq. km in the municipality at baseline (1999)) and the log international price of coffee (real 2010 dollars). Policy is a dummy defined equal to 1 for the period when the requirement for upfront payment of connection fees was removed and 0 for the period before the removal. Baseline controls include elevation, distance from the municipality centroid to the nearest: (i) major road network, border, and main city all interacted with time trends. Columns 1-2 focus on electricity connection by all customers, while columns 3-4 and 5-6 focus on electricity connections by residential and non-residential users respectively. Standard errors clustered at the municipality level in parenthesis.

* Significant at 10 percent level ** Significant at 5 percent level *** Significant at 1 percent level

Table 10: Coffee Price Shocks and Demand for Household Appliances

	Appliance Index		Mobile Phone (0/1)		Radio (0/1)		TV (0/1)		Fridge (0/1)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Coffee Intensity X Coffee Price (log)	0.0114**	0.0115**	0.0113*	0.0109*	0.0232***	0.0244***	0.0049	0.0041	0.0061	0.0066
	(0.0045)	(0.0046)	(0.0062)	(0.0060)	(0.0076)	(0.0075)	(0.0055)	(0.0053)	(0.0079)	(0.0081)
HH Ctrls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Baseline Ctrls X Trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province X linear trends	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Mean dep. var	0.5142	0.5142	0.8898	0.8898	0.6921	0.6921	0.0896	0.0896	0.3851	0.3851
R-squared	0.3024	0.3026	0.1597	0.1606	0.1675	0.1681	0.1685	0.1689	0.2659	0.2661
Observations	10223	10223	10219	10219	10221	10221	10220	10220	10218	10218

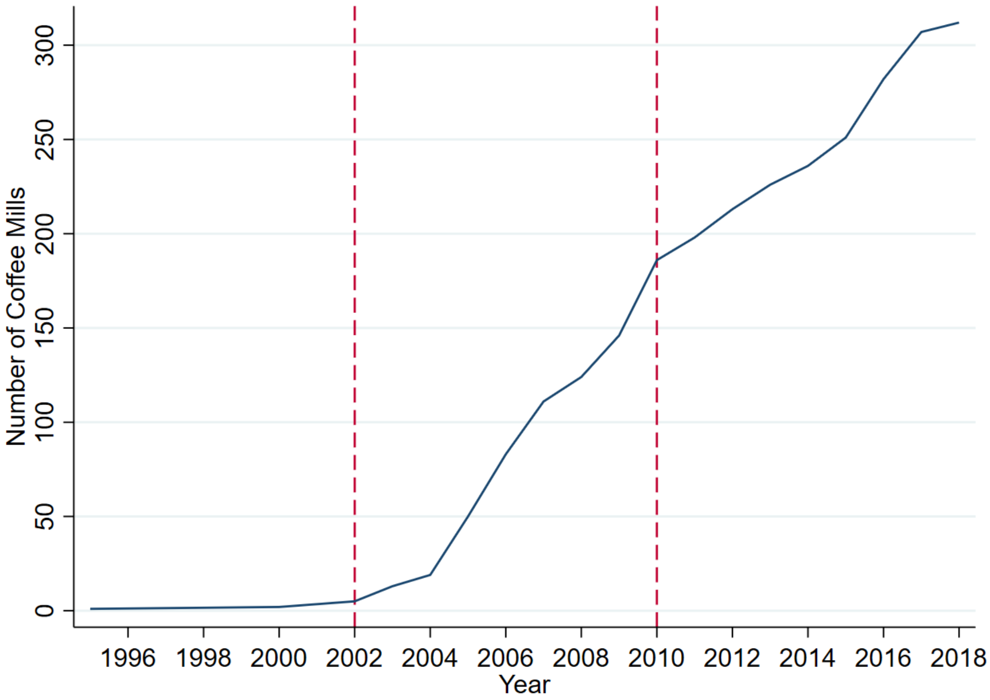
Notes: This table presents estimates of the effect of coffee price shocks on household adoption of household electrical appliances. The dependent variable, appliance index, is measured as the households' ownership share of the following appliances: TV, refrigerator, mobile phone, and radio. Coffee Intensity X Coffee Price is the interaction between the coffee intensity (measured as the number of coffee trees (1000) per sq. km in the municipality at baseline (1999)) and the international price of coffee (real 2010 dollars). Baseline controls include elevation, population density, and distance from the municipality centroid to the nearest: (i) major road network, border, and main city all interacted with time trends. Standard errors clustered at the municipality level in parenthesis.

* Significant at 10 percent level ** Significant at 5 percent level *** Significant at 1 percent level

Appendix

Figures

Figure A.1: Staggered Rollout of Coffee Mills in Rwanda



Tables

Table A.1: Coffee Price Shocks and Employment

	Dep var: Employed (0/1)						
	All			Rural		Urban	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Coffee Intensity X Coffee Price (log)	0.0117***	0.0112**	0.0112**	0.0092**	0.0096**	0.0261*	0.0282**
	(0.0045)	(0.0045)	(0.0044)	(0.0047)	(0.0046)	(0.0141)	(0.0140)
HH Controls	No	Yes	Yes	Yes	Yes	Yes	Yes
Baseline Ctrls X Trend	No	Yes	Yes	Yes	Yes	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province X trends	No	No	Yes	No	Yes	No	Yes
R-squared	0.0877	0.1469	0.1489	0.1530	0.1553	0.1413	0.1420
Observations	69704	69704	69704	54385	54385	15319	15319

Notes: OLS estimations. This table presents estimates of the effect of coffee price shocks on the probability of employment. The dependent variable is a dummy variable equal to 1 if the individual is working and 0 if otherwise. Coffee Intensity X Coffee Price is the interaction between the coffee intensity (measured as the number of coffee trees (1000) per sq. km in the municipality at baseline (1999)) and the international price of coffee (real 2010 dollars). Household controls include gender and age of household head, household size. Baseline (Municipality level) controls include, elevation, population density, distance from the municipality centroid to nearest: (i) major road network, border, and main city all interacted with time trends. Standard errors clustered at the municipality level in parenthesis.

* Significant at 10 percent level ** Significant at 5 percent level *** Significant at 1 percent level

Table A.2: Coffee Price Shocks and Electricity Connections

	Dep. var: # of New Connections per 1000 people								
	All			Residential			Non Residential		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Coffee Producer (0/1) X Coffee Price (log)	0.6331***	0.4198**	0.4545**	0.6351***	0.4134**	0.4576**	0.5576*	0.3904	0.3975*
	(0.2367)	(0.2043)	(0.1807)	(0.2384)	(0.2071)	(0.1828)	(0.2852)	(0.2460)	(0.2288)
Baseline Ctrls X Trend	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province X linear trends	No	No	Yes	No	No	Yes	No	No	Yes
Observations	8320	8320	8320	8320	8320	8320	8320	8320	8320

Notes: Poisson estimations. This table presents estimates of the effect of coffee price shocks on the demand for electricity connections. The dependent variable is the number of yearly electricity connections per 1000 people. Coffee Producing (0/1) X Coffee Price (log) is the interaction between the dummy equal to 1 for municipalities with cultivation at baseline (1999) and the international price of coffee (real 2010 dollars). Baseline controls include elevation, distance from the municipality centroid to the nearest: (i) major road network, border, and main city all interacted with time trends. Columns 1-2 focus on electricity connection by all customers, while columns 3-4 and 5-6 focus on electricity connections by residential and non-residential users respectively. Standard errors clustered at the municipality level in parenthesis.

* Significant at 10 percent level ** Significant at 5 percent level *** Significant at 1 percent level

Table A.3: Robustness Checks: Coffee Price Shocks and Electricity Connections

	Dep. var: # of New Connections per 1000 people								
	All			Residential			Non Residential		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Coffee Intensity X Coffee Price (log)	0.081***	0.056***	0.032*	0.079***	0.053***	0.029*	0.098***	0.076***	0.053**
	(0.024)	(0.018)	(0.017)	(0.024)	(0.018)	(0.017)	(0.027)	(0.021)	(0.022)
Baseline Ctrls X Trend	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Municipality FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province X linear trends	No	No	Yes	No	No	Yes	No	No	Yes
Observations	7488	7488	7488	7488	7488	7488	7488	7488	7488

Notes: Poisson estimations. This table presents estimates of the effect of coffee price shocks on the demand for electricity connections restricting the sample to the period 2000-2017. Essentially we exclude the period when the option of paying connection fees by installment was introduced. The dependent variable is the number of yearly electricity connections per 1000 people. Coffee Intensity X Coffee Price is the interaction between the coffee intensity (measured as the number of coffee trees (100s) per sq. km in the municipality at baseline (1999)) and the international price of coffee (real 2010 dollars). Baseline controls include elevation, distance from the municipality centroid to the nearest: (i) major road network, border, and main city all interacted with time trends. Columns 1-2 focus on electricity connection by all customers, while columns 3-4 and 5-6 focus on electricity connections by residential and non-residential users respectively. Standard errors clustered at the municipality level in parenthesis.
* Significant at 10 percent level ** Significant at 5 percent level *** Significant at 1 percent level