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Rural Electrification, Migration and Structural Transformation: Evidence from Ethiopia

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Abstract

To what extent does rural electrification induce structural change and alter migration patterns? This paper answers this question using a simple multi-sector spatial model and evidence from a panel of rural Ethiopian villages during its recent electricity supply expansion. We document that electrification raised irrigation rates and agricultural yields, roughly doubled non-agricultural business ownership rates, and led to modest increases in durable goods purchases. Furthermore, villages that got electrified experienced increases in in-migration rates and substantial decreases in out-migration rates. Each of these predictions is qualitatively consistent with our theory. Our results suggest that rural electrification leads to substantial structural transformation of village economies and slows rural-urban migration as a result.

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1. Introduction

In developing countries, economic growth goes hand in hand with *structural transformation*, or the process of moving out of subsistence agriculture into more productive economic activities. For many development researchers and policymakers, it is hard to imagine structural change without access to electricity. According to this view, residents of rural areas without electricity have few options for employment besides subsistence agriculture. As a result some simply migrate to more urban areas because these areas have better employment opportunities or living conditions. While migration may be a fine option for some people, it is costly for many, and high rates of out-migration from rural areas tax scarce existing urban infrastructure.

An alternative view is that rural electrification is mostly about redistribution, and primarily serves to improve the quality of village life through better lighting and access to a wider range of consumer durables. Empirically, research on rural electrification has increased substantially in recent years, following the work of Dinkelman (2011), though there is still no consensus on the extent to which rural electrification induces structural transformation, or is mainly redistributive. More generally, there is little consensus on the overall value of rural electrification, with Lee, Miguel, and Wolfram (2016) finding rather modest willingness to pay for electrification by rural Kenyans, and Rud (2012) and Lipscomb, Mobarak, and Barham (2013) finding large longer-run effects on productivity and development in India and Brazil. Furthermore, much of the literature has focused on the effects on individual regions within a country, and hence have ignored general equilibrium effects on migration to or from other regions (Dinkelman and Schulhofer-Wohl, 2015).

In this paper, we examine the effects of rural electrification on structural transformation and migration patterns in Ethiopia, which has dramatically increased its electricity production capacity in the last two decades, rising from just 500 MW in 2000 to around 3,500 MW by 2016. No other country in the world had such a large growth rate of electricity capacity over this period. Ethiopia has also made rural electrification a central focus of its development strategy. Given Ethiopia's almost total concentration of employment in subsistence agriculture in rural areas, and its massive efforts to electrify those areas, one could argue that if rural electrification has not been transformative in Ethiopia, it is unlikely to be transformative anywhere.

To help frame our thinking, we start with a simple multi-region, multi-sector model of how electrification of one region affects employment, productivity and consumption in that region and migration patterns to and from other regions. The model builds on others that employ the Frechet distribution to allow for tractability in migration and sectoral employments patterns, such as Bryan and Morten (2015) and Ahlfeldt, Redding, Sturm, and Wolf (2015). Households in the model are born in one region, but receive a vector region-specific productivity draws governing their productivity in all other regions. Households then choose their region and whether to work in the non-agricultural sector, the traditional agricultural sector, or the modern agricultural sector (which uses electricity). The model delivers simple closed form expressions for consumption, employment, and the location decisions of all households, as well as equilibrium prices and quantities of output in each sector and region.

The model's main comparative statics center on how electrifying one region affects that region and other regions of the economy in general equilibrium. There are three main predictions. First, the model predicts that electrifying a region will raise non-agricultural consumption and productivity in that region. This is because households consume electricity directly and non-agricultural production uses electricity as an input. Second, the model predicts that a sufficiently large decrease in the price of electricity will lead to an increase agricultural productivity as households switch from a traditional agricultural technology to a modern one (that uses electricity). Each technology has constant returns to scale, and so only one will be used at any point. Agents will choose the modern technology only if electricity is sufficiently inexpensive. Third, the model predicts that electrification reduces out-migration from the electrified region increases in-migration from other regions. The reason for this change in migration is that electrifying a region increases both its consumption possibilities and productivity. Hence, workers in the electrified region have less incentive to leave, and workers in all other regions have greater incentive to move in.

To test predictions of the model, we draw on panel evidence from Ethiopian villages in 2012 and 2014 using the Ethiopian Rural Socioeconomic Survey, which is a nationally representative set of villages. We focus on the villages that were not electrified at all in 2011, which is approximately two thirds of them. We then document how villages that became electrified between 2011 and 2013 ("electrified villages") differed from those that were still not electrified at all in 2013 ("non-electrified villages.")

We begin by comparing the newly electrified villages to the non-electrified villages in 2012, before any were hooked up to the electric grid. Across two dozen characteristics, the villages look similar on all but one. Both have similar populations, and are located equally far on average from Addis. Most villages reported net migration out, rather than in. Public goods like schools, hospitals and tar roads were similarly scarce in both village types. Mobile phone ownership is marginally higher in the villages that are electrified by 2014, and statistically significant at the ten percent level, though other durables ownership rates are similar. Economic activities in the two village groups are nearly identical, with virtually all households employed in agriculture. When trying to use all the observables jointly to predict which villages get electrified, we find a negative adjusted R^2 and joint insignificance of all the predictors. We conclude that there are negligible differences between the two village types in 2012, at least based on observables.

We then test the model's predictions by comparing differences from 2012 to 2014 between the non-electrified villages and those that get electrified by 2014. We document a wide range of impacts of rural electrification. Village residents in electrified villages are about twice as likely to operate non-agricultural businesses by 2014, while non-electrified villages see no such changes. These new businesses are most likely to be in retail and wholesale trade, with no differences in manufacturing and food processing, transportation or other non-agricultural businesses. Interestingly, agricultural yields are significantly more likely to rise in electrified villages. The proximate cause is that irrigation rates, and participation in farmer irrigation schemes rises, presumably due to access to electric pumps. No previous study finds these effects; Dinkelman (2011) finds hours increases for females but no significant effects on other variables. We also find that electricity using durables rise though modestly, though the only significant difference is for televisions. Each of these findings is consistent with our theory's predictions.

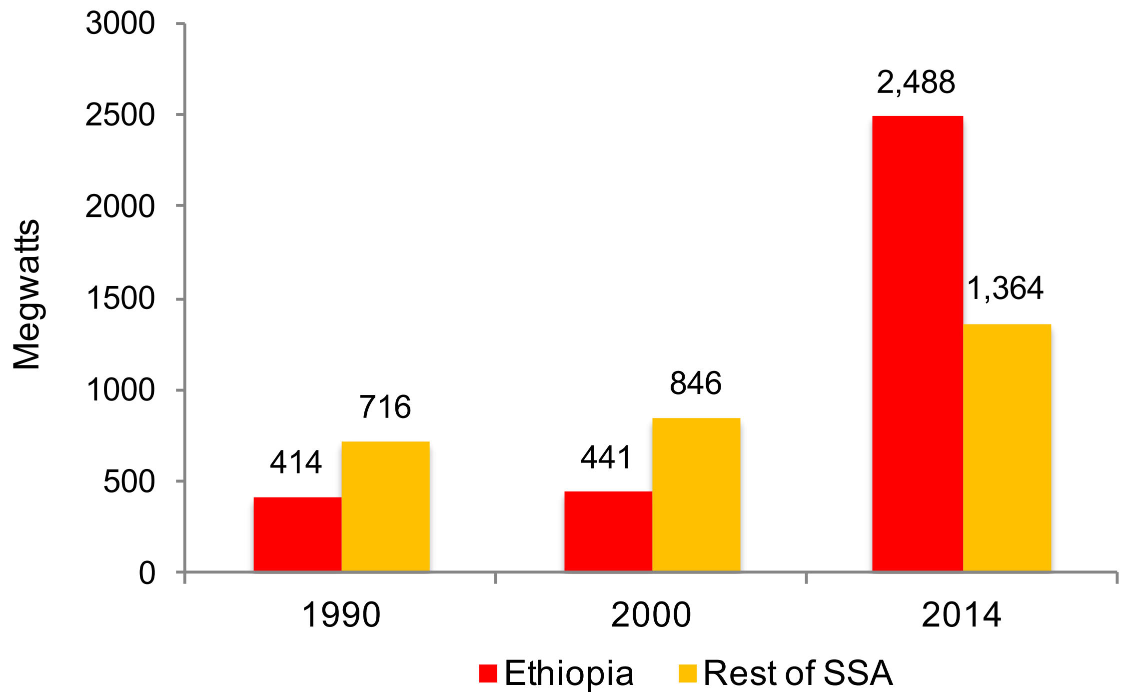
When looking at migration patterns, we find that electrified villages are substantially less likely to send migrants than before, relative to non-electrified villages. Moreover, electrified villages are somewhat more likely to receive migrants. These findings are also consistent with our theory's predictions, and consistent with the findings of Dinkelman and Schulhofer-Wohl (2015) for South Africa. According to our theory, this could either be because consumption of electricity-using durables increased, or because productivity of agriculture or non-agriculture increased, raising incomes. Our empirical findings suggest that it is the productivity increases that most alter migration patterns, since the magnitudes of the productivity increases are much more pronounced than the durable increases. We conclude that electrification is transformative, and not just a means to raise consumption utility in villages.

The rest of this paper is structured as follows. Section 2 provides a brief overview of Ethiopia's recent electrification. Section 3 presents the multi-sector, multi-region model of electrification, internal migration and structural transformation. Section 4 describes the Ethiopian data used to test the model's predictions, and Section 5 presents the main empirical findings for Ethiopia. Section 6 concludes.

2. Ethiopia's Dramatic Recent Electrification

Ethiopia began the new millennium as one of the countries with the lowest rates of rural electrification in the world. Figure 1 plots what we will call Ethiopia's "electricity capital," meaning its stock of electric power plants, in 1990, 2000 and 2014. The source for these calculations is the UDI World Electric Power Plants Database, which collects capacity information (in megawatts, MW) on every electric power facility in the world above a (fairly small) threshold of 25 kilowatts. Ethiopia had just 441 MW of capacity in 2000, which was half the sub-Saharan African Average of 846 MW. Given that Ethiopia is one of the largest countries in Africa, power capacity per capita was negligible, and power consumption was 21 kWh per capita per year on average. This is roughly what the average U.S. resident comes in one day (IEA, 2016). According to the World Bank, just 13 percent of rural Ethiopians had access to electricity.

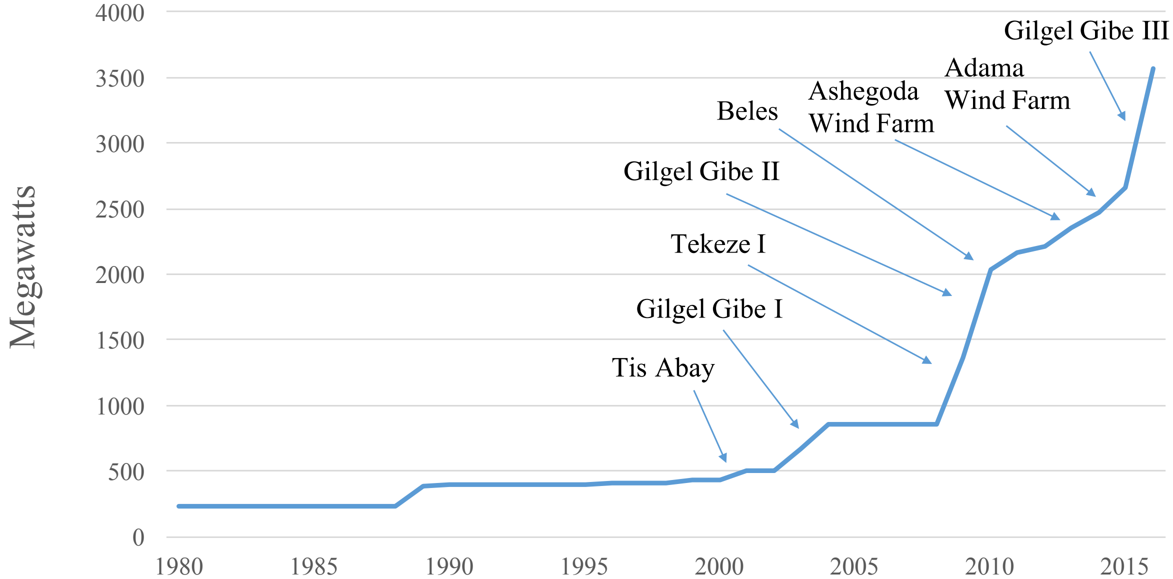
Figure 1: Ethiopia's Electricity Capital Compared to Rest of Africa



By 2014, Ethiopia's electricity capital stock had jumped dramatically to 2,488 MW, which an increase of a factor 5.6. Compared to the rest of Sub-Saharan Africa, which averaged 1,364 MW, Ethiopia had almost double the electricity stock. In per capita terms, Ethiopia tripled its per capita consumption to 64 KwH per year. The rate of rural electrification increased from 13 percent up to 27 percent.

Figure 2 provides more a more granular look at Ethiopia's dramatic electrification over this period, by plotting the time series of its electricity capital stock. Before 2000, the stock barely changed, staying below 500 MW. Afterwards, the country completed in rapid succession a series

Figure 2: Ethiopia's Dramatic Increases in Electricity Capital



of hydroelectric plants, starting from Tis Abay, Gilgel Gibe I, Tekeze I, Gilgel Gibe II and Beles all before 2010. In 2012 and 2013 it completed two large wind farms: Ashegoda and Adama. In 2015, it completed the largest dam to date: Gilgel Gibe III, to arrive at a total stock of over 3500 MW.

As few countries have ever electrified so much so quickly, Ethiopia's case is broadly relevant for understanding the effects of electrification on economic outcomes such as employment structure, internal migration rates and productivity in non-agricultural and agricultural activities. One could argue that if electrification was not transformative in Ethiopia over this period, it is unlikely to be transformative anywhere. We turn next to a model of electrification, to frame our empirical analysis of electrification in Ethiopia, to follow.

3. Model of Electrification, Migration and Structural Transformation

In this section we present a simple spatial model of how electrification affects migration patterns and structural transformation. The model predicts that electrifying a region will raise non-agricultural consumption and productivity in that region. The model also predicts that a sufficiently large decrease in the price of electricity will lead to an increase in agricultural productivity as households switch from a traditional agricultural technology to a modern one (that uses electricity). Finally, the model predicts that electrification reduces out-migration from that region and increases in-migration from other regions.

3.1. Households and Geography

The economy is composed of N regions, each of which is inhabited by a continuum of households. Each household i is endowed with one unit of labor which they supply inelastically to the labor market in exactly one region. If household i born in region j supplies their labor in region k, they must pay an (iceberg) migration cost which reduces their utility by factor $\frac{1}{d_{kj}}$. Parameter d_{kj} is increasing in the distance between regions k and j. Furthermore, $d_{jj} = 1$ for all j, implying that households born in region j that also choose to work in region j do not pay a migration cost.

Following Roy (1951) and Eaton and Kortum (2002), each household i is endowed with a vector of region-specific productivities, $\{v_j(i)\}_{j=1}^N$. Thus, household i's efficiency units of labor in region j are $v_j(i)$. A household's productivity in region j is drawn from the region-specific Frechet distribution

$$F_j(v_j) = \exp(-T_j v_j^{-\zeta}), \qquad T_j > 0 \quad \text{and} \quad \zeta > 1. \tag{1}$$

Household i born in region j draws their region-specific productivities at birth. Based on these draws, they must decide whether to supply their labor in region j or to migrate and supply their labor in region $k \neq j$.[1]

Households split their consumption between an agriculture good, c^a, and a non-agriculture good, c^n, and electricity, c^e. Preferences are a Cobb-Douglas aggregate of these three goods,

$$U(c^a, c^e, c^n) = (c^a)^\gamma (c^e)^\eta (c^n)^{1-\gamma-\eta} \tag{2}$$

where parameter γ governs the relative taste for agriculture consumption and parameter η governs the relative taste for electricity consumption. The Cobb-Douglas assumption is mainly for tractability; our model's comparative statics apply more broadly to any utility function where the three goods are normal.

There is no savings mechanism; households consume all of their income. The budget constraint

[1]Our assumption of region-specific, rather than general, productivities is consistent with the study of Bazzi, Gaduh, Rothenberg, and Wong (2016). They document that when Indonesia undertook a mass relocation program, regions that received migrants from regions with similar crop types had higher productivity than those that received workers from regions with substantially different crop types. They interpret this as evidence that skills are region specific.

for household i in region j is

$$p_j^a c_j^a(i) + p_j^e c_j^e(i) + c_j^m(i) = y_j(i), \tag{3}$$

where $y_j(i)$ denotes the labor income of household i working in region j. Variables p_j^a and p_j^e are the relative prices of the agriculture good and electricity in region j, respectively. The non-agriculture good is the numeraire and can be used to purchase both electricity and the agriculture good. We assume that the non-agriculture good can be traded across regions at zero cost, and therefore has the same price in every region.

The household optimization yields the following demands for the agriculture, electricity, and non-agriculture goods respectively,

$$c_j^a(i) = \frac{\gamma y_j(i)}{p_j^a}, \qquad c_j^e(i) = \frac{\eta y_j(i)}{p_j^e} \qquad \text{and} \qquad c_j^m(i) = (1-\gamma-\eta) y_j(i). \tag{4}$$

3.2. Production

Perfectly competitive firms in each region j produce an agriculture good, Y_j^a, and a non-agriculture good, Y_j^n, from labor (measured in efficiency units) and electricity. Firms purchase the intermediate electricity at exogenous price p_j^e. If the region is connected to the national electric grid, then firms purchase this electricity directly from the grid. If the region is not connected to the grid, firms can still purchase electricity from diesel generators and other off-grid sources. However, this off-grid electricity is considerably more costly than the grid electricity. The government has the option to "electrify" a region by connecting the region to the grid, and thus reducing the price of electricity in that region.[2]

3.2.1. Non-Agricultural Production

The production technology for the non-agriculture good in region j is Cobb-Douglas in labor, L_j^n, and electricity, E_j^n,

$$Y_j^n = A^n (E_j^n)^\theta (L_j^n)^{1-\theta}, \tag{5}$$

where A^n denotes TFP in non-agriculture production (constant across regions) and θ is the factor share of electricity. The representative firm's first order conditions yield the firm's demand

[2] We abstract from trade since rural Ethiopia is largely closed. See e.g Stokey (2001), Teignier (2012), Uy, Yi, and Zhang (1993), Tombe (2015) and Bustos, Caprettini, and Ponticelli (2016), for open-economy models of structural change, in settings where food trade plays an important role.

for electricity,

$$E_j^n = \left(\frac{\theta A^n}{p_j^e}\right)^{\frac{1}{1-\theta}} L_j^n, \tag{6}$$

and the equilibrium wage (per efficiency unit) of labor,

$$w_j^n = (1-\theta)A^n(E_j^n)^{\theta}(L_j^n)^{-\theta}. \tag{7}$$

To derive the production function and the wage as functions of the electricity price, substitute firm electricity demand (equation (6)) into the production function for non-agriculture (equation (5)) and also into the expression for the equilibrium wage (equation (7)),

$$Y_j^n = (A^n)^{\frac{1}{1-\theta}}\left(\frac{\theta}{p_j^e}\right)^{\frac{\theta}{1-\theta}} L_j^n \qquad \text{and} \qquad w_j^n = (1-\theta)(A^n)^{\frac{1}{1-\theta}}\left(\frac{\theta}{p_j^e}\right)^{\frac{\theta}{1-\theta}}. \tag{8}$$

All else constant, equation (8) implies that electrifying a region (i.e. a reduction in the electricity price, p_j^e) increases the region's non-agriculture output and raises the equilibrium wage in the non-agriculture sector.

3.2.2. Agriculture Production

Perfectly competitive firms can produce the agriculture good using a traditional or a modern technology. Production with the traditional technology requires only labor, while production with the modern technology requires both labor and electricity. For example, traditional agriculture might rely on rainfall or small, gravity driven aqueducts to water crops while modern agriculture might instead use an irrigation system with an electric pump. The production functions in region j for traditional agriculture, Y_j^t, and modern agriculture, Y_j^m, are

$$Y_j^t = A^t L_j^t \qquad \text{and} \qquad Y_j^m = A^m(E_j^m)^{\alpha}(L_j^m)^{1-\alpha}, \tag{9}$$

where A^t and A^m denote total factor productivity (constant across all regions) in traditional and modern agriculture, respectively. Parameter α is the electricity share in the production of modern agriculture. We assume throughout that the factor share of electricity in modern agriculture is less than its value in non-agriculture, $\alpha < \theta$.

Following the same procedure as for the non-agriculture good, we derive the production function and the equilibrium wage for modern agriculture as a function of the electricity price,

$$Y_j^m = (A^m)^{\frac{1}{1-\alpha}} \left(\frac{\alpha}{p_j^e} \right)^{\frac{\alpha}{1-\alpha}} L_j^m \qquad \text{and} \qquad w_j^m = p_j^a (1-\alpha)(A^m)^{\frac{1}{1-\alpha}} \left(\frac{\alpha}{p_j^e} \right)^{\frac{\alpha}{1-\alpha}}. \tag{10}$$

The firm's first order condition for labor yields the equilibrium wage in the traditional agriculture sector

$$w_j^t = p_j^a A^t. \tag{11}$$

Agriculture goods produced with the traditional and the modern technologies are perfect substitutes. However, since the equilibrium wages in both sectors do not depend on labor (equations (10) and (11)), all households will choose to work for the producers that use the technology with the higher marginal product of labor, and thus pay a higher wage. Therefore producers of the agriculture good in region j will use either the traditional or the modern technology, but not both.

All other variables held constant, the electricity price determines whether the traditional or the modern technology has the highest marginal product of labor. Specifically, equation (10) implies that decreases in the electricity price increase the modern agriculture producer's equilibrium wage, w_j^m. Let $\widetilde{p}$ denote the value of the electricity price that equates the traditional and modern wages. Solving the equality $w^t = w^m$ for $\widetilde{p}$ yields

$$\widetilde{p} = \alpha (A^m)^{\frac{1}{\alpha}} \left(\frac{1-\alpha}{A^t} \right)^{\frac{1-\alpha}{\alpha}}. \tag{12}$$

Note that this cutoff value is the same across all regions (since TFP does not vary by region). Firms will produce the agriculture good with the traditional technology when $p_j^e > \widetilde{p}$ and with the modern technology when $p_j^e < \widetilde{p}$. Therefore, region j's output of the agriculture good, Y_j^a, is given by

$$Y_j^a = \begin{cases} Y_j^t & : p_j^e \geq \widetilde{p} \\ Y_j^m & : p_j^e < \widetilde{p} \end{cases} \tag{13}$$

Advances in modern agriculture technology, increase the cutoff value for p_j^e, implying that regions will switch to the modern technology at a higher electricity price.

Proposition 1 *Electrifying a region using traditional agriculture will cause the region to switch* *to modern agriculture as long as the decrease in the electricity price is sufficiently large.*

The intuition for this result is simply that if electrifying region j reduces p_j^e below the cut-off price, $\widetilde{p}$, then equation (13) implies that region j will switch from traditional to modern agriculture.

3.3. Within-Region Equilibrium

Households in each region demand positive quantities of both the agriculture and the non-agriculture goods (equation (4)). The model's equilibrium forces allocate households between agriculture and non-agriculture production to meet these demands. This allocation requires that households are indifferent between working in the agriculture and the non-agriculture sectors, and thus necessitates equal wages across the two sectors,

$$w_j^n = \begin{cases} w_j^t & : p_j^e \geq \widetilde{p} \\ w_j^m & : p_j^e < \widetilde{p} \end{cases} \tag{14}$$

Since wages (given by equations (7), (10), and (11)) are independent of labor in each sector, the price of the agriculture good adjusts in each region to ensure that equation (14) holds. This yields the follow equilibrium price for the agriculture good in region j,

$$p_j^a = \begin{cases} \dfrac{(1-\theta)(A^n)^{\frac{1}{1-\theta}}\left(\frac{\theta}{p_j^e}\right)^{\frac{\theta}{1-\theta}}}{A^t} & : p_j^e \geq \widetilde{p} \\ \dfrac{(1-\theta)(A^n)^{\frac{1}{1-\theta}}\left(\frac{\theta}{p_j^e}\right)^{\frac{\theta}{1-\theta}}}{(1-\alpha)(A^m)^{\frac{1}{1-\alpha}}\left(\frac{\alpha}{p_j^e}\right)^{\frac{\alpha}{1-\alpha}}} & : p_j^e < \widetilde{p} \end{cases} \tag{15}$$

Electrifying a region raises the price of the agriculture good or, equivalently, reduces the price of the non-agriculture good.[3] The within-region equilibrium conditions imply that the equilibrium wage in region j, w_j, equals the wage in the non-agriculture sector,

$$w_j = w_j^n = (1-\theta)(A^n)^{\frac{1}{1-\theta}}\left(\frac{\theta}{p_j^e}\right)^{\frac{\theta}{1-\theta}}. \tag{16}$$

[3] This result is conditional on our assumption that $\theta > \alpha$.

The labor income of household i in region j equals

$$y_j(i) = w_j v_j(i). \tag{17}$$

Electrifying region j increases the equilibrium wage which raises labor income for all households in region j. This increase in labor income combined with the decrease in the electricity price raises household demand for electricity.

Proposition 2 *Electrifying a region increases household consumption of electricity.*

To see this result, differentiate the demand for electricity by household i in region j (equation (4)) with respect to the electricity price in region j,

$$\frac{\partial c_j^e(i)}{\partial p_j^e} = \underbrace{-\eta y_j(i)\left(\frac{1}{p_j^e}\right)^2}_{\text{Substitution effect}} + \underbrace{\left(\frac{\eta}{p_j^e}\right)\frac{\partial y_j(i)}{\partial p_j^e}}_{\text{Income effect}} < 0 \tag{18}$$

Decreases in the electricity price increase electricity demand through both income and substitution effects. The substitution effect (first term in equation (18)) occurs because the decrease in the relative price of electricity causes households to substitute the consumption of electricity for both agriculture and non-agriculture consumption. The income effect (second term in equation (18)) arises because the decrease in the electricity price increases wages in region j, raising household income and, thus increasing demand for electricity, as well as for the agriculture and non-agriculture goods.

Proposition 3 *Electrifying a region increases non-agriculture production per household.*

The intuition for this result is that electrifying a village increases labor income (equation (16)) which raises household demand for the non-agriculture good (equation (4)), which, in turn, increases its supply per household.

3.4. Inter-Region Equilibrium

We next solve for the equilibrium allocation of households across the N regions. A household born in region j, will migrate to region k if his utility in region k, net of his migration costs, is greater than his utility in region j. To solve for the inter-region equilibrium, we must first solve for household utility in each region. Substitute the demand functions for the agriculture, electricity, and non-agriculture goods (equation (4)) into the utility function (equation (2)) to derive the utility of a household, i, born region j as a function of labor income and relative prices,

$$U_j(i) = y_j(i)\left(\frac{\gamma}{p_j^a}\right)^{\gamma}\left(\frac{\eta}{p_j^e}\right)^{\eta}(1-\eta-\gamma)^{1-\eta-\gamma}. \tag{19}$$

Electrifying a region reduces the price of electricity, causing households to consume more of the electricity good, raising utility. Electrification also increases labor income, y_j, which raises utility through the income effect. However, working in the other direction, electrification increases the relative price of the agriculture good, which, all else constant, decreases the household's consumption of the agriculture good, lowering utility. To determine which of these effects dominates, substitute the the equilibrium price of agriculture (equation (15)), and household labor income (equations (16) and (17)) into equation (19) to obtain household utility as a function of the electricity price,

$$U_j(i) = H(p_j^e)v_j(i) \tag{20}$$

where

$$H(p_j^e) = \begin{cases} (1-\theta)(1-\eta-\gamma)(A^n)^{\frac{1}{1-\theta}}\left(\frac{\theta}{p_j^e}\right)^{\frac{\theta}{1-\theta}}\left(\frac{\eta}{p_j^e}\right)^{\eta}\left[\dfrac{\gamma A^t}{(1-\theta)(A^n)^{\frac{1}{1-\theta}}\left(\frac{\theta}{p_j^e}\right)^{\frac{\theta}{1-\theta}}}\right]^{\gamma} & : p_j^e \geq \widetilde{p} \\ (1-\theta)(1-\eta-\gamma)(A^n)^{\frac{1}{1-\theta}}\left(\frac{\theta}{p_j^e}\right)^{\frac{\theta}{1-\theta}}\left(\frac{\eta}{p_j^e}\right)^{\eta}\left[\dfrac{\gamma(1-\alpha)(A^m)^{\frac{1}{1-\alpha}}\left(\frac{\alpha}{p_j^e}\right)^{\frac{\alpha}{1-\alpha}}}{(1-\theta)(A^n)^{\frac{1}{1-\theta}}\left(\frac{\theta}{p_j^e}\right)^{\frac{\theta}{1-\theta}}}\right]^{\gamma} & : p_j^e < \widetilde{p} \end{cases}$$

$H'(p_j^e) < 0$, implying that electrifying region j increases the utility of households in the region.[4] Hence the utility gains from higher labor income and electricity consumption dominate the utility losses from the lower agriculture consumption (income held constant).

We next solve for the ex-ante probability (i.e. before the region-specific productivities real-

[4] $H'(p_j^e) < 0$ under our assumption that $\theta > \alpha$. The exact parameter requirements for $H'(p_j^e) < 0$ are that $\gamma\left(\frac{\alpha}{1-\alpha}\right) < (1+\gamma)\left(\frac{\theta}{1-\theta}\right) + \eta$. Our assumption that $\theta > \alpha$ is stronger than this condition.

ize) that a household born in region j chooses to supply his labor in region k. The utility of household i born in region j and working in region k is

$$U_{kj}(i) = H(p_k^e)\left(\frac{\nu_k(i)}{d_{kj}}\right).$$

The household will migrate to the region where they receive the highest utility net of migration costs. Taking this migration into account, the utility of a household i, born in region j is then

$$U_j(i) = \max\{U_{kj}(i);\ k = 1, \ldots, N\}.$$

Since each household's labor productivity in region j is the realization of a random variable, ν_j, his expected utility in region k is also the realization of the random variable, $U_{kj} = H(p_k^e)\left(\frac{\nu_k}{d_{kj}}\right)$. Moreover, the highest expected utility is the realization of the random variable, $U_j = \max\{U_{kj}; k = 1, \ldots, N\}$. The likelihood that a household i born in region j supplies his labor to region k is the probability, π_{kj}, that region k's utility turns out to be the highest.

Let $G_{kj}(U)$ be the CDF for the expected utility for households born in region j and working in region k.

$$G_{kj}(U) = \text{Prob}[U_{kj} \leq U] \tag{21}$$

$$= \exp\left(-T_k\left(\frac{H(p_k^e)}{d_{kj}}\right)^{\zeta} U^{-\zeta}\right) \tag{22}$$

We next solve for the distribution of the highest utility available to a given household born in region j, $G_j(U)$. This utility will be greater then U unless the utilities in every region are less than U.

$$G_j(U) = \text{Prob}\left[U_j \leq U\right] \tag{23}$$

$$= \prod_{k=1}^{N} G_{kj}(U) \tag{24}$$

$$= \exp\left(-U^{-\zeta}\sum_{k=1}^{N}\psi_{kj}\right) \qquad \text{where} \qquad \psi_{kj} = T_k\left(\frac{H(p_k^e)}{d_{kj}}\right)^{\zeta} \tag{25}$$

Finally, we can solve for the probability that a household from region j chooses to work in region k, π_{kj}. A household from region j will migrate to region k if the utility in region k is greater than the utility in all the other regions.

$$\begin{aligned}\pi_{kj} &= \text{Prob}\left[U_{kj} \geq \max_{s \neq k} U_{sj}\right] \\ &= \int_0^\infty \prod_{s \neq k} G_{sj}(U) dG_{kj}(U) \\ &= \frac{\psi_{kj}}{\sum_{s=1}^N \psi_{sj}} \end{aligned} \tag{26}$$

Equations (25) and (26) imply that the probability that a household from region j migrates to region k depends, in part, on the electricity price in region k. This observation leads to the following proposition.

Proposition 4 *Electrifying a region raises in-migration and lowers out-migration.*

To see that electrification increases in-migration, observe that $\frac{\partial \pi_{kj}}{\partial p_k^e} < 0$. Decreases in the electricity price in region k increase the probability that households migrate from region j to region k. Similarly, to see that electrification reduces out-migration, observe that $\frac{\partial \pi_{jj}}{\partial p_j^e} < 0$. Decreases in the electricity price in region j increase the probability that households in region j choose to work in region j.

3.5. Summary of Theoretical Predictions

In sum, Propositions 1-4 provide four predictions that we can test directly with our differences-in-differences analysis of electrified and non-electrified villages in Ethiopia. First, Proposition 1 implies that electrifying a village causes a shift from traditional to modern agriculture. In our empirical work, we will look at the effects of electrification on the fraction of farmers that use an irrigation system. If electrification leads to an increase in irrigation, then this is evidence of a shift towards modern agriculture, in accordance with the model's results.

Second, Proposition 2 claims that electrifying a village increases household consumption of electricity. Increases in household electricity consumption could imply that households are using more light and/or that households purchased electricity-using durables. We will test the latter channel. If electrification leads to an increase in the fraction of households that own electricity-using durables, such as electric stoves, sewing machines and televisions, we will interpret this change as evidence that electrification increased household consumption of electricity, as the model predicts.

Third, Proposition 3 shows that electrifying a village increases the production of the non-agriculture good per household. We can test this prediction directly by analyzing the effects of electrification on the fraction of households that have a non-agriculture business. Finally, Proposition 4 finds that electrifying a village will increase in-migration and decrease out-migration. We can also directly test this prediction by analyzing the effects of electrification on whether a village is more likely to be a net-sender or a net-receiver of migrants.

4. Data

We now describe how we test the predictions of the model using a representative panel of rural villages from Ethiopia from 2012 to 2014.

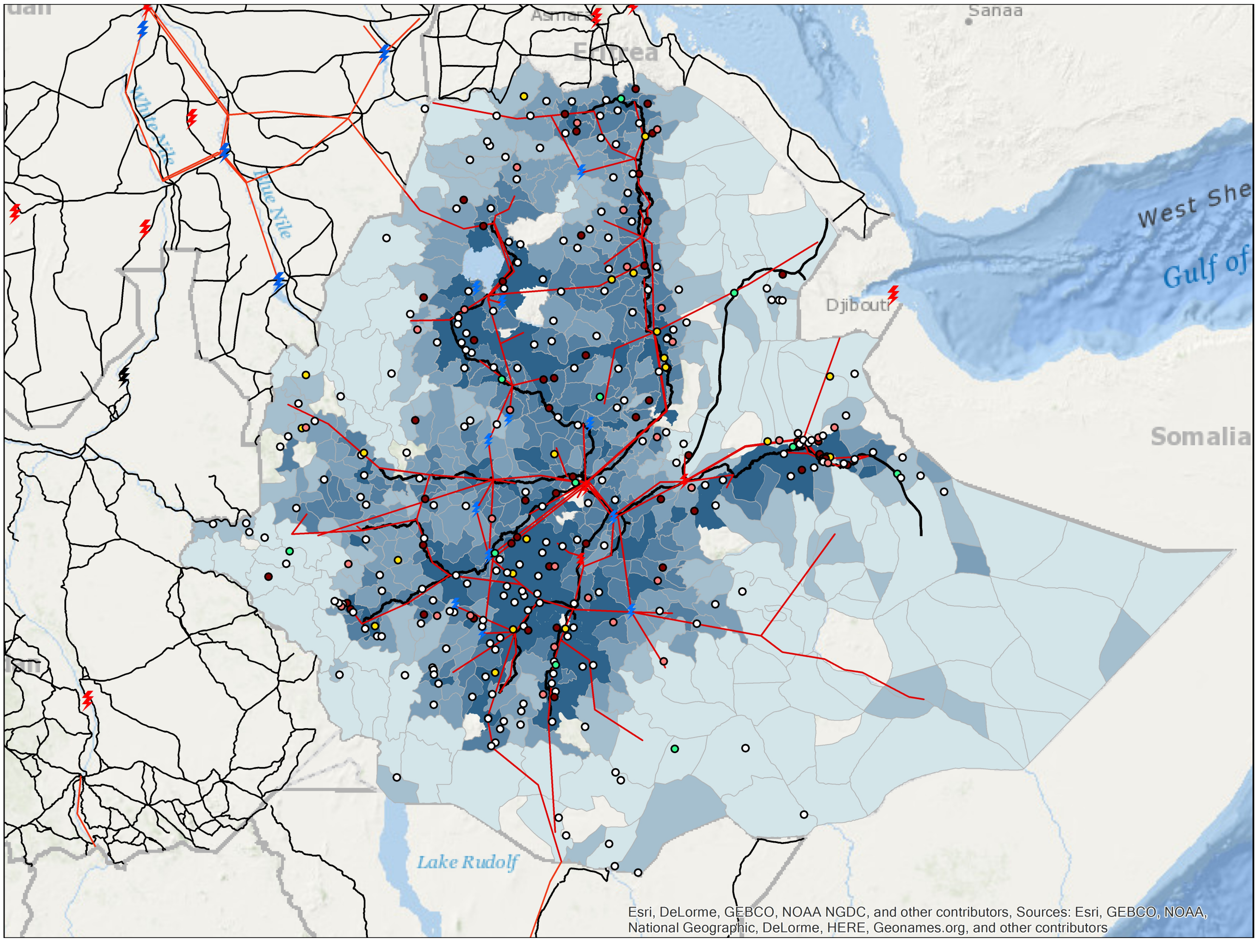
4.1. Ethiopian Rural Socioeconomic Survey

Our main data source for the paper is the Ethiopian Rural Socioeconomic Survey (ERSS) conducted in 2011/2012 and again in 2013/2014 on a set of enumeration areas representative of parts of Ethiopia. The former survey was representative of all rural areas of Ethiopia, while the latter was nationally representative. Usefully for our purposes, most of the enumeration areas surveyed in 2012 were also surveyed in 2014. Figure 3 shows the location of sample enumeration areas in the ERSS, along with population density, major roads (black) and the high-voltage electricity grid; it is clear that the survey covers a representative of Ethiopia's populated areas. We restrict attention to these rural enumeration areas (henceforth "villages") that were surveyed twice, so as to take advantage of the panel structure. We further restrict attention to villages that are at least 25 kilometers from Addis and have no more than 10,000 persons, to make sure our sample is truly of rural villages and not suburban or urbanized areas.

Since our focus is on electrification, we restrict attention to villages in which none of the respondents report having access to grid electricity in 2012. This allows us to compare villages that became connected to the grid in 2014 to those that remain unconnected in 2014. We end up with a nationally representative panel of 215 rural Ethiopian villages that are not electrified as of 2012.

The period 2012 to 2014 was a period of large increases in electricity production and distribution in Ethiopia. At a national level, we calculate that total electricity production capacity in Ethiopia grew from 2,159 MW in 2011 to 1475 by the end of 2014, a 15 percent increase in capacity. Moreover, there was a substantial push to electrify urban areas besides Addis Ababa. Along the way, the Ethiopian Electric Utility, the government agency in charge of power distri-

Figure 3: Ethiopian Population Density and ERSS Sample Villages



bution, made a commitment to electrify rural villages near their target cities.

What were the criteria used to decide which villages to electrify? Several government sources suggest the answer is equity. Ethiopia's recent Universal Access Plan states that the primary goal of rural electrification is to bring electricity access to all rural areas. In practice, the central government provides quotas to each region on the number of villages they can choose to electrify, and the regions decide on the list of individual villages.[5]

[5]In a private meeting with the CEO of the Ethiopian Electric Utility, we asked which criteria the regional governments use to select rural villages for electrification. His answer was equity, rather than cost or village growth potential, though the Utility and Ethiopian Electric Power Company often advise regional governments to consider cost as well to the extent possible.

4.2. Non-Electrified and Electrified Villages

We focus on comparisons of two groups: "non-electrified villages", which we define as villages with no access to grid electricity in either year, to "electrified villages," or those that did not have grid electricity in 2012 but got access by 2014. To classify villages into one of these two groups, we use household-level questions on access to grid electricity. Formally, non-electrified villages are those households in which exactly zero percent of households reporting having grid electricity in both years. Electrified villages have at least one household that report having grid electricity in 2014.

The rationale that moving from zero to a positive fraction of households with grid electricity likely reflects an expansion of the electricity grid, rather than increased demand for electricity by village residents. Of the total, we classify 171 villages as non-electrified and 43 villages as electrified.

Table 1: Average Village Characteristics in 2012

	Village Type		
	Not Electrified	Electrified by 2014	Difference (p-val)
Population	4,574	4,925	350 (0.38)
Dist. to Major Road (km)	53	46	7 (0.46)
Dist. to Addis (km)	336	325	11 (0.63)
Dist. to Addis via road (km)	512	461	-51 (0.14)
Dist. to Djibouti via road	962	895	-67 (0.19)
Dist. to Electrified E.A.	44	38	-6 (0.49)
On Line From Dam to Addis,%	16.3	9.3	-7 (0.25)
Health center (%)	18.1	27.9	9.8 (0.15)
Tar road (%)	16.3	18.6	2.3 (0.71)
Received Migrants (%)	23.2	20.9	-2.3 (0.75)
Sent Migrants (%)	43.0	55.8	12.8 (0.13)

Source: Author's Calculations Using Ethiopian Rural Socioeconomic Survey (2012, 2014).

Table 1 presents average characteristics of the two types of villages. In terms of population, which is the first row, non-electrified villages average 4,574, compared to 4,925 for electrified villages. The third data column reports the difference, which is 350, and the p-value from a two-sided t-test of the null hypothesis that the difference is zero, which is 0.38. Thus, populations are not statistically different for the two village types.

The next four rows of Table 1 present various measures of geographic isolation, measured using distance to a major road, distance to Addis Ababa as the bird flies, distance to Addis Ababa via roads, and distance to the port of Djibouti via roads. In short, both sets of villages are approximately equally isolated, being 53 and 46 kilometers from the nearest major road, for example, and 512 and 461 kilometers from Addis via road. None of the differences in distances are statistically significant.

The middle two rows report two measures that may be informative about the cost of electrification. The first reports the distance in kilometers to the nearest electrified enumeration area that has at least half of its households reporting access to grid energy in 2012. Non-electrified villages are 44 kilometers away, compared to 38 kilometers for villages that later get electrified. The difference that is statistically insignificant. The second measure reports the fraction of villages located within 20 kilometers of a straight line connecting a hydroelectric dam to Addis Ababa. This may mean that the village will be less costly to electrify in the future, if power lines are run from the dam directly to Addis. Among non-electrified villages, 16.3 percent are located such, compared to 9.3 percent of villages that get electrified. The difference is again statistically insignificant. Neither of these measures support the role of cost as a primary factor in determining which villages get electrified.

The last four rows of Table 1 compare the two village types by access to public goods and migration patterns, in particular the fraction of villages with a health clinic or hospital, the fraction with a tar road, the fraction villages reporting they received more migrants than they sent, and the fraction reporting that they sent more migrants than they received. The public goods access is similar in the two regions, with both non-electrified and electrified villages having a modest 18.1 and 27.9 percent with access to health clinics, and 16.3 and 18.6 percent having a tar road. The migration characteristics are also similar, which may be informative about other unobservables at the village level. Among non-electrified villages, 23.2 percent had more migrants moving in than out, compared to 20.9 percent among electrified villages. Out migration was at 43 percent in non-electrified villages and 55.8 percent in electrified villages. Neither difference is statistically significant, and all in all, both groups are net senders of migrants, which is consistent with Ethiopia's rapidly rising rates of urbanization over this period.

To summarize the village level comparisons, we find no significant differences in 2012. Still, households within the villages could differ in important ways. Table 2 reports average characteristics of household respondents in the ERSS. The first four rows report the average percent of households with access to tap water, a flush toilet, having a mud floor and using a generator for lighting. In both village types, less than ten percent of households have access to tap water

Table 2: Average Household Characteristics by Village Type in 2012

	Village Type		
	Not Electrified	Electrified by 2014	Difference (p-val)
Tap Water (%)	9.6	8.9	0.7 (0.86)
Flush Toilet (%)	2.0	0.2	-1.8 (0.36)
Mud Floor (%)	96.9	94.8	-2.1 (0.14)
Use Generator (%)	23.7	24.2	0.5 (0.93)
Non-agric. business	4.9	5.4	0.6 (0.65)
Sold agric. product	6.3	8.7	2.4 (0.30)
Mobile Phone	19.7	27.2	7.5* (0.08)
Electric Stove	1.0	1.8	0.8 (0.22)
Sewing Machine	1.5	2.5	1.0 (0.17)
Television	1.6	2.7	1.1 (0.16)

Source: Author's Calculations Using Ethiopian Rural Socioeconomic Survey (2012, 2014)

or toilets, and nearly all have a mud floor. Around one quarter of households use a generator for their lighting. None of the differences are statistically significant at the ten percent level or lower.

The next two rows of Table 2 report the average fraction of households reporting that they operate a non-agricultural business of any kind, and the fraction selling some agricultural product. Just 4.9 percent of non-electrified villagers and 5.4 percent of villagers whose villages are later electrified operate non-agricultural businesses. A somewhat surprising 6.3 percent and 8.7 percent of villagers sold agricultural product. The lack of higher percentages here is probably explained by the fact that most agricultural households are subsistence producers who do not typically sell their output. Whatever the cause, neither difference is statistically significant.[6]

The final four rows of Table 2 report ownership of electricity-using durable goods. Two features are worth noting here. First, mobile phone ownership rates are high for both villages, at 19.7 percent and 27.2 percent, with a statistically significant difference between them (at the ten percent level). Assuming this is not an artifact of the relatively small sample size, this would cloud any causal interpretation of the difference-in-difference results presented below. Still, for

[6]The ERSS contains other questions on hours worked in non-agricultural versus agricultural activities, and we report some results for these variables in the Appendix. Unfortunately, the hours questions are not comparable in 2012 and 2014, however, which limits the comparability. In 2012, the majority (XX%) of hours are in agriculture across the two villages, with no significant difference between them.

the other durable goods, electric stoves, sewing machines and televisions, we see no significant differences, casting doubt on a story that electrified villages were at higher income levels on average in 2012, and somehow better poised for structural transformation in the coming years.

All in all, across twenty metrics, all but one show similar characteristics with statistically insignificant differences, including population, extent of geographic isolation, access to public goods, existing migration patterns, housing quality, sectoral composition and several household durable goods. This suggests the parallel trends assumption needed for a causal interpretation of a difference-in-difference comparisons, to follow. The lack of differences between village types in 2012 is also consistent with the direct account of the Ethiopian Electric Utility that reports equity as being the primary factor in deciding which villages got electrified over this period, rather than estimated potential for future growth.

An additional approach is assessing determinants of electrification is to attempt to predict electrification by 2014 using the variables in Tables 1 and 2 for 2012. In the Appendix, we report the result of a regression of electrification by 2014 on these village and household characteristics, using the non-electrified villages in 2012 as observations. Table 3 reports the results. None of the variables besides the constant are significant, and the adjusted R^2 is -0.009. The F-stat of joint significance of all independent variables is 0.90 with a p-value of 0.59. We conclude that future electrification is not easily forecastable in 2012 using these observables at least. This is again consistent with equity of electrification being the primary consideration in deciding which rural villages to electrify, rather than cost or village characteristics.

Table 3: Predicting Electrification by 2014

Population	7.53e-06 (0.000013)	0.000013 (0.000013)
Dist. to Major Road (km)	1.88e-07 (8.63e-07)	1.44e-07 (9.27e-07)
Dist. to Djibouti via Road (km)	-0.000078 (0.00011)	-0.000083 (0.00012)
Dist. to Addis via Road (km)	-0.00015 (0.00017)	-0.00019 (0.00019)
Dist. to Electrified EA	-8.74e-08 (9.82e-07)	-2.60e-07 (1.02e-06)
Sent Migrants, pct	0.077 (0.067)	0.067 (0.069)
Received Migrants, pct	0.049 (0.080)	-0.022 (0.086)
Flush Toilet, pct		-0.19 (0.26)
Mud Floor, pct		-0.46 (0.36)
Tap Water, pct		0.0026 (0.13)
Use Generator, pct		0.090 (0.096)
Non-agricultural business		0.059 (0.35)
Sold agricultural product		0.34 (0.23)
Tar Road, pct		-0.00056 (0.078)
Health Center, pct		0.10 (0.073)
Electric Stove, pct		-0.0075 (0.98)
Sewing Machine, pct		-0.48 (1.00)
Mobile Phone, pct		0.23 (0.15)
Television, pct		0.71 (1.01)
Constant	0.26** (0.13)	0.61 (0.38)
Observations	213	213
Adjusted R^2	-0.011	-0.009

Source: Author's Calculations Using Ethiopian Rural Socioeconomic Survey (2012, 2014). Sample is all rural villages that are not electrified in 2012. Dependent variable is electrified by 2014. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

5. Empirical Findings

In this section, we compare villages that became electrified by 2014 to those that remained non-electrified. In particular, we assess the model's predictions for the effects of electrification on consumption of electricity-intensive goods, the extent of non-agricultural activities within the village, agricultural productivity and (electricity-using) irrigation rates in electricity, in-migration rates and out-migration rates. We also ask whether other public goods were extended contemporaneously along with the electricity grid.

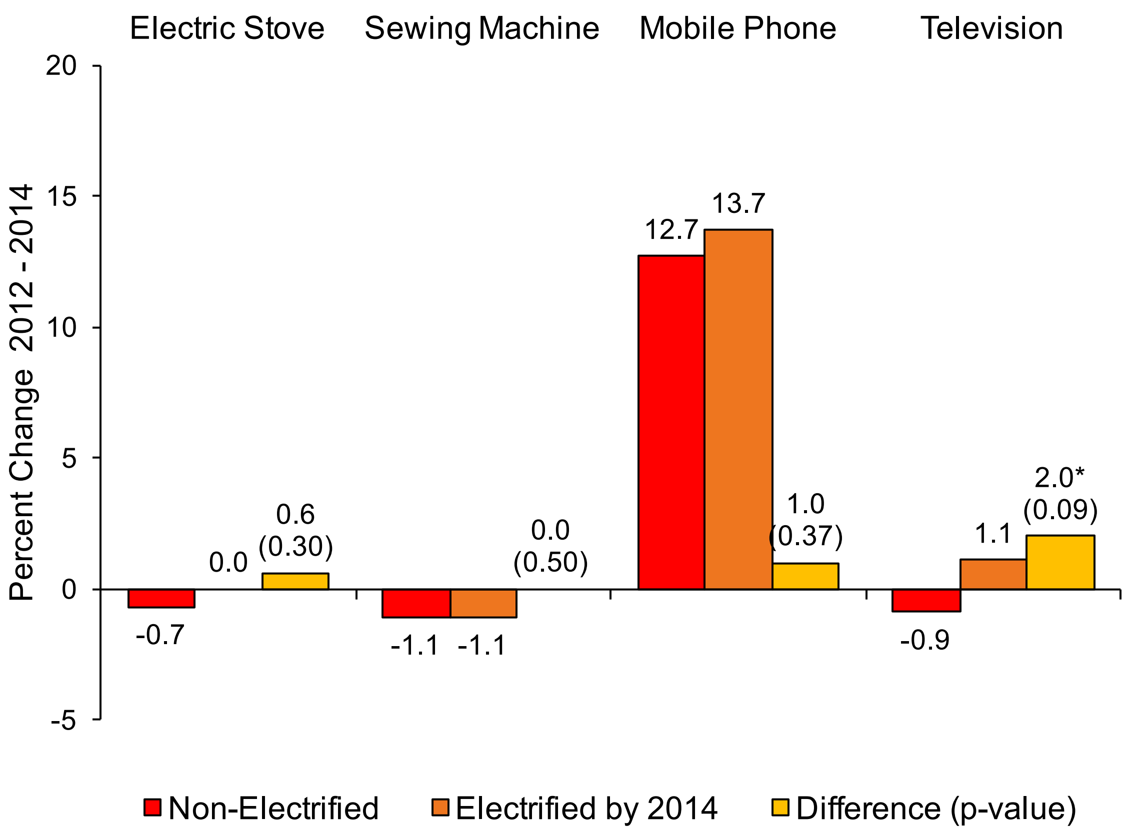
5.1. Consumption of Electricity Intensive Goods

Our main findings concern the difference in economic outcomes from 2012 in 2014 in electrified villages compared to differences over the same period in non-electrified villages. In other words, we use a differences-in-differences approach to estimating the effects on rural electrification. The simplest prediction of the model is that electrification leads to increases in consumption of electricity, or electricity-using durables. This is also consistent with the emphasis on the rising demand for energy-using durables by the middle class Gertler, Shelef, Wolfram, and Fuchs (2016) as electricity access will continue. Using the ERSS data we can compute changes in the ownership rates of four main electricity-using durable goods: electric stoves, sewing machines, mobile phones and televisions.

Figure 4 plots changes in durable ownership from 2012 to 2014. The rad bars plot the average change for the non-electrified villages, the orange bars plot the average changes for the electrified villages and the yellow bars are the simple difference (with p-value in parenthesis). As the Figure shows, changes in ownership of stoves and sewing machines were negligible across both village groups. Changes in mobile phones were fairly dramatic, at a 12.7 percent and 13.7 percent increase in the two village groups. The difference, however, was statistically insignificant.

The one place where we find a significant difference in ownership rate increases is in televisions. Non-electrified villages have a decrease of 0.9 percent in ownership rates, while electrified villages have an increase of 1.1 percent. The difference is 2 percent, which is statistically significant at the ten percent level (p-value 0.09). Still, this is a fairly modest difference in economic terms. We conclude that the pure consumption effects of electrification are positive but not overwhelming.

Figure 4: Differences in Household Durable Good Ownership



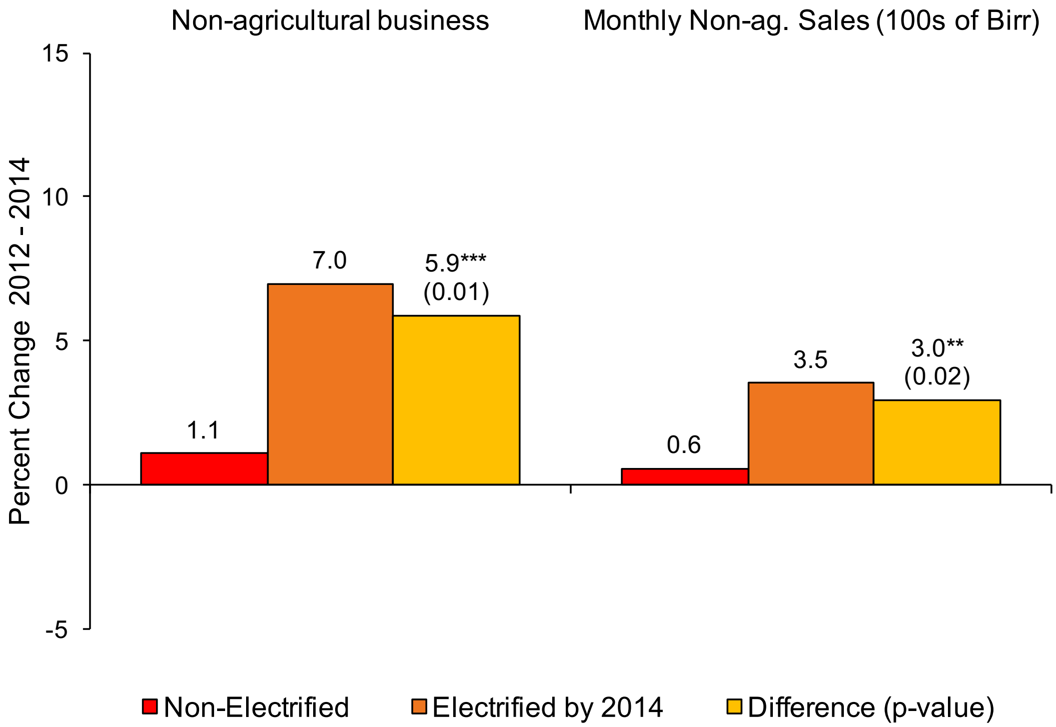
5.2. Non-Agricultural Businesses

Our model predicts that electrification increases non-agricultural productivity as well. The best simple proxy for non-agricultural productivity in the ERSS is the data on operation of non-agricultural businesses and monthly sales revenues from those businesses, conditional on operation.

Figure 5 reports our findings for non-agricultural businesses. The fraction of households having an agricultural business increased by just 1.1 percent in non-electrified villages compared to 7 percent in those that got electrified, for a difference of 5.9 percent, which is significant at the one-percent level. This amounts to roughly doubling the number of non-agricultural businesses in the electrified villages, which is quite substantial. Monthly non-agricultural sales also increases significantly more in the electrified villages, by 300 Birr on average, across the whole village. This difference is again statistically significant at the one-percent level.

Table 4 looks further by industry, to see which types of businesses were most prevalent. Our

Figure 5: Changes in Non-Agricultural Businesses



data allow a breakdown into five major sectors: manufacturing and food processing, retail and wholesale trade, restaurants and hotels, transportation and other non-agricultural businesses. What we find is that most of the new businesses in the electrified villages are in retail and wholesale trade. There, non-electrified villages have a decline in ownership rates of 1.1 percentage points. Electrified villages on the other hand have an increase of 6.5 percentage points, which is a statistically significant difference at the one percent level. Coming up from such a low base (less than five percent ownership in most villages), this represents a more than doubling of retail and wholesale trade businesses, which is substantial in economic terms.

Other industries do not show much of a difference with electrification. Manufacturing and food processing is one of the goals of the Ethiopian government, particularly in rural areas, where food processing is a natural sector to expand given the predominance of agriculture. Still, there was essentially no change in operation of manufacturing or food processing businesses in either non-electrified or electrified villages. Restaurants would also seem to be a natural business to open after electrification, though we saw no differences there. One possibility is that entrepreneurs open restaurants that also offer retail sales, and are classified mostly as retail establishments. Its not obvious why transportation businesses would expand, but we

Table 4: Differences in Non-Agricultural Business by Industry

	Percentage Point Changes 2012-2014		
	Non-Electrified	Electrified in 2014	Difference
Manufacturing and Food Processing	-0.1	0.0	-0.2 (0.94)
Retail and Wholesale Trade	-1.1	6.5	7.6*** (0.01)
Restaurants and Hotels	0.1	-0.2	-0.3 (0.69)
Transportation	4.7	2.5	-2.2 (0.40)
Other Non-agricultural Business	0.6	0.4	0.1 (0.95)

Source: Author's Calculations Using Ethiopian Rural Socioeconomic Survey (2012, 2014). *p*-values are in parentheses in the Difference column. ***,**, and * mean statistically significant at the 1-, 5- and 10-percent levels.

find no changes there or for other miscellaneous non-agricultural businesses.

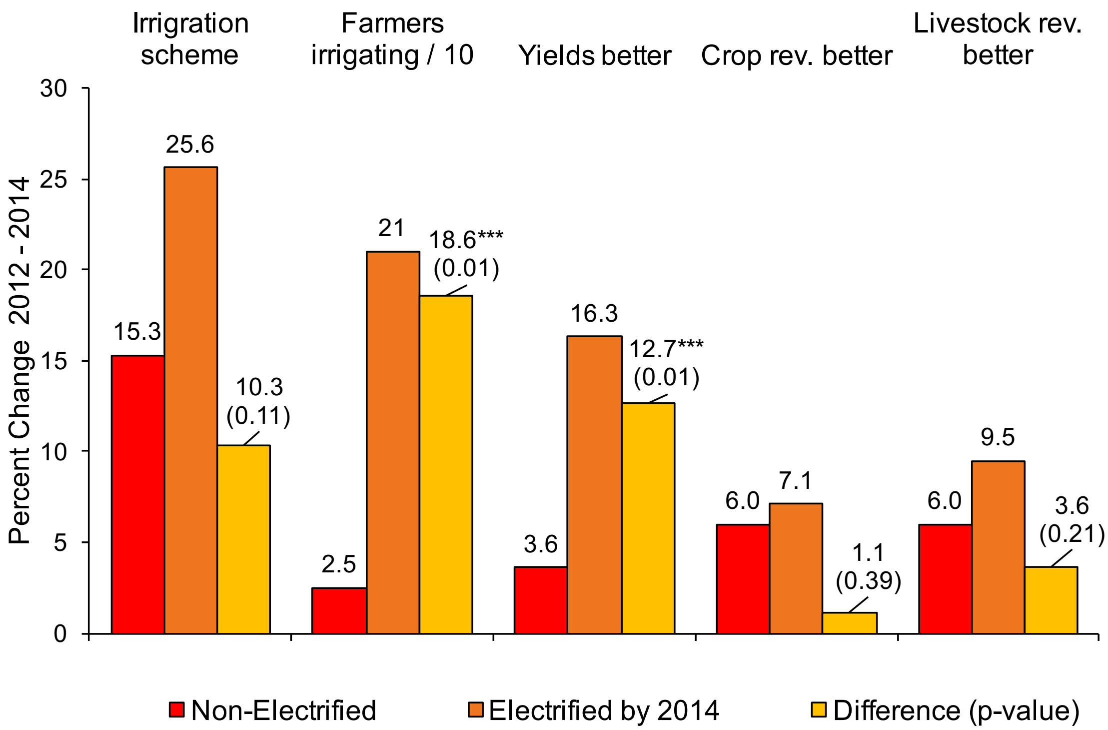
5.3. Agricultural Production

Figure 6 reports the percent differences from 2012 to 2014 in agricultural variables in non-electrified villages (red bars), electrified villages (orange bars) and their difference (yellow bars). The number in parentheses below the difference is the *p*-value from the null hypothesis that the true difference is zero, representing the probability that one would observe such a large value by coincidence when the true difference is zero.

The first three bars cover the changes in the percent of villages that have an irrigation scheme, where farmers collectively attempt to irrigate village farmland. Non-electrified villages saw 15.3 percent more irrigation schemes, while electrified villages saw 25.6 percent more. Electrified villages were therefore 10.3 percent more likely to have an irrigation scheme, a difference which is marginally statistically significant. The next three bars the number of farmers participating in irrigation schemes (divided by ten, for expositional purposes). Electrified villages saw 210 more farmers participating, compared to just 25 for non-electrified villages, for a highly significant difference of 185 more farmers irrigating.

How did the irrigation affect farm productivity and revenues? The third set of bars show the fraction of villages reporting that yields were much better in 2014 than 2012. A remarkable 16.3 percent of electrified villages report having much higher yields, compared to 3.6 percent in non-electrified villages, for a highly significant difference of 12.7 percent. This higher productivity in farming could very well be the result of the increased irrigation, which has a proven

Figure 6: Changes in Agricultural Production



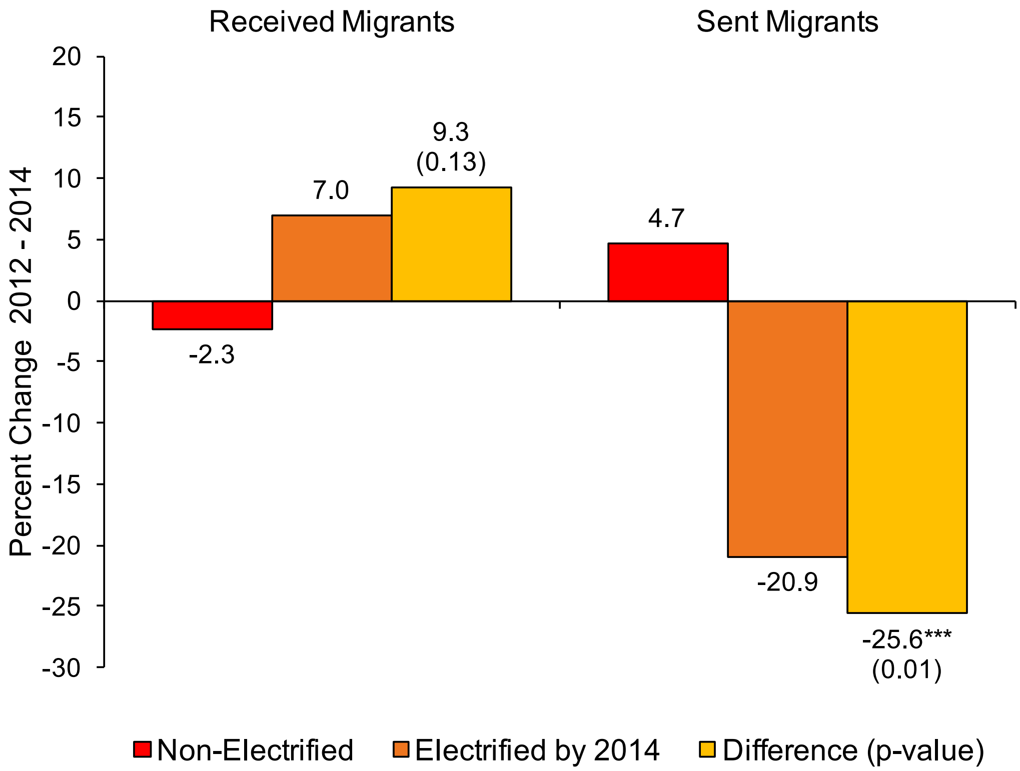
positive effect on yields in Ethiopia, though it is hard to prove this claim definitively.

5.4. Migration Patterns

Figure 7 shows how migration responds to electrification. The first set of bars reports changes in the fraction of villages reporting that they received more migrants than they sent. Non-electrified villages are 2.3 percent less likely to receive migrants, while electrified villages are 7.0 percent more likely, for a difference of 9.3 percent. Though only marginally significant, this points in the direction of electrified villages becoming more likely to be receivers of migrants.

The second set of bars reports changes in the fraction of villages sending more migrants than they receive. Non-electrified villages are 4.7 percent more likely to be net senders of migrants, while electrified villages are a dramatic 20.9 percent less likely to net senders of migrants. The difference is 25.6 percent, and statistically significant at well below the one percent level. In summary, village migration patterns are clearly associated with electrification. Electrified villages are somewhat more likely to receive migrants, and substantially less likely to send them. This points to substantial increases in village productivity or living quality more generally after electrification.

Figure 7: Changes in Migration Patterns



5.5. Other Public Goods

Finally, we look at whether other public goods were introduced simultaneously in villages that became electrified over this period. If so, one may not want to conclude that any of the above effects were the result of electrification itself, but rather multiple new public goods that were introduced. We focus on four public goods that we can measure in the ERSS: distance to schools, whether there is a health clinic in the village, whether the village has tap water, and whether there is a tar road in the village.

Table 5 reports the differences in these public goods rates across the two village types between 2012 and 2014. Schools and health clinics had similar and statistically insignificant changes over this period, as did access to a tar road. Interestingly, villages that became electrified had significantly larger changes in tap water access over the period: non-electrified villages had 3.5 percent increases in access, compared to 14.4 percent increases on average in electrified villages.

One interpretation of this finding is that, as outlined above, village electrification efforts co-

Table 5: Differences in Other Public Goods

	Percentage Point Changes 2012-2014		
	Non-Electrified	Electrified in 2014	Difference
Distance to school	0.3	-1.5	-1.8 (0.20)
Health clinic in village	3.0	-7.0	-10.0 (0.16)
Have tap water	3.5	14.4	10.9** (0.05)
Have tar road	1.7	-4.4	-6.1 (0.37)

Source: Author's Calculations Using Ethiopian Rural Socioeconomic Survey (2012, 2014)

incided with efforts to increase access to tap water. In this case, one should interpret all the results in the previous section as the effects of receiving both electricity and tap water. Another interpretation, which we think makes more sense, is that tap water access itself is the result of electrification. In Ethiopia, it is local governments that are in charge of tap water provision, while electrification is undertaken by the (national) Ethiopian Electric Power company and the Ethiopian Electric Utility. So any increases in tap water would have been independent to any electrification, at the village level. More directly, electrification would allow for electric pumps to pump water from wells, which would make it easier to increase tap water access. While it is hard to prove this order of cause and effect, the political independence of local governments and national power utilities suggests tap water and electricity are independent decisions, and the reverse direction of causality (tap water to electricity) seems fairly implausible.

6. Conclusion

To what extent does rural electrification alter migration patterns and induce structural transformation? We answer this question both theoretically and empirically. We build a model with many regions and an agriculture and non-agriculture sector, building on spatial models of structural change. We test the model's predictions using a panel of rural Ethiopian villages that are not yet electrified in 2012. We then compare villages that got electrified by 2014 to those that remained non-electrified. Three types of evidence suggest a causal interpretation of electrification is plausible. First, direct conversations with the Ethiopian Electric Utility directly responsible for the rural electrification efforts suggest that their main considerations was cost and equity, and not underlying potential for growth. Second, we show that on a set of village and household metrics in 2012, villages that went on to get electrified appear similar to those that did not. Third, a forecast of electrification from observables yields jointly insignificant explanatory power of observables.

As the model predicts, we find that electrifying a village leads to substantial decreases in out-migration, more modest increases in in-migration, a shift from agricultural to non-agricultural activities, and (modest) increases in household durable ownership, in particular televisions. We also find that electrified villages were more likely to provide access to tap water over the same period, and it is most likely that electricity led to the tap water access, rather than the other way around (or the two being coordinated). We conclude that connecting a rural area to the electricity grid leads to transformative effects on village economies. Electrification increases access and sales of non-agricultural business, and raises agricultural productivity by way of increased use of irrigation. Rural residents respond by decreasing out-migration rates of electrified villages and increasing in-migration rates from other regions. Policymakers are aware that the costs of rural electrification are high, particularly in per capita terms. This study provides some evidence showing that the benefits of rural electrification are significant as well.

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