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The Effect of Rural Electrification on Firm Creation - New Evidence from Ghana

Tom Carlowitz*

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Abstract

Billions of dollars are spent each year on electrification infrastructure projects in the hope to benefit the 770 million people who still lack access to electricity. However, the evidence to date on the effects of such projects is mixed. In this paper, I study the effect of rural electrification on firm creation in Ghana by focusing on the effect on female-owned microenterprises. I combine firm census data covering over 638,000 firms (including informal and rural establishments) with electricity access and geo-spatial data. I address the endogeneity of the grid expansion using an instrumental variable approach. The instrument is the distance to a hypothetical grid connecting historical regional capitals, border towns, and main hydropower plants. I find that a 10% increase in district-level electrification leads to the creation of 152 female-owned firms, which corresponds to a 37% increase. I show that this effect is largely driven by two channels: i) a reduction in home production activities by women and ii) a lowering of required startup capital for microenterprises. The findings of this paper are consistent with previous literature, showing large effects of electrification particularly for women.

Keywords: rural electrification, infrastructure, microenterprises, firms, Ghana

JEL Classification: L26, O13, O14, O18, Q41, R11

*Graduate, MSc Economics for Development, University of Oxford. tom.carlowitz@gmail.com. This paper is an adapted version of my master's dissertation. I am grateful to my supervisor Niclas Moneke for his support and advice. I would also like to thank Christopher Woodruff for valuable feedback and Frank Adusah-Poku for his help in getting access to relevant data.

Centre for the Study of African Economies

Department of Economics · University of Oxford · Manor Road Building · Oxford OX1 3UQ

T: +44 (0)1865 271084 · F: +44 (0)1865 281447 · E: csae.enquiries@economics.ox.ac.uk · W: www.csae.ox.ac.uk

1 Introduction

770 million people worldwide still lack access to electricity, most of whom live in Sub-Saharan Africa. Policymakers are convinced that electrification is a key driver of economic development. Electricity could benefit households through safer cooking, allowing children to study at night, or enabling the use of water pumps. Electricity has also the potential of transforming the economy. Modern energy infrastructure is believed to improve industrial development, firm productivity, and aggregate employment (Lee et al., 2020).

Governments and international organizations are investing billions of dollars in electrification projects each year in the hope to harness these benefits. USAID (2020) and other US agencies provided around USD 7 billion financial support for the Power Africa initiative. The African Development Bank (2019) planned to invest around USD 12 billion between 2014-2020 in African power infrastructure. Globally, The World Bank spends around a third of its budget on infrastructure projects, of which electrification accounts for the largest share (Akpandjar & Kitchens, 2017).

Despite these large investments and the policy relevance, we still know little about the causal effects and channels of electrification infrastructure projects. In particular, there is only limited empirical evidence on the impact of such projects in Sub-Saharan Africa. The majority of current and future investments are made in the region, however, the context makes it likely that effects of electrification could differ from those found elsewhere (Peters & Sievert, 2016).

To shed new light on this question, I study the effect of electrification in Ghana. Ghana is one of the few countries in Sub-Saharan Africa that provides an ideal study setting. The country created a long-term National Electrification Program (NEP), which successfully increased access to electricity by expanding the electricity grid. In just 14 years, Ghana improved its rural electricity access rate from just 19.7% in 2000 to 64% in 2014 (Kumi, 2017).

I focus my analysis on the effects on firm creation rather than household outcomes, which previous literature has identified as a more promising outcome of electrification (Kassem, 2018; Rud 2012; Lee et al., 2020). In particular, I study whether electrification leads to the creation of female-owned microenterprises. Previous studies have shown potentially larger effects of electrification for women, driven by the hypothesis that electricity reduces the time women spend on household activities (Lee et al., 2020).

I have collected two main data sources for my analysis, which allow me to build a spatial cross-sectional data set for the year 2014. I use electrification data from the Ghana Ministry of Energy to measure access to electricity. I also use the recently released firm census in Ghana for 2014, which covers 638,234 firms, including small, informal, and rural firms. The availability of such data is rare for a low-income country in Sub-Saharan Africa.[1]

Measuring the causal effect of electrification is econometrically challenging. Large-scale infrastructure projects, such as the expansion of electricity grids, are likely to be placed endogenously. In fact, Ghana's electrification program was primarily targeted towards rural and politically favourable areas, creating a bias in conventional OLS estimation (Briggs, 2021).

To overcome this challenge, I make use of an instrumental variable approach, inspired by recent work in the infrastructure placement literature (Duflo and Pande, 2007; Banerjee, Duflo & Qian, 2020; Kassem, 2018). I construct a new instrument for the context of Ghana's electricity sector by creating a hypothetical electricity grid. The hypothetical grid connects exogenously placed hydro power plants, historical regional capitals and border towns, using Prim's minimum spanning tree algorithm. The instrument is the distance of each district in Ghana to the hypothetical grid. The distance creates exogenous variation in electrification rates, abstracting from demand-side factors. As endogeneity concerns might still be present, I supplement this approach with a rich set of geo-spatial controls and a battery of robustness checks. While I do not observe temporal changes, I am able to explore differences across districts this way.

My results show that electrification has a significant effect on the creation of female-owned microenterprises. A 10% increase in district-level electrification leads to the creation of 152 female-owned microenterprises, based on cross-sectional differences across districts. This corresponds to a 37% increase female-owned microenterprises. This finding is consistent with previous literature, particularly the seminal paper by Dinkelman (2011), who showed that electrification increases female employment and business ownership by "releasing women to the labor market" in South Africa. While previous research in other countries has identified this channel using household survey data, this is to my knowledge the first paper showing this effect with actual microenterprise data. In section 5.3, I discuss potential channels driving my result, using additional data sources. Electrification is reducing the time women spend on home production and lowers required

[1]Previously infrastructure literature had to rely on proxies to measure access to electricity such as distance to substations (e.g., Dinkelman, 2011; Lipscomb, 2013; Kassem, 2018). Most firm census data in SSA only covers formally registered firms.

startup capital for electricity-dependent microenterprises.

This paper contributes to the existing literature in several ways. First, it contributes to a growing literature that studies the effect of large-scale infrastructure such as electricity grids, roads, and railways in low-income countries (Duflo & Pande, 2007; Banerjee, Duflo & Qian, 2012; Lipscomb et al., 2013; Faber, 2014; Donaldson, 2018; Asher & Novosad, 2019; Moneke, 2020).

Second, it adds to a growing strand of literature that looks at the effects of electrification on household outcomes, welfare, and growth. More specifically, this paper provides further insights on the broader economic effects of the buildout of electricity grids, rather than the benefits of decentral 'off-grid' solutions such as solar home kits. The seminal paper within this strand of literature is Dinkelman (2011), who studied the effect of South Africa's mass roll-out of electricity to rural areas. Within a few years, rural electrification significantly raised female employment by 30-35%, but had no significant employment effects for men. Similar results have been demonstrated by Grogan and Sandanand (2013) in Nicaragua. The authors show that electricity provision increased the propensity of rural Nicaraguans to work outside of home, but only for women. Lipscomb et al. (2013) studied the long-term effect of electrification in Brazil, finding a large reduction in poverty and an increase in formal employment. The findings of this literature suggest that the impact of electrification is larger for aggregate outcomes such as employment, firm growth and manufacturing output, rather than micro-level household indicators. In addition, positive outcomes seem to be larger when studying the effect of electrification infrastructure such as grid expansions instead of small-scale decentral energy solutions (Lee at al., 2020). These two findings are supported by the results of this paper.

Third, this paper is related to the strand of literature that looks at the effect of electricity on firm outcomes. While many papers have studied the effect of electricity shortages on firm productivity (Reinikka & Svensson, 1999; Allcott, Collard-Wexler & O'Connell, 2016), this paper provides insights on the relationship between access to electricity and firm creation. Rud (2012) has shown that during 1965–1984 electrification led to an increase in the number of factories and manufacturing output in India. Similarly, Kassem (2018) demonstrated causal evidence on the effect of electrification on the growth of manufacturing firms in Indonesia, using rich spatial and temporal data. Electrification attracts more firms to the market and increases average productivity.

Fourth and finally, this paper adds to a small and recent literature on electrification effects in Ghana, which has mainly focused on household outcomes. Using household survey data, Adu et al. (2018) find that real household expenditure per capita is 63.7% higher for households with access to electricity. Moreover, the authors show that richer households benefit more from having electricity access. Adusah-Poku and Takeuchi (2019) find that expenditure, employment status and gender are robust predictors of household electrification. The only paper I am aware of that studied the effect of access to electricity on firms in Ghana is Akpandjar and Kitchens (2017), who find an increase in firm employment due to electrification. The authors analyse a panel of 82 Ghanaian firms between 1992–2002. In this paper, I use a much larger sample of 638,234 firms in Ghana for the year 2014 and a different empirical approach.

The rest of the paper is organized as follows. Section 2 describes the context of this paper, by providing background information on Ghana's electrification program. Section 3 provides an overview of the data sets used and summary statistics. Section 4 discusses the identification strategy and construction of the instrument. Section 5 and 6 provide the main results of this paper, a discussion of channels and additional robustness checks. Section 7 concludes.

2 Context: Ghana's Electrification Program

Ghana has implemented one of the most successful electrification programs in Sub-Saharan Africa. From 2000 to 2014, overall access to electricity grew from 43.7% to 78.3%. This increase was largely driven by rural electrification, which improved from just 14.9% to 64% during the same period (World Bank, 2020a). With a rural electrification rate of 64% in 2014, Ghana is placed well above the 19.7% average for Sub-Saharan Africa. To date, Ghana is ranked 3rd out of 34 countries in Sub-Saharan Africa in terms of access to electricity by the International Energy Agency (IEA, 2020).

Ghana's success in providing access to electricity was driven by a strong political commitment. In 1970, the country launched the Rural Electrification Project (REP) with the target of connecting rural towns and areas with 1000-5000 inhabitants to the main grid (Bonan, 2017). In 1989, the REP was replaced by the National Electrification Program (NEP), aiming at connecting all rural and urban towns above a population of 500 as well as regional capitals. A crucial component of Ghana's NEP was the Self Help Electrification Project (SHEP), under which communities within a distance of 20 km of the existing medium- and low voltage grid (33kV or 11kV) became eligible for a grid extension (Bonan, 2017). The NEP set the target of achieving universal access to electricity for the population by 2020.

Ghana's electrification strategy was driven by an expansion of the transmission and distribution grid infrastructure, rather than the implementation of decentral solutions, justifying the approach of this paper[2]. Until the end of 2015, only around 10 MW of off-grid solar were installed in the country, which is less than 1% of the country's total capacity (Energy Commission, 2019a). The buildout and expansion of the electricity grid was an expensive undertaking. Aglina et al. (2016) estimate that the costs of connecting one household to the grid under the NEP were around USD 2000.

Ghana's electricity supply is primarily based on hydro and thermal power. Ghana's hydro power generation comprises 3 plants with a combined generation of 6,017 GWh and 11 thermal power plants with a generation of 9,803 GWh (Ghana Energy Commission, 2019b). Almost a third of the country's electricity supply (4,273 GWh) comes from the Akosombo Dam located at Lake Volta, the largest artificial lake in the world. Historically, the Akosombo Dam accounted for 70% of national demand. Construction for the dam already began in 1961, crucially shaping the country's electricity supply and grid infrastructure. The second largest hydro power plant in the country is the Bui dam, with an annual generation of around 1,000 GWh. The relative importance and size of the two main dams motivates the construction of my instrument (see section 4).

3 Data

3.1 Data Sources

I construct a cross-sectional data set on electrification and firms in Ghana for the year 2014, supplemented by various controls. As I do not have information on the specific location of firms, all data sources are aggregated to the district level (216 districts).

To derive a measure for electrification, I use data on the electrification of communities in Ghana in 2014 from the Ministry of Energy (Energy Commission, 2021). The data set provides an overview of all communities including their location and population, and indicates whether or not they are connected to the electricity grid. Population estimates of the data are consistent with regional and national population statistics. I use this information to construct an aggregate measure of the district-level electrification rate.

[2]Decentral solutions include for example solar home systems or mini-grids, which have became popular in other parts of Sub-Saharan Africa in recent years

The rate is the share of the population in each district that has access to grid electricity. For instance, a district that consists of 2 communities with a population of 5,000 and 10,000, and where only the larger community has access to electricity, would have a district-level electrification rate of 66.7%. It is crucial to note that this rate measures the share of population that has *access* to electricity and not the share that actually uses electricity. This way, the measure refers to the potentially more relevant policy question of the effects of electricity access.

The data on firms is based on the 2014 national firm census, the "Integrated Business Establishment Survey (IBES)". The firm census covers 638,234 firms and is unique for a low-and middle income country in Sub-Saharan Africa. It covers all non-household establishments, including small, rural, and informal enterprises, across all sectors of the economy. The basic counting procedure for the census was whether or not an establishment has a signpost/ signboard for the business and a fixed location (GSS, 2014). In addition, the store space needed to be not used primarily as residence by households. The census provides information on the form of organization, sector, subsector, sex of ownership, number and sex of persons engaged, skill level of employees and year of commencement. The sector with the largest relative share of female-owned microenterprises is the hospitality sector. I calculate the share of firms active in this sector to control for sectoral differences across districts.

I supplement these two main data sources by including and merging various data sources used for the construction of the instrument and controls. I have digitized information from the oldest available annual report of the Volta River Authority, the former transmission grid operator in Ghana (VRA, 1969; Appendix Figure 4). I use this information to obtain the name and location of historical regional capitals considered for the planning of the electricity grid. I also use information from the World Bank (2020b) to get the coordinates of the main hydropower plants in Ghana. The coordinates of regional capitals and hydropower plants are used to construct the instrument - a hypothetical electricity grid (see section 4.2.). In addition, I create a measure for the urbanization share of each district as a control variable, based on the population census in 2010. The urbanization share is calculated as the share of the number of households within a district that are classified as urban, divided by the total number of households in a district. I also use the same census data set to get the population of each district, which is used as a further control variable. Lastly, I collected data on the main road network in Ghana from the World Food Program. I calculate the average euclidean distance of each district to the main road network using GIS software. This measure of distance to the nearest main road serves as an additional control variable (see section 4.2.). I also calculate the shortest distance of each district to the two largest cities of Ghana, Accra and Kumasi, and to the coast.

3.2 Descriptive Statistics

Table 1 provides an overview of the summary statistics of all main variables. Figure 1 shows the statistical distribution of district-level electrification rates and the size of firms. Figure 2 shows the spatial distribution of electrification rates.

Table 1: Summary Statistics of Main Variables

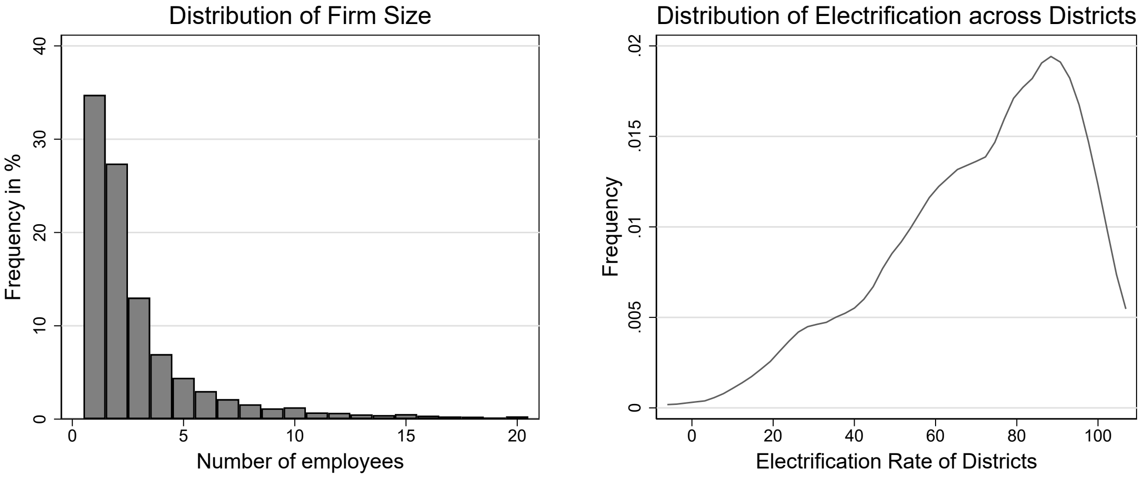
		mean	sd	min	max
Dependent Variables	Number of Firms	2120	1666	318	9920
	Number of Female-owned Firms	990	956	88	5308
	Electrification Rate in %	71	22	1	100
	Distance to hypothetical grid in km	52	50	1	214
Controls	Population ÷ 1000	102	50	12	297
	Area in km^2	1131	1223	19	8351
	Distance to Road in km	16	18	0	117
	Urbanization Share in %	33	24	0	100
	Share Hosp. Sector in %	10	3	2	23
	N	207			

Note: Summary statistics for each district in Ghana (n=207), the level of analysis. Distances are Euclidean distances.

Electrification

Despite Ghana's rapid increase in rural electrification, there are large spatial differences in electrification rates across districts. The district-level electrification rate ranges from 1% in Mamprugu Moagduri to 100% in several districts in the Greater Accra (capital) region. Spatial variation exists both across the 10 regions in Ghana and within regions. The average electrification rate is around 45% in the Upper East region and 88% in the Greater Accra region. Within the Northern region, the electrification rate ranges from 1% to 99% across districts. Even within the more developed Greater Accra region, rates vary from 57% to 100%. My empirical strategy builds on this large spatial variation of

Figure 1: Distribution of Firm Size and Electrification Rates



Note: The left figure shows the relative distribution of the firm size of the 638,234 firms in the sample, measured by number of employees. The right figure shows the kernel density (epanechnikov) of electrification rates across districts (n=207).

electrification rates. Figure 1 shows the kernel density distribution of electrification rates across districts. The distribution is centered at around 82%, reflecting the common ”last mile” problem of electricity grid expansions.

Firms

The distribution of firm size measured by the number of employees is highly left-skewed and representative for a low-income country. Around a third of all firms are own-account firms employing no additional workers. Around 84% of firms have five or less employees. Following the definition of the Ghana Statistical Service, 509,033 firms are micro-sized establishments (1-5 workers), 117,329 are small-sized (6-30 workers), 9,333 are medium-sized (31-100 workers), and 2,539 firms are large with more than 100 workers. This empirical observation is consistent with previous research on firm size distributions in low-income countries that find not only a “missing middle” of firms, but also a lack of large firms (Hsieh & Olken, 2014). The sectoral distribution of firms reflects Ghana’s strong service and relatively weak industrial sector in 2014.[3] Around 0.4% of firms (2,831) are classified as being active in agriculture, 17% (108,242) in industry, and 82.6% (527,161) in the service sector. Within the industry sector, more than 90% are manufacturing firms, whereas a majority of firms in the service sector are active in the subsectors ‘wholesale & retail trade’ and ‘accommodation & food’. Around 84% of all firms are informal establishments and not registered with public authorities.

[3]Ghana’s industrial sector has grown significantly in the years after 2014

4 Identification

4.1 Identification Challenges

Estimating the causal effects of infrastructure placements is inherently challenging. In an ideal experiment, the buildout of the electricity grid would be implemented randomly, leading to random electrification rates across districts. However, in practice it is almost never feasible for policymakers to randomly build or expand infrastructure due to the high costs involved. For instance, the ongoing construction of the Aboadze - Prestea transmission line in Ghana costs around USD 27 million, or USD 167,000 per km (GRIDCo, 2018). In reality, the electricity grid is therefore often built endogenously towards targeted areas, requiring a careful analysis. If the grid connections would be targeted towards high growth areas, conventional OLS estimates would likely be upward biased. If connections would primarily target poor rural areas, OLS results would be downward biased. The direction of the bias is difficult to tell ex ante and ex post without further analysis. In the specific case of Ghana, electrification was driven by equity considerations and targeting the rural population. However, projects were also targeted towards growth areas and regions with critical voters (Briggs, 2021). The targeting of both high-growth (upward bias) and low-growth areas (downward bias) was confirmed to me in a phone conversation with an engineer from the Ghana Grid Company. The company typically conducts demand forecasting for a 10-15 years period, building the grid towards growing areas to ensure financial returns. At the same time, selected grid projects are donor funded with the primary aim to extend the grid to rural areas. Without the donor funding, financial returns would be to small to justify the investment.

4.2 Instrumental Variable Approach

To overcome the challenge of endogenous infrastructure placement, I make use of an instrumental variable approach. I study the effect of district level electrification rates E on a number of firm outcomes Y in district d for the year $t = 2014$, where X is a set of district level controls. Y comprises the number of firms per district and the number of female-owned firms. X includes the population, area, urbanization share, distance to the nearest road of each district, and share of firms in the hospitality sector.

$$Y_{dt} = \alpha_0 + \alpha_0 \widehat{E}_{dt} + \beta X_{dt} + \mu_{dt} \tag{1}$$

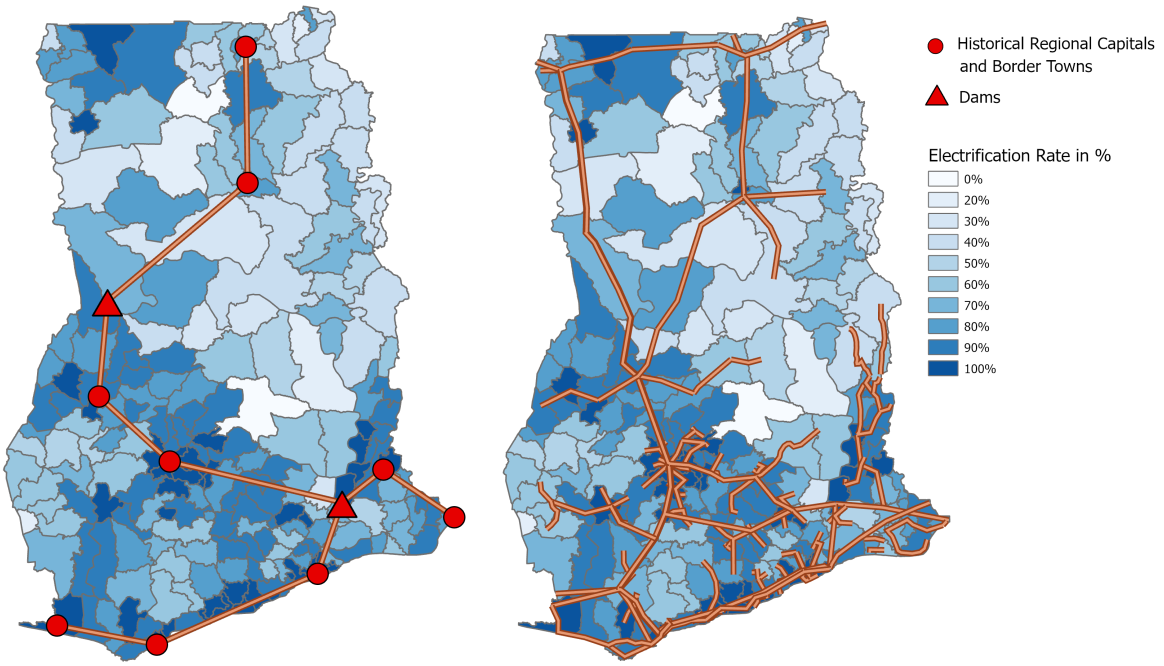
I instrument the district-level electrification rate E using the distance of each district Z to a hypothetical electricity grid.

$$E_{dt} = \pi_0 + \pi_1 Z_{dt} + \pi_2 X_{dt} + \varepsilon_{dt} \tag{2}$$

The underlying intuition of the IV approach is that the instrument (distance) allows to isolate the plausibly exogenous variation of the electrification rates, driven by exogenous cost considerations. I create the instrument in the following way.

I construct a hypothetical electricity transmission grid connecting historical regional capitals, border towns, and the two main hydro power plants in Ghana, using GIS software and Prim's minimum spanning tree network algorithm. Prim's minimum spanning tree is simply a set of edges (lines) that connects all vertices (capitals, border towns etc.), while minimizing the weight (distance) between the edges. Figure 2 shows the hypothetical electricity grid in comparison to the actual transmission grid. The figure also shows the electrification rate of all districts in Ghana. A visual inspection shows that, as expected, districts closer to the hypothetical (or actual) grid tend to have higher electrification rates. The instrument Z is the average distance of each district to the hypothetical grid. I calculate the average distance by taking the mean distance of the 5 largest cities of each district to the grid.

Figure 2: Map of Ghana showing constructed hypothetical electricity grid versus actual transmission grid



(a) Hypothetical Electricity Grid (IV) (b) Actual Electricity Transmission Grid (For comparison)

Note: The distance of each district to the hypothetical electricity grid is the instrumental variable. The hypothetical electricity grid is constructed by connecting historical regional capitals, border towns and the main hydro power plants (dams). The shading of districts reflects the electrification rate of each district. The actual electricity grid is shown for comparison purposes only and not used for empirical analysis.

The hypothetical electricity grid abstracts from endogenous grid buildout factors that would have influenced the buildout of the grid (e.g., building a grid line through or to a favorable district). When constructing the hypothetical grid, I make use of the individual historical context of Ghana's power sector. Historically, most of Ghana's electricity supply comes from hydro power plants. The Akosombo Dam, Ghana's largest hydro power plant, accounted for around 70% of the country's electricity demand. When the construction for the transmission grid began in 1960, the primary goal was to supply the power of the Akosombo Dam (and later the Bui Dam) throughout the country and neighboring countries such as Togo and Benin (Kumi, 2017). Figure 4 of the appendix shows the original grid planning map, retrieved from a historical 1969 annual report of the Volta River Authority (former transmission grid operator). The map shows the location of the 7 historical regional capitals, as well as the two hydro power plants Akosombo Dam and Bui Dam, which I use for the construction of the hypothetical grid.

In contrast to other power plants (such as coal power plants), hydro power plant construction is mainly driven by global geography, rather than endogenous demand factors. From an engineering perspective, a suitable site for a hydropower plant (hydroelectric dam) strictly requires a steep river gradient and a strong river flow, to utilize the potential energy of water (Gulliver and Arndt, 1991). This geographic characteristic make hydropower plants useful for instrumental variable approaches (see for instance Duflo and Pande (2007) who use the geographic placement of dams as an IV to study agricultural production in India). The construction of the Akosombo Dam was mainly driven by the suitable geography of the Volta River (African Affairs, 1956).[4]

The mechanism of the instrument (distance of a district to the hypothetical grid) can therefore be illustrated in the following way. Imagine a straight transmission line between the Akosomba Dam and a regional capital. Now let's say two similar districts A and B are placed along this line. Simply by being located closer to this straight line, district A would have a higher probability of getting access to electricity than district B, because it would be easier and cheaper to connect district A. Similarly, if a district by chance happens to lie exactly on the straight line connecting dams and regional capitals, it would almost randomly receive access to electricity.

While this approach allows me to create plausibly exogenous variation in electrification rates, it is limited to observations at one point in time. Hence, I relate my results on firm creation to the (plausibly exogenous) cross-sectional differences in outcomes across districts, rather then making a fully valid causal argument that electrification actually 'created' firms.[5]

Threats to identification

Instrument validity requires the satisfaction of the exogeneity assumption. This means that the instrument (distance to hypothetical grid) only affects the outcome variable (e.g., number of firms) through the electrification rate of each district. One concern that comes to mind is that for some districts that are located around historical regional capitals, being close to the hypothetical grid also implies being close to the regional capital and potential hubs of economic activity. This would affect firm outcomes through a different channel (distance to city or market access) and violate the exogeneity assumption. However, I consider this to be only a minor threat to identification. Some of the regional historical

[4]It was also driven by a close proximity to nearby bauxite reserves used for the production of aluminium, which would be an additional geographic factor

[5]A valid causal argument would need additional time-dimensional and firm data

capitals used for the instrument are fairly small cities today (e.g., the northern regional capital Bolgatanga, the most northern node in the map, is only the 27th largest town today). For the historical capitals that are indeed large today, I provide additional controls and robustness checks. I remove all metropolitan district capitals from my sample (9 districts). In addition, I control for the urbanization share of each district in the first and second stage. I also show that my results are robust to removing all urban districts ($n = 48$) from the sample as well as removing all districts of historical regional capitals, dams, and border towns (nodes in map). In section 6, I provide a further robustness check by controlling for the shortest distance of each district to Accra and Kumasi, the by far largest cities of the country.

Another potential concern is that other important infrastructure such as roads are correlated and located along similar routes as the hypothetical grid. I therefore control for the distance to the main road of each district. Furthermore, districts could differ in important ways other than the distance to the grid. The three most important observable characteristics that may affect district-level firm outcomes are area, population, and level of urbanization (see for instance Lipscomb et al., 2013; Kassem, 2018). These characteristics are of particular relevance for Ghana, as values vary widely across districts (see table 1). I control for all of these three characteristics.

A few concerns and threats to identification remain. Increase of the electrification rate in one district could lead to the in-migration of people and firms. While I am unable to rule out that this might affect my results, in-migration is potentially less of a concern as districts in my sample are relatively large units (mean = 1,139 km^2). In addition, I show that my results are fully robust to focusing on rural districts only, and in-migration to rural areas can generally be expected to be rather low. Another remaining concern is that districts differ in other (unobservable) ways than what I am controlling for. For instance, districts could differ in their political connections to the main party or access to capital and credit, which might affect firm outcomes. However, I expect these factors to be only of minor importance for my empirical setting.

5 Results

5.1 First Stage Results

Table 2 shows the first stage regression results using OLS (column 1) and OLS with controls (column 2).

Table 2: First Stage Regression Results

Dependent variable: Electrification Rate	(1)	(2)
Distance to hypothetical grid	-0.194***	-0.094***
	(0.031)	(0.029)
Population		0.055**
		(0.024)
Area		-0.004***
		(0.001)
Log(Distance to Road)		-1.125
		(0.849)
Urbanization Share		0.296***
		(0.064)
Share Hosp. Sector		0.780*
		(0.429)
Constant	80.796***	59.039***
	(1.867)	(7.046)
Observations	207	207
R2	0.188	0.414
F-Statistic	38.8	21.3
F-Statistic Instrument	38.8	10.7

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: First stage regression where the electrification rate of each district is instrumented by the distance to the hypothetical electricity grid. Standard errors are clustered at the district level.

Results show a strong negative correlation between the distance to the hypothetical electricity grid and the electrification rate of each district. The further away a district is located from the grid, the lower its electrification rate. A district that is 10 km further away from the hypothetical grid, has a roughly 1% lower electrification rate. The instrument is sufficiently correlated with the outcome variable ($\rho = -0.43$) and the results of test statistics ensure instrument relevance. The first stage F-statistic on excluded instruments is above 10 as recommended by Stock et al. (2002). A further weak identification test shows that the Cragg-Donald F-statistic (12.226) exceeds the Stock and Yogo (2005) critical value of a 15% maximum bias of the instrument (8.96 for one endogenous variable and one IV). I can therefore reject the null hypothesis that the bias of the IV is larger than 15% of the bias of conventional OLS, caused by the endogenous placement of infrastructure. Standard errors are clustered at the district level.

5.2 Second Stage Results

Table 3 shows the main results of this paper.

Table 3: Effect of Electrification on Total Number of Firms and Female-owned Firms

	Number of Firms		Number of Female-owned Firms			
	OLS	IV	OLS		IV	
	(1)	(2)	(3)	(4)	(5)	(6)
Electrification Rate	6.521**	8.827	22.282***	4.089**	38.940***	15.209**
	(3.229)	(11.509)	(2.558)	(1.809)	(6.412)	(6.594)
Population	10.806***	10.656***		5.498***		4.775***
	(2.363)	(2.467)		(1.229)		(1.407)
Area	-0.099	-0.088		-0.085**		-0.033
	(0.063)	(0.084)		(0.034)		(0.049)
Log(Distance to Road)	-145.038***	-141.919***		-70.656**		-55.613*
	(51.407)	(51.693)		(27.824)		(29.222)
Urbanization Share	31.254***	30.454***		19.689***		15.832***
	(5.181)	(6.402)		(3.291)		(3.996)
Share Hosp. Sector	-25.016	-26.926		1.553		-7.656
	(18.618)	(20.708)		(10.394)		(12.870)
Constant	182.248	61.787	-585.072***	-288.836	-1762.654***	-869.700**
	(368.112)	(677.386)	(147.544)	(206.231)	(444.371)	(378.803)
Observations	207	207	207	207	207	207
R2	0.636	0.636	0.267	0.651	0.118	0.610
F-Statistic	32.1	25.9	75.9	32.8	36.9	26.6
Mean Dependent Variable	2120	2120	990	990	990	990

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: Main results of OLS and IV regressions. Column (6) is the main specification of this paper. All control variables are shown in table. Standard errors are clustered at the district level.

Columns 3 – 6 show OLS and IV results on the effect of district-level electrification on the number of female-owned firms. For comparison purposes, I show the effect on the number of total firms in column 1 and 2. I also report results for male-owned enterprises in Table 8 of the appendix. My main specification is column 6. I find that a 10% increase in the electrification rate leads to the creation of 152 female-owned firms, based on cross-sectional differences across districts. The result is significant at the 5% level. The IV estimates are significantly larger than OLS estimates but robust standard errors are larger for the IV specification. The relative size of the IV estimates compared to OLS indicate that conventional OLS results would be downward biased. This result is in line with previous findings in the electrification infrastructure literature (Rud, 2012; Lipscomb and Mobarak; 2013) and shows that electrification in Ghana was presumably targeted towards rural and potentially less developed areas (see section 2). The effect on the total number of firms (column 2) is positive but not statistically significant, presumably due to less statistical power.

In table 4, I show results for alternative specifications of the effect of electrification on female-owned firms. Column 1 shows my main specification for comparison. Column 2 shows the effect on female-owned microenterprises only (firms with 5 or less employees), which account for around 84% of the sample. Results for that specification are almost equal. Column 3 shows results on a logarithmic scale. A 10% increase in electrification corresponds to a 37% increase in female-owned firms. In column 4 I show results for additionally removing all border towns, historical regional capitals and dam districts from the sample. The effect size decreases only slightly. Lastly, column 5 shows the main effect for rural districts only ($n = 155$), which significantly increases the effect size. All specifications include the main controls listed in table 3. I provide further robustness checks in section 6.

Table 4: Effect of Electrification on Female-owned Firms: Alternative Specifications (IV)

	(1)	(2)	(3)	(4)	(5)
Electrification Rate	15.209**	15.255**	0.037***	14.735**	23.277***
	(6.594)	(6.284)	(0.014)	(7.057)	(8.334)
Observations	207	207	207	199	155
R2	0.610	0.604	0.395	0.581	0.023
Main Controls	yes	yes	yes	yes	yes

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: Alternative specifications to main result of this paper (column 1). Alternative specifications look at, for instance, microenterprises and rural districts only. Standard errors are clustered at district level.

My main hypothesis is that the results are primarily driven by two underlying mechanisms: electrification i) reduces the time women spend on home production activities, enabling the start of microenterprises and ii) lowers the startup capital required for certain types of microenterprises typically operated by women. In the next section, I provide further evidence on the presence of these mechanisms in my empirical setting.

5.3 Discussion of Channels

Releasing women to the labor market

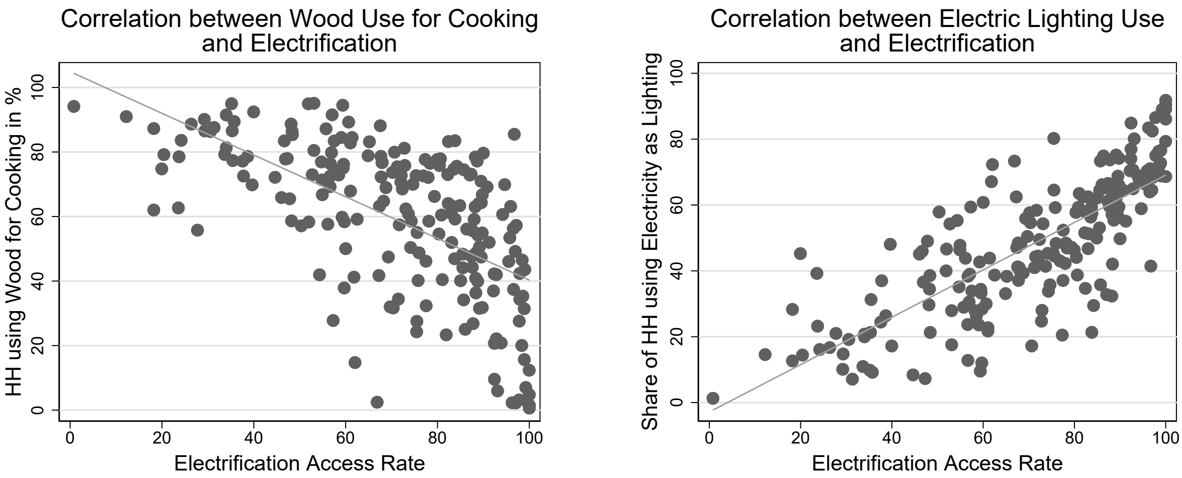
Having shown that electrification leads to the creation of female-owned microenterprises, I now turn to the analysis of potential underlying channels and mechanisms. I first look at the effect of electrification on women's labour supply, which previous literature has identified as one main effect of electrification (see Dinkelman, 2011 for South Africa, Grogan & Sadanand, 2013 for Nicaragua; Chowdhury, 2010 for Bangladesh). Electrification is freeing the time women spend on home production, creating opportunities to supply labor to the market or start microenterprises.

In the following, I test how likely this mechanism is driving my results in the individual context of Ghana. I supplement my main analysis by using additional variables from the 2010 Population Census and add data from the 2009 time use survey in Ghana (GSS, 2011). The population census covers around 2.5 million individuals (10% of population), the time use survey covers a smaller sample of 4,800 randomly selected households. While both surveys were conducted a few years before my endline results in 2014, they still provide useful information on home production and time use by women, which likely have not changed significantly in a few years.

I first consider the effect of electrification on the use of wood for cooking and the use of electric lighting across districts. Table 5 shows OLS and IV estimates on these two outcomes using my main district-level specification. Each value in the table shows the effect of electrification on the respective outcome variable. Figure 3 additionally illustrates the corresponding correlation. A 10% increase in the district-level electrification access rate, corresponds to an around 8.6% reduction in the use of wood for cooking by households and a 8.8% increase in the use of electric lighting.[6]

[6] The increased usage of electric lighting is not necessarily obvious. As I measure the effect of access to electricity, not all households might choose to use it and continue using other sources of lighting.

Figure 3: Correlation between Electrification and selected Home Production Indicators



Note: Figure shows simple OLS correlation between the electrification rate and home production indicators across districts (n=207). Each dot represents one district. The use of wood for cooking and electric lighting is the % share of households in each district that use the respective technologies.

Table 5: The Effect of Electrification on Wood Use for Cooking and Electric Lighting

	OLS		IV	
	no controls	controls	no controls	controls
	(1)	(2)	(3)	(4)
Use of Wood for Cooking	-0.646***	-0.185***	-1.214***	-0.863***
	(0.057)	(0.046)	(0.164)	(0.253)
Use of Electric Lighting	0.720***	0.484***	1.030***	0.881***
	(0.039)	(0.041)	(0.130)	(0.246)
N	207	207	207	207

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: Each cell in the table shows a separate regression outcome, where the district-level electrification rate is regressed on either wood use for cooking or the use of electric lighting. Controls include all controls of main specification. Standard errors are clustered at the district level.

These changes in home production and amenities have potentially large implications for the time use of women in Ghana. The Ghana Time Use Survey (GSS, 2009) measures how men and women spend their time within a 24 hour period. Females spend on average 98 minutes of their day on food preparation (versus 27 minutes for men). As moving away from cooking with wood to cooking with electricity or kerosine significantly reduces cooking time, electrification could have a large impact on women's time use. In addition, a reduction in wood use also implies that less time is needed for fuel collection, which accounts for around 25 minutes a day for Ghanaian women (GSS, 2009). An increasing use of electric lighting could have similar time-saving effects. Electric lighting, compared to candles or kerosine lamps, makes it easier for women to extend their effective day time and allows to move certain household activities to later hours (Grogan Sadanand, 2013).

Lastly, electrification could free-up time for women through the use of electric appliances such as washing machines, refrigerators, or electric cleaning appliances. Females in Ghana spend around 49 minutes each day on cleaning and textile care (in addition to 98 minutes spent cooking) (GSS, 2009). Ideally, I would be able to show that electrification leads to an uptake of electric appliances. As I do not have representative district-level data, I rely on descriptive analysis. Around 209 out of 2,503 surveyed rural households own a fridge, but only 5 out of 2,503 own a washing machine. These findings suggest that electrification is likely to have the largest effect on women time use through a reduction of cooking time.

Reducing required Startup Capital for Microenterprises

Apart from reducing home production time, I speculate about a second channel that is likely driving my results and which is less frequently discussed in other studies.[7] For rural households, grid electricity is often significantly cheaper than self-generated electricity from diesel generators. Grid electricity also requires no upfront costs like for instance the generator itself. As many individuals in LIC are credit constraint (Banerjee Duflo, 2014), electrification could lower barriers to start electricity-dependent microenterprises, which are often operated by women.

Ideally, I would be able to show which types of female-owned microenterprises are most affected by electrification in my empirical setting. Due to the limited granularity of the firm census data, I only observe broader firm categories such as "other services" or "wholesale and retail". Nevertheless, general evidence from LIC suggests that a large number of typically female-owned businesses benefit or require electricity. For instance, hair salons, dressmaking, small craft-works, guesthouses, shops with refrigerated products, or small restaurants.

A simple back-of-the-envelope-calculation shows that grid electricity could make a large difference for such businesses. Without grid electricity and in the absence of credit and rental markets, prospective business owner would need to buy their own diesel gen-

[7]One study discussing this channel is Akpan et al. (2013) using a small survey in Nigeria. I am not aware of any study focusing on infrastructure placements.

erator. The costs of a generator in Ghana are around USD 400/ kW (Reber et al., 2018), hence around USD 2000 for a small 5kW generator. This would be roughly 14x the average monthly living wage in Ghana. A diesel generator typically requires around 0.10 gallon/ kWh and the average diesel price in Ghana was 3.14 USD/ gallon in 2019 (Bank of Ghana, 2019). Running costs of a diesel generator are therefore approximately 31.5 US cents / kWh. In contrast, grid electricity requires no upfront investment in most cases and costs only 14.5 US cent/ kWh (Energy Commission of Ghana, 2017). This way, grid electricity could not only reduce required startup capital, it also affects the long-term profitability of microenterprises. With the availability of grid electricity, female entrepreneurs might be more likely to start their own business.

6 Robustness

Additional Controls

One threat to my identification strategy is the possibility that the distance between a district and the hypothetical electricity is correlated with other relevant determinants of firm outcomes. A closer look on the spatial distribution of the electricity grid (see figure 2) makes it clear that there is a higher grid density around (1) the metropolitan region of Accra and Kumasi, the by far largest cities in the country, and (2) the coastal area. The distance of a district to (1) or (2) could have a large effects on firm outcomes (e.g., through better market access). Hence, an additional robustness check is useful. In Table 6, I use my main empirical specification, and additionally control for the distance of each district to the coast, and the shortest distance to either Accra or Kumasi. Both OLS and IV estimates become less precise, but the effect size remains fairly robust (14.785 versus 15.209).

Table 6: Additional Control Variables

	OLS		IV	
Number of Female-owned Firms	(1)	(2)	(3)	(4)
Electrification Rate	22.282***	2.325	38.940***	14.785
	(2.558)	(1.864)	(6.412)	(19.048)
Distance to Coast		-0.116		-0.288
		(0.410)		(0.470)
Distance to Accra and Kumasi		-0.560		0.332
		(0.566)		(1.517)
Observations	207	207	207	207
R2	0.267	0.658	0.118	0.613
Main Controls	no	yes	no	yes

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: Table shows main empirical specification (Table 3, column 6) with additional control variables to validate robustness. Columns (2) and (4) include all main controls. Standard errors are clustered at the district level.

Alternative Grid

To provide further robustness of my results I construct an alternative instrument. One potential alternative instrument could be the gradient/ slope of district, as it is generally more costly to build transmission lines in steeper regions (Lee et al., 2020). However, the individual geographic characteristics of Ghana make such an instrument unlikely to work. There exists only little variation in elevation across the country. In addition, a significant part of the country is covered by Lake Volta, which implies a low gradient but still high costs to build a (submarine) transmission line.

Instead, I construct an alternative instrument which is not a hypothetical electricity grid, but the historical electricity grid in Ghana. While such an instrument is potentially more endogenous than a hypothetical grid, it follows a similar logic as the main instrument. I have digitized the 1990 historical grid map of Ghana using geospatial software and reconstructed the historical grid (VRA, 1990). Table 6 presents the results using this alternative grid and my main empirical specification. My results are robust to this alternative instrument. The effect size slightly increases to 16.378 but results are also less precise, likely driven by a loss in statistical power.

Table 7: Alternative Instrument Identification

	OLS		IV	
Number of Female-owned Firms	(1)	(2)	(3)	(4)
Electrification Rate	22.282***	4.089**	42.061***	16.378*
	(2.558)	(1.809)	(7.252)	(9.083)
Observations	207	207	207	207
R2	0.267	0.651	0.057	0.600
F-Statistic	75.9	32.8	33.6	26.4
controls	no	yes	no	yes

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: Table shows the effect of electrification on female-owned firms using an alternative instrument. The alternative instrument is the distance of each district to the historical 1990 grid in Ghana. Standard errors are clustered at the district level.

7 Conclusion

In this paper, I study the effect of large-scale electrification on firm creation in Ghana. I combine two unique data sets on district-level electrification access and firm outcomes covering over 638,000 firms, including informal and rural establishments. To control for the endogeneity of the electricity grid placement, I use the distance to a constructed hypothetical grid as an instrument.

I show that electrification has a significant effect on female-owned microenterprises. A 10% increase in district electrification corresponds to the creation of 152 female-owned microenterprises. Using additional data from the population census and time use surveys, I show that this effect can be mainly explained by a time reduction in home production activities of women. This result is consistent with previous findings in other countries (e.g., Dinkelman, 2011; Grogan and Sadanand, 2013). While prior research studying the effect of large-scale electrification infrastructure on female microenterprises relied on employment data, this is the first paper identifying this channel using actual microenterprise data on the country-level.

More in-depth research and further robustness checks are needed to derive definite policy recommendations from these results. Nevertheless, the findings allow to speculate about some potential implications for electrification projects in low-income countries. First, the results of this paper provide further evidence that the impact of an expansion of the electricity grid is potentially large, whereas studies focusing on small-scale micro-level effects often find rather modest effects. Conducting rigorous impact evaluations on infrastructure programs is often more difficult compared to randomized control trials. However, the IV approach presented in this paper provides additional evidence that this can be achieved methodologically. The instrument could also be used to study other outcomes in the context of Ghana. Second, the findings suggest that the effects of electrification could be underestimated. Effect sizes are larger when controlling for the endogeneity of the grid expansion. In addition, access to electricity could affect individuals and households through a variety of channels, which are frequently underestimated.

Considering that billions of dollars are spent each year on electricity projects in LIC, we need a better understanding of these channels and their interaction to guide policymaking.

8 Appendix

Figure 4: Original Electricity Transmission Grid Planning Map of the Volta River Authority (VRA, 1969)

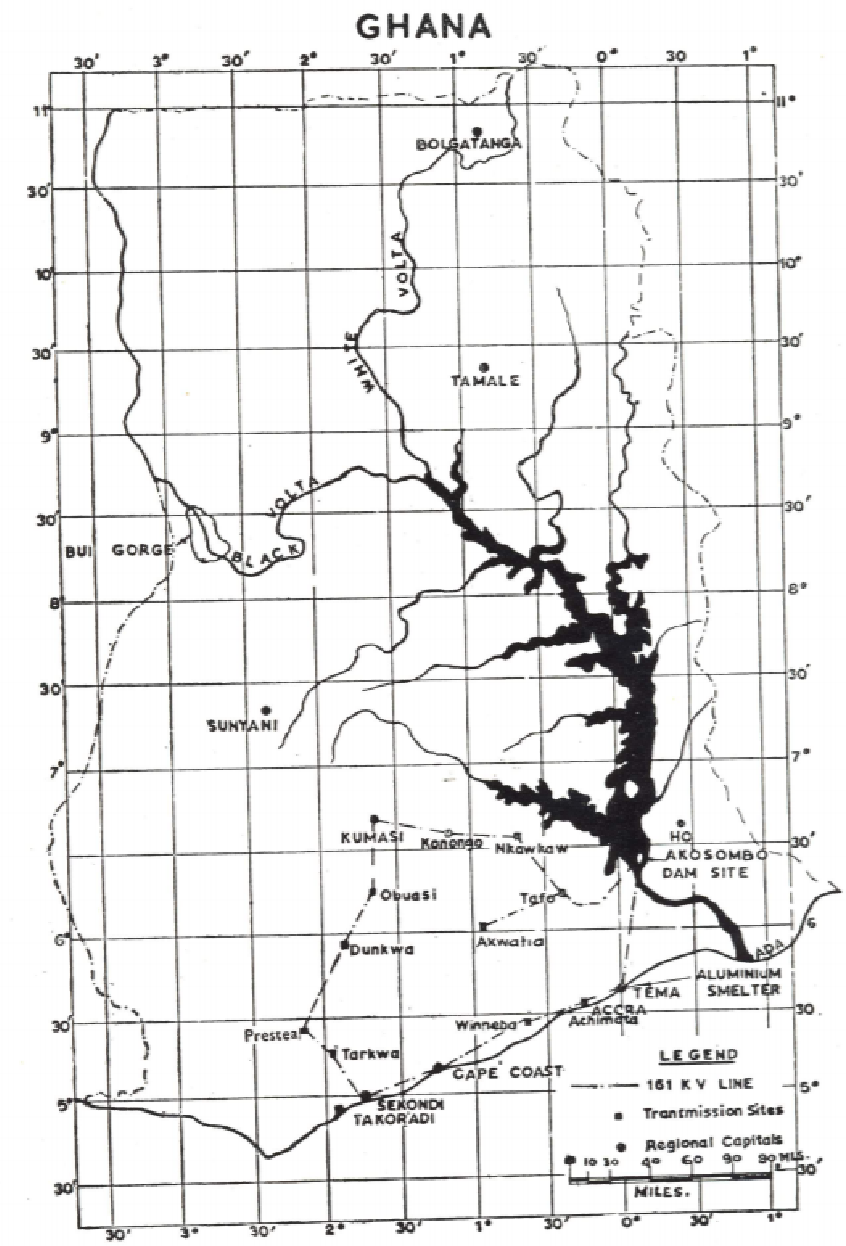


Table 8: Effect of Electrification on Total Number of Female-owned Firms and Male-owned Firms

	Number of Female-owned Firms				Number of Male-owned Firms			
	OLS		IV		OLS		IV	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Electrification Rate	22.282***	4.089**	38.940***	15.209**	15.962***	2.563	22.865***	-4.543
	(2.558)	(1.809)	(6.412)	(6.594)	(2.026)	(1.683)	(5.258)	(7.071)
Population		5.498***		4.775***		5.347***		5.809***
		(1.229)		(1.407)		(1.265)		(1.299)
Area		-0.085**		-0.033		-0.020		-0.053
		(0.034)		(0.049)		(0.032)		(0.047)
Log(Distance to Road)		-70.656**		-55.613*		-81.452***		-91.066***
		(27.824)		(29.222)		(27.242)		(29.460)
Urbanization Share		19.689***		15.832***		13.940***		16.405***
		(3.291)		(3.996)		(2.316)		(3.376)
Share Hosp. Sector		1.553		-7.656		-23.174**		-17.289
		(10.394)		(12.870)		(9.529)		(11.283)
Constant	-585.072***	-288.836	-1762.654***	-869.700**	-19.623	344.179*	-507.576	715.379*
	(147.544)	(206.231)	(444.371)	(378.803)	(118.929)	(182.786)	(359.367)	(421.991)
Observations	207	207	207	207	207	207	207	207
R2	0.267	0.651	0.118	0.610	0.192	0.593	0.156	0.570
F-Statistic	75.9	32.8	36.9	26.6	62.0	26.4	18.9	20.1
Mean Dependent Variable	990	990	990	990	1109	1109	1109	1109

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

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