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Energy Demand and Energy Efficiency and Conservation Practices of Manufacturing Industries in Ethiopia

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Abstract

Studies document that micro and small enterprises are growing rapidly in Ethiopia. The industrial sector consumes a large proportion of electricity in the country. The growing number of micro and small enterprises is also creating pressure on electricity consumption. This may lead to power outages caused by overburdened generation, transmission, and distribution infrastructure. Routine outages also lead to increased costs associated with outage adaptations. Improved energy efficiency has spillover benefits by reducing power outages and this in turn allows more customers to access power and may also improve customer satisfaction and payment rates. In this regard, the purpose of this study is to investigate firms' use of energy efficiency and conservation measures and analyse the impact of these measures on their electricity consumption. We use data from a survey of 1000 micro and small enterprises in Addis Ababa, Ethiopia. Using a translog cost function model and a system of regression equations, we find that electricity and other factors of production such as labor found to be substitutes instead of being complementary. Where wages are low, firms may substitute manual labor for some of electricity-based operations. Further, the econometric results show that firms that use energy efficient method consume less electricity than those use conservation methods. The results have policy implication in terms of promoting energy efficiency and conservation methods.

Keywords: Energy efficient technologies, energy conservation practices, enterprises, Ethiopia

JEL codes: D22; Q40; Q41

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ABSTRACT

Studies document that micro and small enterprises are growing rapidly in Ethiopia. The industrial sector consumes a large proportion of electricity in the country. The growing number of micro and small enterprises is also creating pressure on electricity consumption. This may lead to power outages caused by overburdened generation, transmission, and distribution infrastructure. Routine outages also lead to increased costs associated with outage adaptations. Improved energy efficiency has spillover benefits by reducing power outages and this in turn allows more customers to access power and may also improve customer satisfaction and payment rates. In this regard, the purpose of this study is to investigate firms' use of energy efficiency and conservation measures and analyse the impact of these measures on their electricity consumption. We use data from a survey of 1000 micro and small enterprises in Addis Ababa, Ethiopia. Using a translog cost function model and a system of regression equations, we find that electricity and other factors of production such as labor found to be substitutes instead of being complementary. Where wages are low, firms may substitute manual labor for some of electricity-based operations. Further, the econometric results show that firms that use energy efficient method consume less electricity than those use conservation methods. The results have policy implication in terms of promoting energy efficiency and conservation methods.

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1. Introduction

Ethiopia is one of the few African countries whose governments have formulated and implemented an Industrial Development Strategy (IDS) introduced in the early 2000s (Gebreeyesus, 2016). As a result, the contribution of the industrial sector to the country's economic growth has improved since the early 2000s. The industrial sector grew by more than 10% annually averaged over the same period (EEA, 2015). Like those in many other developing countries, the Ethiopian industrial sector is dominated by micro, small and medium scale enterprises (MSMEs). MSMEs are the second largest employer, after the agricultural sector, providing jobs for around 50% of the urban labor force (Kellow et al., 2010). It is therefore important to study the sector's energy demand, and energy conservation practices, as well as the effect of price changes on these conservation practices and the effect of energy conservation practices on energy consumption in the sector.

In Ethiopia, the industrial sector is the leading consumer of energy, after the residential sector. The industrial sector consumes about 40% of total electricity, which is greater than the residential electricity consumption (33%) (Hassen et al, 2018). This is also the case in many other developing countries (Hillary, 2004; Swan and Ugursal, 2009; Cagno and Trianni, 2013; Never, 2016). The literature shows that MSMEs are generally less energy efficient than large enterprises. As a result, the rapid growth of the sector puts pressure on the energy sector (Mulugetta, 2008; Cagno et al., 2010; Bazilian et al., 2011). Meeting the high demand for energy in the sector is thus a prominent challenge in developing countries (Armaroli and Balzani, 2007; Brew-Hammond, 2010; Bhattacharya et al., 2012).

The use of energy efficient technologies (e.g., machinery and light bulbs) and energy conservation practices enhances the competitiveness of individual firms by minimizing production costs (Cantore et al., 2016; Li and Lin, 2016). Improved energy efficiency also has spillover benefits for the energy sector by reducing power outages caused by overburdened generation, transmission, and distribution infrastructure. This reduces the costs of coping with routine outages (Allcott, Collard-Wexler, and O'Donnell, 2016) while reduced outages allows more consumers to access power (Carranza and Meeks, 2018) and may also improve customer satisfaction and payment rates. Furthermore, energy conservation practices and energy efficient technologies are important in reducing the emission of greenhouse gases (GHGs) (Fleiter et al., 2012; Fetter, 2017). Although our study is set in Ethiopia, it will be relevant to many other settings, since power outages are common in many developing countries, and it is widely expected that the manufacturing sector in these countries (including Ethiopia) will continue to grow.

The purpose of this proposed study is first to document the energy demand of manufacturing industries in Ethiopia by estimating the responsiveness of these industries to energy price changes. The study then aims to estimate the effect of use of energy conservation and energy efficient practices on these industries' energy consumption (demand). One of the mechanisms by which enterprises respond to energy price increases is the adoption of energy efficient technologies. The Ethiopian Electricity Utility (EEU) increased electricity price in December 2018 by more than 100%. This creates an opportunity to analyze the effect of such price changes on the enterprises' propensity to adopt energy efficiency production measures. Information regarding the price-sensitivity of energy demand, and enterprises propensity to adopt energy efficiency measures are important for energy policy measures aimed at price-determination. Also important are the substitution possibilities of different energy sources and between energy and other inputs in the production process. Furthermore, information on what conservation measures work in reducing energy usage is also of prime importance for the Ethiopian Energy Authority (EEA).

There are a growing number of industrial energy demand, energy intensity and efficiency studies in the literature. However, many of these studies are either from developed countries or transitional economies (e.g. Dargay, 1995; Lundgren et al 2016, Zhang et al, 2016; Soni et al, 2017; Chowdhury, 2018). Lundgren et al (2016) and Zhang et al (2016) studied firm level energy demand and energy efficiency in Swedish manufacturing using stochastic frontier analysis (SFA) and data envelopment analysis (DEA), respectively. They found that there is potential to improve energy efficiency in all sectors. Sahu and Narayanan (2009) studied the energy intensity of manufacturing industries in India. They found an inverted U-shaped relationship between energy intensity and firm size. However, these studies did not look at the impact of the enterprises' energy conservation practices on their energy consumption.

In Africa, Kan et al. (2020) studied energy use in the South African manufacturing industry using the energy consumption Index method. They found that the manufacture of basic iron and steel, petroleum products, chemicals, and chemical products account for 80% of aggregate energy consumption and were amongst the least effective in energy use. However, this study does not control for the effect of other factors like firm size, firm manager and worker characteristics, and firm characteristics. Hassen et al. (2018) and Never (2016) studied barriers to enterprises' adoption of energy conservation practices and energy efficiency measures not the effect of these conservation and efficiency measures on energy demand of the manufacturing industry.

Most of the empirical literature is either on the determinants of energy efficiency and intensity, or the use of energy efficient practices. We found few studies on the effect of energy conservation practices on firms' energy demand. Further, many of the efficiency or determinant studies are in the context of developed or transitional economies. To the best of our knowledge, in Africa, there is a dearth of evidence on the energy demand of manufacturing firms and on the effect of use of energy conservation and energy efficient practices on energy consumption (demand). This study aims to fill this gap. The main data source for this study is a two-wave dataset from Addis Ababa, Ethiopia collected by the Environment and Climate Research Center (ECRC) at the Policy Studies Institute (PSI).

We find that energy and other factors of production such as labor are substitutes rather than complementary production methods. Thus where wages are low, firms may use manual labor for some electricity-based operations. The results also show that firms that use energy efficient methods consume less electricity than those that never use these methods. Further, firms that use energy efficient technologies consume about 215kwh less than if those who only use energy conservation methods. Firms that do not use energy efficient technologies, in the counterfactual case, would have consumed 157.08Kwh less energy if they had adopted energy efficient technologies. TThe results have policy implications in terms of promoting efficiency and conservation methods in the manufactoring sector in Ethiopia.

The rest of the paper is organised as follows. Section 2 discusses the data and sampling method.Section 3 presents the empirical strategy of the study. Sections 4 and 5 provide the descriptive and econometric results of the study, respectively, and the Section 6 concludes.

2. Data sources

This study uses the Micro and Small Enterprise Survey conducted by Ethiopian Development Research Institute, a panel dataset comprising two waves of data collection. In wave 1 a baseline survey of micro and small manufacturing enterprises was conducted in December 2016 and May 2017, hereafter referred to as the 2016-2017 survey data. The survey was conducted in 10 largest cities in Ethiopia (Addis Ababa, Adama, Jimma, Bahir Dar, Gondar, Dessie, Dire

Dawa, Jigjiga, Mekelle, and Hawassa), located in seven regional states of Ethiopia. The baseline survey was conducted as part of the 'Entrepreneurship and Small Business Development (ESBD) Research Programme', a project that aimed to generate data and knowledge on small business development in Ethiopia, with a focus on micro and small firms in the manufacturing sector (Gebreeyesus et al., 2018). The energy study was an integral part of that project.

During the baseline survey, data were collected from 8,174 micro and small enterprises located in the 10 sample cities. Since the firms were randomly selected from firms in these cities, the selected sample is representative of micro and small firms in urban Ethiopia. Of the 8,174 firms, 3,310 (40.5%) were considered microenterprises (having five or fewer employees), 4,553 (55.7%) were small enterprises (six to 30 employees), and 311 (3.8%) were medium-size enterprises (31 to 100 employees) (Gebreeyesus et al., 2018). In selecting the original sample, micro and small enterprises were randomly selected from the list of all micro and small enterprises. Medium enterprises were not initially part of the survey. However, some of the firms had been categorized as small in the pre-survey but were found to be medium-sized during data collection.

The follow up survey (second wave) was conducted by the Policy Studies Institute for the project "Energy Audit Randomized Experiment". Due to resource limitations, the follow up survey was repeated only in Addis Ababa and the sample size was reduced to 1,000 of the 4,493 original firms. Following the advice of energy audit experts from the Ethiopian Energy Authority (EEA), the project team decided to focus on firms with relatively high electricity consumption. Firms engaged in metal- and wood-working activities were those with the highest electricity consumption. From the list of these types of firms, 1,000 were randomly selected with probability of selection proportional to firm size. Of these, 787 were micro- and 213 were small enterprises. This is similar to the proportions of the firms in the baseline study in Addis Ababa (in the baseline survey about 73% of the firms were classified as micro- and about 27% were small enterprises).

3. Empirical Strategy

Energy Demand of Manufacturing Industries

Following Dargay (1983), demand for energy sourcesby a manufacturing firm can be derived from the minimization of a translog cost function. We have chosen the translog form because it reduces to fairly simple demand relationships that are relatively easy to work with. The production function assumes that energy is considered as a direct factor of production, like labor and capital. Given the cost function, $C = c(Q, P_E, P_L, P_k, P_M)$ (Where, Q is gross production (output), P_E is price of energy, P_L is labor wage, P_K is price of capital, and P_M is average price of materials,) the translog cost function is specified as:

$$LnC = \alpha_0 + \alpha_q LnQ + \sum \alpha_i LnP_i + \tfrac{1}{2}\gamma_{qq}(LnQ)^2 + \tfrac{1}{2}\sum\sum \gamma_{ij}\, LnP_i LnP_j + \sum\sum \gamma_{qj}\, LnQ\, LnP_i \quad (1)$$

The input demand functions are derived from the cost minimization of the above translog function and using the Shepard's Lemma. Because the cost function is in log form, the factor demand functions are expressed in terms of cost shares. This is because the partial derivatives in the Lema gives, $\partial LnC/\partial \ln P_i = P_i X_i / C = S_i$, where S_i is the share of the ith input in the total cost and X is the quantity of the inputs used. Thus, the demand for energy, as one of the factor of production is given by,

$$S_i = \alpha_i + \sum \gamma_i LnP_i + \gamma_{iq} LnQ + \beta Z_i + \varepsilon_i \quad (2)$$

Where i refers to the different inputs. Z is other company, entrepreneur, and worker related characteristics that can affect demand, and e is the error term. The coefficients g measures own elasticity and cross-price elasticity. This allows us not only to study the price-sensitivity of energy demand, but also to explain this response in terms of the substitution relationships between energy and other production factors. If possibilities for substitution are substantial, higher energy prices could be absorbed with minimal effects on production. On the other hand, if substitution possibilities are limited, adjustment by industry to higher energy prices will be difficult.

Equation 2 is a simultaneous equation of the different factors of production and different sources of energy. Because share equations must sum to unity, the estimated disturbance covariance matrix is singular. The most common method of dealing with this problem is to delete one equation from the system and choose an estimation procedure, which will result in estimates that are invariant to which equation is deleted. In this study, we employ a full information maximum likelihood estimation procedure.

Effect of the energy efficient technologies and conservation practices

The energy efficient technologies we considered in this study are energy efficient machinery (energy star machinery, and retrofitting factories with modern production technologies) and energy efficient light bulbs. Energy conservation practices include turning off lights and machinery when not in use, repairing and replacing industrial air compressors when they leak or malfunction, improving insulation, recovering waste heat, and using cogeneration. Energy consumption is measured in quantity (e.g. kg, liter, or kwh).

Because there is self-selection in the use of energy efficient technologies and conservation practices, estimating the effect using OLS will result in biased estimates. In the absence of an exogenous instrument, quasi-experimental methods such endogenous switching regression methods will minimize bias. In this study, we will use a multinomial endogenous switching regression model. In what follows, we present a description and application of this method in the proposed project.

Enterprises may use none, one, or more energy conservation practices and energy efficient technologies. Hence, we classify enterprises into three regimes: firms that adopt none of the practices and technologies(j=0), firms that adopt a single practice or technology(j=1) and firms that adopt more than one practice and/or technologies(j=3). Following Kassie et al (2015), such categorization of adoption of the practices and technologies into three regimes leads to the use of a multinomial endogenous switching regression model.

In a multinomial endogenous switching regression model, the first step is to specify the multinomial selection model, which is mostly derived from the latent model. In this case, assume that I_{ij}^* is the latent combination of technologies that maximize energy saving (or minimize the energy consumption). Hence, the latent combination of technologies can be modeled as follows;

$$I_{ijt}^* = X_{ijt}\theta_j + \bar{X}_{ij}\alpha + \varepsilon_{jit} \qquad (3)$$

Where i is referring to firms, t is a time variable, j is the combinations of technologies and practices (j=0, 1, 2), X_{jit} is firm and entrepreneur characteristics, and e_{jit} is the error term. Following Kassie et al(2015), Mundlak (1978) and Wooldridge (2002) we exploit panel level information and include the mean of time varying explanatory variables (e.g. firm size, firm revenue, education level of manager) to deal with the issue of unobserved heterogeneity.

Given the latent model in Equation (3), the observed combination of technologies and practices

(I_{jit}) in terms of the latent technology is written as

$$I_{Jit} = \begin{cases} 0 \;\; if\; I_{0it}^{*} > \underbrace{\max}_{j\neq 0}\left(I_{jit}^{*}\right) or\; \varepsilon_{0it} < 0 \\ 1 \;\; if\; I_{1it}^{*} > \underbrace{\max}_{j\neq 1}\left(I_{jit}^{*}\right) or\; \varepsilon_{1it} < 0 \\ 2 \;\; if\; I_{0it}^{*} > \underbrace{\max}_{j\neq 2}\left(I_{jit}^{*}\right) or\; \varepsilon_{2it} < 0 \end{cases} \quad (4)$$

Equation (4) implies that the i[th] enterprise will adopt a technology or combination of technologies and practices j to maximize its expected benefit (saved quantity of energy) if it provides greater expected benefit than the alternative combination $m, m \neq j$, i.e, $\varepsilon_{jit} = \underbrace{\max}_{j\neq 0}(I_{mit}^{*} - I_{mit}^{*}) < 0.$

Assuming that e_{jit} in Equation 3 is independently and identically Gumbel distributed, the probability that an enterprise will choose a technology or combination of technologies and practices j $\left(P_{jit}\right)$ can be specified by a multinomial logit model as,

$$P_{jit} = Pr\left(\varepsilon_{jit} < 0 \middle| X_{iit}\right) = \frac{\exp\,(X_{jit}\theta_j + \bar{X}_{jit}\alpha)}{\sum_{m\neq 0}^{2}\exp\,(X_{mit}\theta_j + \bar{X}_{mit}\alpha)} \quad (5)$$

Energy consumption of the enterprises under the above three technology/conservation practice regimes is specified as,

Regime 0: $Y_{0it} = X_{0it}b_0 + \bar{X}_{0i}d + h_{0it} \;\; if \;\; I_{it} = 0$ 6a

Regime 1: $Y_{1it} = X_{1it}b_1 + \bar{X}_{1i}d + h_{1it} \;\; if \;\; I_{it} = 1$ 6b

Regime 2: $Y_{2it} = X_{2it}b_2 + \bar{X}_{2i}d_2 + h_{2it} \;\; if \;\; I_{it} = 2$ 6c

where Y_{jit} is the energy consumption of enterprise i at time t using j energy conservation and efficient technologies, X_{jit} is enterprises characteristics, and h_{jit} refers to energy consumption function error terms that capture the uncertainty faced by an enterprise and which satisfies

$E(h_{ijt}) = 0$. The means of time varying explanatory variables (e.g. firm size, firm revenue) are included in the model to control for time invariant firm specific unobserved heterogeneity. If the error terms in equation 3 (e’s) and the error terms in equation 6 (h’s) are not independent, a consistent estimation of b and d requires the inclusion of the selection correction terms of the alternative choices in (6). Consistent estimates of b and d in the outcome equations (6) can be obtained by estimating the following multinomial endogenous switching regression model:

Regime 0: $$Y_{0it} = X_{0it} b_0 + \bar{X}_{0i} d_0 + l_{0i} r_0 + u_{0it} \quad if \quad I_{it} = 0 \qquad \text{7a}$$

Regime 1: $$Y_{1it} = X_{1it} b_1 + \bar{X}_{1i} d_1 + l_{1i} r_1 + u_{1it} \quad if \quad I_{it} = 1 \qquad \text{7c}$$

Regime 2: $$Y_{2it} = X_{2it} b_2 + \bar{X}_{2i} d_2 + l_{2i} r_2 + u_{2it} \quad if \quad I_{it} = 2 \qquad \text{7c}$$

Here, u is the error term with an expected value of zero, r is the covariance between e and h, l is the inverse Mills ratio computed from probabilities in equation (5) (for details see Bourguignon et al. , 2007 and Kassie et al,2015).

For equations (7a-7c) to be identified, it is important to use a selection instrument in addition to those automatically generated by the non-linearity of the selection model of adoption. In equation (7), we exclude the following set of instruments from the energy consumption function: the gender, education and experience of the manger. These variables may not directly influence the energy consumption function except via the mangers’ adoption decision.

The effect of switching regression can be estimated using the *selmlog* Stata software command, however due to insufficient observations in the base category (i.e firms that use neither conservation nor efficiency methods), only firms that use conservation methods and firms that use energy efficiency methods are compared..

4. Descriptive Statistics

This section presents the descriptive statistics of the outcome and control variables. The key explanatory variable is the use of efficiency and conservation measures. The efficiency measure includes use of energy efficient light bulbs and machinery. The conservation measure we consider is turning off light bulbs when they are not in use. Tables 1 and 2 shows the descriptive statistics of these measures in 2016 and 2020. As shown in Table 1, in 2016, 98.8% of the firms use either energy efficient technologies or conservation measures. In 2020, the percentage of non-users decreased by 0.5%. This result shows that almost all firms in the sample use either efficiency or conservation measures.

Table-1: Firms use of efficient and conservation measures.

Efficiency and conservation measures taken	Year		
	2016	2020	Total
No efficiency and conservation measure (%)	1.2	0.7	0.95
Used Conservation or efficiency measures (%)	98.8	99.3	99.05
Total sample	1,000	998	1,998

Note:The total saple selected from the baseline survey is 1000. However, information about the two firms efficieny is recored as a missing value in the follow up survey. The columun values are percentage of firms which use/ do not use efficiency or conservation measures

In Table-2, we disaggregate the binary users and non-users into percentage of users of specific efficiency and conservation measures. As shown in Table 2, about 33% of the firms implemented turning off lights in 2016, and only 27% in 2020.. In terms of energy efficient technologies, about 66% of the firms used energy efficient light bulbs in 2016 and 72% in 2020. 26% used energy efficient machinery in 2016, and 39% in 2020. Thus, although the percentage of firms using energy conservation measures decreased in 2016, the percentage adopting energy efficient technologies increased in 2020. Table 2 also shows that the percentage of users of both efficiency and conservation measures increased from 25% in 2016 to 36% in 2020.

Table-2: Firms use of efficient and conservation measures(dis-aggrigated)

Efficiency and conservation measures taken	Year		
	2016	2020	Total
Use turning of lights (%)	32.57	26.95	29.76
Use energy efficient light bulbs (%)	66.23	72.34	69.28
Use energy efficient Machines (%)	26.32	38.99	32.59
Used both efficiency and conservation measures (%)	24.97	36.37	30.66
Total sample	1,000	998	1,998

Note: The columun values are percentage of firms which use/ do not use efficiency or conservation measures

As stated in Section 3 above, 1,000 firms were randomly selected for the 2020 follow-up survey. Metal- and wood-working firms were purposively selected for the energy audit project. In this sub-sample, about 54% of the firms engage in wood- and and 43% in metal-work activities, while in the original baseline survey about 24% engaged in woodwork and 21% in metal-work activities [Table-3]. Although all firms were initially selected as wood- and metal-work firms, about 3% of firms in the sub-sample were found to be engaged in food and leather production activities.

Table 3: Economic activities of sample firms from Addis Ababa

Firm type	2016 sample (4,493 firms)	2020 sample (1,00 firms)
Wood-work	24%	53.89%
Metalwork	21%	43.21%
Food and beverages	25%	2%
Garments	14.36%	0%
Leather and leather products	2.92%	0.89%
Other	15.55%	0%
Total	**100.00%**	**100.00%**

Table 4 shows the mean revenue and mean costs of the sample firms in 2016 and 2020. As shown in Table 4, the sample firms made about 17% profit (profit to cost ratio) in 2016 and only 4% in 2020. The decline in profit could be related to the overall economic slowdown in the country. Labour and material costs constituted about 96% of the total cost in 2016 and about 78% in 2020. Electricity costs account for less than 1% of the total cost of production of the firms.

Table 4: Revenue and costs of firms

	2016	2020
Annual average revenue in ETB[1]	960,783.2	946,522.3
Annual average cost in ETB	819,022.9	908,232.1
Annual average profit[2] in ETB	141,760.3	38,290.2
Profit percent ((profit/cost) x 100)	17%	4%
Share electricity in the total cost	0.3%	0.4%
Share other utilities in the total cost	0.8%	0.7%
Share of labour cost in the total	20.0%	22.1%
Share of material cost in the total	75.7%	57.6%

Note: Labour cost is the total annual wage or salary costs of employees. Share of labor cost is defined as proporion of total labor cost in the total production cost of the firm

[1] ETB refers to Ethiopian Birr. The exchange rate was 1 USD to 21.3 ETB at the time of the baseline survey in 2016 and 1 US$ to ETB 39.3 at the time of the follow up survey in 2020.
[2] The profit is the pre-tax profit and does not take into account depreciation.

Figure 1: Average electricity consumption (in kWh)

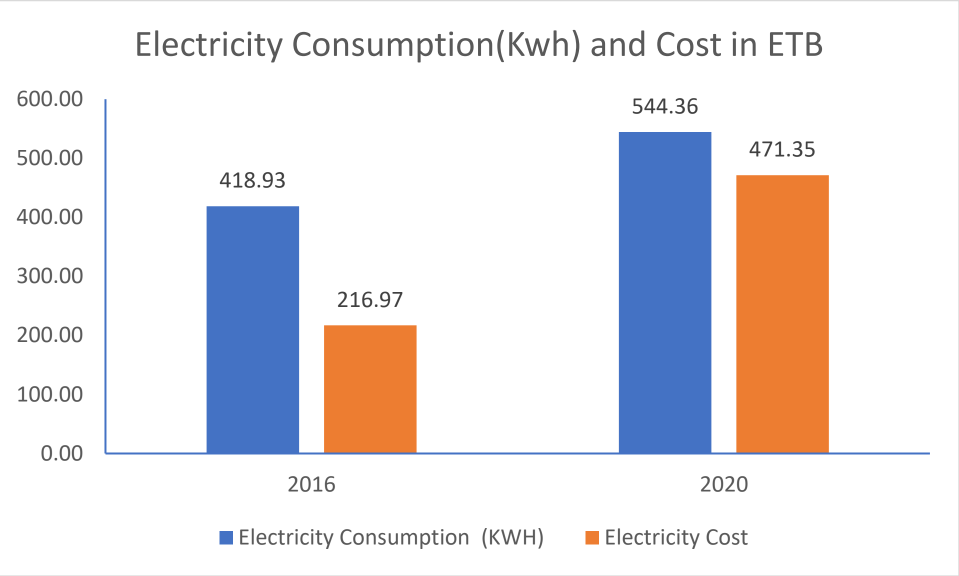

Figure 1 shows the average electricity consumption (measured in kilowatt hours kWh) and electricity cost (measured in ETB) of the firms in 2016 and 2020. This chart shows that the average electricity consumption of firms increased by about 30% over the period, while the cost of electricity increased by more than 200%. Although the cost of electricity increased by more than 100%, this does not significantly change the share of electricity in the total cost (Table 4) as the firms' electricity consumption is generally low and the tariff was increased from a very low base.

Table 5: Electricity consumption of users and non-users of efficiency and conservation measures

Efficiency and conservation measures taken	Mean Electricity consumption (in kwh)
No efficiency and conservation measure	640.84
Use efficiency or conservation measures	457.43

Table-5B: Electricity consumption of users of efficiency measures, conservation measures, or both measures

Efficiency and conservation measures taken	Mean Electricity consumption (in kwh)
Only turning of lights used	544.35
Used efficient technologies measures only	415.23
Used both efficiency and conservation measures	387.35

Table 5A compares electricity consumption by users and non-users of efficiency and conservation measures and shows that the latter consume 40% more electricity. Table 5B shows consumption by type of measure. . Furthermore, firms that use energy efficient technologies consume about 31% lesss electricity than those that use only conservation measures (i.e turning off light bulbs). Firms that use both efficieny and conservation measures consume 7.2% less electricity than firms that use only energy efficient technologies. This implies that firms are saving more energy from the use of energy efficient technolgies than the conservation method (turning off lights).

Table 6: Summary statistics for firm characteristics

Variables	Base year [2016]			Follow-up [2020]		
	Observations	Mean	SD	Observations	Mean	SD
Average price of electricity **[** in ETB]	1,000	0.34	0.15	1,000	0.66	0.23
Wage rate per day	1,000	58.66	18.01	1,000	97.93	14.70
Interest rate (Bank interest rate on loans]	1,000	0.13	0.00	1,000	0.12	0.00
Metal work [1=yes, 0=No]	1,000	0.49	0.50	1,000	0.43	0.50
Location of the firm [in industrial park=1, Outside park=0]	1,000	0.44	0.50	1,000	0.67	0.47
Age of the manager [years]	1,000	39.15	9.34	1,000	41.90	9.33
Gender of the manager [1=male, 0= female]	1,000	0.94	0.24	1,000	0.94	0.24
Manager's years of education	999	10.14	5.07	998	10.41	5.31
Owner's years of experience in Business	999	8.37	6.53	998	10.43	5.30
Separate meter [1= yes, 0=no]	998	0.61	0.41	997	0.61	0.42
Size of the firm [1= micro and 0=small]	1,000	0.73	0.44	1,000	0.79	0.41
Rented Building [1=yes, 0=No]	1,000	0.81	0.39	1,000	0.86	0.34
Ownership of the firm						
Share company [1= yes, 0=no]	1,000	0.05	0.23	1,000	0.05	0.23
Partnership [1= yes, 0=no]	1,000	0.34	0.42	1,000	0.40	0.49
Sole proprietorships [1= yes, 0=no]	1,000	0.47	0.50	1,000	0.42	0.49
Cooperative [1= yes, 0=no]	1,000	0.14	0.35	1,000	0.01	0.08
Other [1= yes, 0=no]	1,000	0.00	0.00	1,000	0.00	0.03

Table 6 shows the descriptive statistics for the variables which are used as control variables in the regressions. As can be seen from this table, a large proportion of firms are either partnerships or sole private ownership companies. In 2020, about 67% of the firms were located in industrial parks and about 79% were classified as micro enterprises, based on the number of employees. The average electricity price [defined as montly electricity bill divided by mothly kilowatt hour] has doubled, which is consistent with the Ethiopian Electricity Utilities' electcity tariff increment. Further, the averarge daily wage rate of employees of these micro and small enterprises increased by almost 67%. The increase in the wage rate is associated with overall price increases in the country.

5. Econometrics Results

Energy Demand of Manufacturing Industries

As discussed in the empirical strategy section, following Dargay (1983), we use the translog cost function to derive the energy demand function. The translog function results in simple demand functions that are relatively easy to work with. Since the cost function is logarithmic, its partial derivative with respect to the logarithm of factor prices results in the factor demand functions are expressed in terms of cost shares [see section 4 for details].

Table-7: Joint estimation factor demand functions

	Cost share of electricity		Cost share of labor		Cost share of Material inputs	
VARIABLES	Coef.	SE	Coef.	SE	Coef.	SE
Average price of electricity **[** in ETB]	0.12***	0.01	0.26***	0.02	0.03	0.02
Wage rate per day	-0.21***	0.00	0.25***	0.00	-0.00***	0.00
Interest rate (Bank interest rate on loans]	-2.35***	0.70	-3.25***	1.21	-3.50***	0.85
Age of the manager	-0.00	0.00	-0.00	0.00	-0.00	0.00
Highest education level of the manager	-0.10	0.10	-0.10	0.10	-0.10	0.10
Separate meter [1= yes, 0=no]	-0.02	0.21				
Use of Energy efficient light bulbs[1=yes, 0=no]	-0.07***	0.01				
Use of Energy efficient machine [1=yes, 0=no]	-0.17***	0.01				
Number of workers			-0.00**	0.00		
Age of the firm			0.00	0.00	-0.00	0.00
Constant	-0.34***	0.09	0.70***	0.16	0.58***	0.11
Observations	1,335		1,335		1,335	

Note:The three dependent variables in this table are: Cost share of electricity [columns 1 and 2], Cost share of labor [columns 3 and 4], and Cost share of material inputs [columns 5 and 6]. *** represents significant at the 1 percent level, ** represents significant at the 5 percent level and * represents significant at the 10 percent level.

Because of data limitations, we consider only electricity, labor and material input as factors of production, and their demand functions are derived using translog cost function. Other energy sources are not considered as less than 1% of the firms use other energy sources. The results of the joint estimation of the cost shares using the full information maximum likelihood method are shown in Table 7.

The result of the electricity demand function is presented in column 1 of Table 7. The result shows a postive and significant relationship between the price of electricity and cost share of electricity , i.e, if the average electricity price increases by 1 percenent, the cost share of electricity will increase by 0.12%. The smaller share of electricity price may be related to the low tariff rate of electricity in Ethiopia. The postive electricity price in the electricity cost function is expected as this can be defined as negative own price in the quantity demand function.

The coefficients of wage and interest rates are negative in the electricity cost function. We expect complemtarity between labor and electricity as an increase in wage rate may be an indication of overall price increases in the country. Usually workers demand high wages if there is an increase in the cost of consumer products. This implies that cost of electricity may reduce if an enterprise's hours of operation are reduced as a result of higher wage rates. Further, if wages are lower, firms may replace electricity for labour (i.e use manual operations). An increase in interest rates also has a negative effect on electricity costs as a higer interest rate means a lower capacity of the enterprise to expand their business operations or limit the business ability to purchase machineries, which use electrcity, on loan. The results also show that the use of energy efficient light bulbs and machinery has a negative and significant effect on the cost share of electricity.

Effect of the use of energy efficient technologies and conservation practices

The energy efficient technologies considered are energy efficient light bulbs and machinery. The conservation measure is turning off lights when they are not in use) . We define a multinomial logit model using a value of zero for firms who do not use any of the efficieny and conservation measures, 1 if the firm uses only the conservation measure, 2 if the firm uses only efficiency measures and 3 if the firm adopts both efficiency and conservation measures. The results of the multinomial regression model are presented in Table-8.

Table-8: Multinomial regression results of efficiency and conservation measures

	Turn off light		Energy efficienct technolgies		Both efficiency and conservation	
VARIABLES	Coef	SE	Coef	SE	Coef	SE
Metal work [1=yes,0=No]	0.20	0.49	0.14	0.49	1.26*	0.67
Age of the manager	0.03	0.07	0.02	0.07	0.11	0.09
Gender of the manager	-0.65	0.79	-0.68	0.79	-0.92	1.29
Educlevel level of the manager	1.01***	0.19	1.16***	0.29	1.78***	0.23
Owners years of experience in busness	-0.01	0.05	-0.08	0.05	-0.01	0.07
Separate meter[1=yes, 0=no]	-0.66	0.57	-0.11	0.57	-0.55	0.75
Location of the firm [in industrial park=1, Outside park=0]	0.24	0.86	0.12	0.86	0..12	1.08
Firm size[1=micro ,0=small]	-0.78	1.00	-0.57	1.00	1.76	1.45
Rented Building[1=yes,0=No]	-0.75	0.57	0.54***	0.17	0.47***	0.15
Constant	8.41***	2.77	10.92***	2.78	4.65	3.60
Observations	1,978		1,978		1,978	

Note:The base catagory is firms that do not adopt energy efficient or conservation practices, *** represents significant at the 1 percent level, ** represents significance at the 5 percent level, and * represents significant at the 10 percent level.

The results in Table 8 show that there is significant difference between firms that use efficiency and conservation measures and those that do not use these methods, in terms of managers, education level and building type. More specifically, more educated managers are more likely to use efficiency and conservation measures than managers with less education. Further, there is no significant difference between firms that work in their own building and those that rent a building in terms of turning off lights. However, there is a significant difference in their use of energy efficient light bulbs and energy efficient machineries. Firms working in their own buildings are more likely to use adopt these efficiency measures.

The second objective of this paper is to analyse the impact of these efficiency and conservation measures on electricity consumption using a multinomial endogenous switching regression method, however, due to the convergence problem, we could not get an estimate using a multinomial endogenous switching regression. This is mainly because we do not have enough observations in the base category (i.e. those firms that do not use efficiency or conservation measures). Instead, we compare firms the use only conservation measures (turning of lights) and firms that use energy efficient technologies.

Tables 9 presents the expected electricity consumption (KWh) under actual and counterfactual conditions. Cells (a) and (b) represent the expected electricity consumption observed in the sample. The expected electricity consumption (KWh) of firms that use only energy efficient technologies is 415.2kwh, while consumption is about 544.3 KWh for firms that use only conservation measures. This simple comparison, however, can be misleading, and lead to the conclusion that on average the firms that use energy efficient technologies consume about 129.2 KWh less than firms that use conservation measures (Table-9), which underestimates the real impact.

Table-9: Average Electricity Consumption; Treatment and Heterogeneous Effects estimated from endogenous switching regression

	Status of their Energy Efficiency (CE)		
Sub-sample	Only use efficiency measures	Only use conservation measures	Treatment Effects
Firms that only use efficiency measures	a) $E(KWh\_1 \mid E=1)$ =415.2	C)$E(KWh\_1 \mid E=0)$ =630.67	ATT= -215.47***(22.19)
Firms that only use conservation measures	d) $E(Kwh\_0 \mid E=1)$ =387.22	b)$E(Kwh\_0 \mid E=0)$ =544.3	ATU= -157.08***(31.74)
Heterogeneity Effects	BH_1= 23.28***(11.94)	BH_2=49.93***(15.82)	TH=0.45(3.04)

***= 1% level of significance, **=5% level of significance and *=10% level of significance, Numbers in brackets are standard errors.

The last column of table 9 presents the treatment effects of the use of energy efficient technologies on electricity consumption. As shown, in the counterfactual case, cell (c), firms which adopt energy efficient technologies consume about 215kwh less electricity than if they were only to use the conservation method. In the counterfactual case (d) of Table 9, firms that use only energy conservation measures would have consumed 157.08Kwh less if they had adopted energy efficient technologies.

These results show that firms that use energy efficient technologies consume less electricity than firms that use energy conservation measures, In addition, the last row of Table 9, which adjusts for potential heterogeneity in the sample, shows that firms who use energy efficient technologies would have consumed significantly more than firms that do not use energy efficient technologies, which implies heterogeneity among firms.

6. Conclusion

In Ethiopia the industrial sector accounts for a large proportion (40%) of total electricity consumption in the country. Micro, small, and medium sized enterprises (MSMEs) comprise more than 50% of the industrial sector in the country. MSMEs are generally less energy efficient than large enterprises. As a result, rapid growth of the sector puts pressure on the energy sector. Studying the energy efficiency and energy demand of micro and small enterprises will help policymakers design policies to make these sectors more energy efficient. Improved energy efficiency also has spillover benefits by reducing power outages caused by overburdened generation, transmission, and distribution infrastructure. routine outages increase adaptation costs to firms. This paper studies energy demand of micro and small enterprises in Ethiopia and the effect of energy efficiency and energy conservation measures adopted by these firms on their energy consumption.

The study is based on two waves of a survey of 1000 micro and small enterprises in Addis Ababa. The sample firms were randomly selected, in proportion to their size. Of these, 723 were micro and 267 are small. We selected firms with high rates of electricity consumption. Almost all of these firms were engaged in metal and wood working activities.

The study used both descriptive and regression approaches to analyse energy demand and the effect of energy efficiency and conservation measures on energy consumption. The results show that in 2016 about 66% of the firms use energy efficient light bulbs and 26% use energy efficient machinery By 2020 the percentage of firms using energy efficient light bulbs had increased to 72% and those adopting energy efficient technologies had increased to 39%. However, the percentage of firms using energy conservation measures (turning off lights when they are not in use) decreased from 33% in 2016 to 27% in 2020. Further, the average electricity consumption of firms increased by about 30% over the survey periods, while the cost of electricity increased by more than 200%. Comparing electricity consumption of users and non-users of efficiency and conservation methods, non-users on average consume 40% more electricity than users of efficiency and conservation measures. Furthermore, firms that use energy efficient appliances consume about 31% less electricity than those that use only conservation measures. Firms that use both efficiency and conservation measures consume 7.2% less electricity than firms that use only energy efficient technologies. This shows that firms save more energy from the use of energy efficient technologies than from conservation measures (turning off lights).

The econometric results show that energy and other factors of production such as labor are substitutes rather than complementary. The negative relationship between the cost of electricity and wage rates implies that enterprises may reduce hours of operations due to the need to pay higher wages. Further, if wages are lower, firms may substitute labor for some electricity-based operations (i.e., use manual based operations). An increase in the interest rate also has a negative effect on electricity costs as a higher interest rate means limited loans from banks. This may also mean a lower capacity of the enterprise to expand their business operations, and therefore lower electricity costs. Limited bank loans may hamper the ability of a business to purchase electricity-based machinery.

The econometric results also show that firms that use energy efficient technologies consume less electricity than firms that use energy conservation measures.

The key findings of this study show that firms that adopt energy efficient measures consume less electricity than those that do not adopt such measures. The government should include micro and small enterprises in their energy efficiency policy and promote energy auditing programs that promote these efficiency measures.

However, the paper is not without limitation. Since we only consider firms in metal and woodwork industries, the results may not be generalizable to the entire manufacturing industry in the country. We suggest future studies consider a wider spectrum of firms.

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