Estimating Economic Cost of Power Interruption for Manufacturing Firms in Ethiopia: Using Stated Preference Approach

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Abstract

In sub-Saharan African countries firms are suffering from frequent, long-lasting and random power outage, which makes it difficult to plan and undertake production activities. Thus, understanding the cost for firms due to unreliable power supply is important especially for policy makers and new investors who plan investment in the energy sector. Thus, the objective of this study is to estimate the economic cost of power interruption to manufacturing firms in Ethiopia specifically in the South Eastern industrial belt (area prone to frequent power interruption). The study covers small, medium and large-sized enterprises including different industry sectors. To this end, we conducted a choice experiment, collected data from 600 firms, and estimated a mixed logit model. The study finds that manufacturing firms located out of the capital city incur substantial economic cost due to power outage. An average firm's total cost of outage is 51,777 ETB (US$976) per month, which corresponds to a ninefold increase from the firms' average current monthly electricity bill. The cost of outages also amounts to 2.22 percent of the firm's monthly sales. Our results indicate the existence of significant heterogeneity in terms of size and sector in which the firm operates. Policy implications based on the findings are; since the cost of a power outage is significant, firms are investing on own energy alternatives to cope up outage, and firms have willingness to pay to avoid outages, this shows there is a market for expensive and reliable power supply which suggests building more power plants as means to supply reliable electricity. One option is minimizing subsidies and introducing optimal tariffs that are cost recovering for new grid investment. This could also attract international and private investors to the sectors. The government should also introduce incentive regulations that encourage participation of private sector in the generation of electricity. Furthermore, the government should increase intensity of diversification of source of electricity in order to liberate industries from rainfed dependence. Finally, the government should make blackout schedule reliable (try to make it during night time since majority of firms are shutdown at night) as it may help firms to shift their productions from machinery dependent to manual methods and makes the necessary substitutions such as from make to buy of intermediate inputs due to a shortage of electricity in order to reduce economic cost of power outage.

Key words: Economic Cost; Power interruption; Stated Preference Method; Firms; Willingness to Pay

1. Introduction

1.1. Background

Energy plays an irreplaceable role in the economy, both on the supply and demand side. On the demand side, energy is one of the products that consumers choose to buy to maximize their utility. On the supply side, energy is a key factor in addition to capital, labor and materials and is seen to play an important role in the economic and social development of countries because it is a key factor in economic growth and rising standards of living (Chontanawat et al., 2006). Therefore, reliable electricity supply is the main requirement to achieve sustainable economic growth and induce structural change. The power supply is expected to meet the growing energy demand in all sectors of the economy, especially in manufacturing industry. Ethiopia is not exceptional in this regard.

The availability and reliability of electricity services are crucial for economic development, as electricity plays an important role as an engine of social and economic change. No country has ever developed beyond a subsistence economy without access to energy services. Energy is necessary for the operation of large industrial machines and promotes the productivity of human capital by supplying electricity to schools, hospitals and modern communication technology. Chronically poor electricity supply is one of the biggest challenges facing businesses in Africa because of its importance to economic development and social well-being. For example, unreliable electricity is a major obstacle for African businesses (78% of African businesses experienced power outages every year, 41% of businesses considered electricity to be a major obstacle to their business operations, the highest in the world, African businesses experience power outages on average more than 50 hours per month, which means 25 days of lost business activity per year, which is more than any other continent) (Olalekan Oseni, 2019).

The economic costs of power outages for firms in these developing countries are significant due to the higher frequency and duration of power outages. The economic costs of power failure are large and can be opportunity costs, indirect costs and direct costs. For example, the opportunity cost to firms of blackouts is that, in addition to the effect of underutilization of capacity, African firms lose about 5% of their annual sales value due to blackouts (Amoah et al., 2019). Projected outage costs range from $2 to $32/kWh depending on firms' vulnerability to blackouts, and estimated direct costs, including estimated backup (self-generation) costs in Africa, are $0. 7/kWh, which is about four times higher when costs are reflected in grid electricity tariffs in countries such as Nigeria ($0.15/kWh) and Uganda ($0.17/kWh) (Olalekan Oseni, 2019). These challenges are not exceptional to Ethiopia.

Ethiopia is struggling to join middle-income countries that are strategically focused on manufacturing-based economies. However, economic growth requires sufficient electricity production and supply, where a deficit in this regard is observed in Ethiopia. Although Ethiopia has set ambitious energy targets, availability issues remain[1]. Access to sufficient and high-quality electricity continues to be one of Ethiopia's greatest development challenges; about 55 percent of the population does not have electricity. In addition to directly improving living standards, electricity indirectly improves incomes and welfare by increasing agricultural productivity, industrial productivity, business opportunities, job creation and industrialization in rural areas (Gunatilake et al., 2012). The reliability of the electricity supply is crucial for developing economies that plan their economic development to be highly dependent on the manufacturing industry.

Extensive evidence has been recognized in the literature on the importance of reliable electricity availability for economic growth (Andersen and Dalgaard, 2013). However, adequate and reliable electricity supply is far from a reality in developing countries and is a problem in sub-Saharan Africa in general and Ethiopia in particular. Electricity supply in these sub-Saharan African countries is characterized by frequent, prolonged blackouts and occasional blackouts. Energy companies in sub-Saharan Africa are mostly state-owned and choose to keep tariffs very low to appease their urban constituency. The current low electricity rates make the expensive investment required to improve supply economically unfeasible (Collier and Venables, 2012). For example, in Ethiopia the domestic electricity tariff was 0.01 USD/kwh, while in Germany it was 0.37 USD/kwh and in Nigeria it was 0.06 USD. In industry, the global average price of electricity was $0.123 per kWh, while in Ethiopia it was $0.023 per kWh, indicating a lower tariff (Energy and Environment, 2020)[2]. Although it is in the interest of customers to pay low electricity rates, the

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[1] In the ten years strategic plan the government has an aggressive energy policy framework designed to expand installed electricity capacity from approximately 4478 MWs in 2020 to 19,900 MWs by 2030, expand distribution line from 18,400 KMs in 2020 to 29,900kms by 2030, increase the number of customers from 5.8 million in 2020 to 24.3 million by 2030, increased the grid line users from 33 % in 2020 to 96 % by 2030 and reduce that of the off grid users from 11 % in 2020 to 4% by 2030(Ten year strategic plan document, 2020). The total demand for power is projected to grow by 30% per year.

[2] https://www.statista.com/statistics/263492/electricity-prices-in-selected-countries/

question remains whether they are willing to pay more to improve the electricity service, especially to improve the reliability of supply. The purpose of this study is to measure the willingness to pay for the improvement of electricity supply security among an important customer group in developing countries, small, medium and large manufacturing companies in Ethiopia. In this study, we focus on firms in general and in particular on small, medium and large manufacturing firms, because they are economic actors that play a key role in promoting economic growth and creating job opportunities in developing countries (Carlsson et al., 2020). In addition, although industry sector accounts for 38 percent of the country's electricity consumption, its share is expected to exceed that of households, making firms an attractive target (Mondal et al., 2018)

1.2. Rationale of the study

Lack of reliable electricity service is listed as a major obstacle to firms' growth in developing countries. According to a 2018 Center for Global Development (CGD) report, about 40 percent of firms in sub-Saharan Africa reported lack of electricity as a major constraint to doing business. The same study also found that the average firms in sub-Saharan Africa lost about 49 hours of economic activity in a typical month due to downtime in 2018. Among Ethiopian firms, on average firms lost about 57 hours of economic activity per month as a result of interruptions in the same period. The estimated annual sales loss for the average Ethiopian firms was about 11.4 percent[3] (Ramachandran et al., 2018). Allcott et al. (2016) reported that power shortage reduced the average output of Indian manufacturing firms by about 5 percent. However, the impact on productivity was small because most of the inputs could be saved during the downtime. Fisher-Vanden et al. (2015) state that the increase in electricity shortages increased the unit costs of production for Chinese firms by approximately 8 percent. To mitigate the negative effects of power outages, firms in developing countries have used various strategies, such as more flexible production and better storage capacity. One obvious strategy is to invest in backup power generation equipment such as diesel generators. Backup diesel generators are expensive, and it is estimated that in sub-Saharan Africa, self-produced electricity costs three to ten times more than electricity purchased from the grid (Eifert et al., 2008; Foster and Steinbuks, 2009). Even if a firm uses a generator, it still suffers from loss of production because it takes a lot of time and cost to restart the machines after an outage, and self-generated power may not be enough to produce at full capacity (Beenstock, 1991).

[3] https://www.enterprisesurveys.org/en/data/exploretopics/infrastructure#sub-saharan-africa--7

Evidence shows that 49 percent of firms in Ethiopia owned generator and they experience a significant financial value and environmental costs (Ramachandran et al., 2018). Diesel generators also have a negative impact on air quality and noise levels. In addition, a backup generator requires a large initial investment cost at the time of purchase, because it is difficult, if not impossible, to obtain a loan for this type of investment in most sub-Saharan countries. Investing in a backup generator is therefore very likely to be suboptimal, as it uses funds that could have been allocated to increasing production capacity (Reinikka and Svensson, 2002).

Long-term and sustainable solutions to improve the country's electricity supply security include investments in generation and distribution capacities and a more flexible pricing model, such as peak load pricing. In fact, underpricing is one of the main causes of acute shortage of generation capacity in Africa (Collier and Venables, 2012). Long-term electricity security strategies are particularly important in developing countries, where power outages are common and demand is constantly increasing. Large infrastructure programs such as grid improvement and modernization require large investment costs and are generally beyond the reach of utilities in sub-Saharan Africa. One way to gradually finance investments is to increase the electricity tariff. It is not easy to implement an increase in rates to finance investments, because the increase occurs before investments are made. Therefore, it is imperative to understand the willingness of customers to pay for such improvements. This article examines the willingness of small, medium and large manufacturing firms to pay to improve the reliability of electricity supply. Because we focus on the value of improvements that lead to levels of reliability that currently do not exist, we use a stated preference method: the choice experiment. Most studies to date have used a revealed preference approach, where indirect inferences about costs are made based on firms' actual avoidance costs, such as those spent on backup generators. However, in many developing countries, firms' expenditures on equipment to cope with outages (such as backup generators) can be limited by credit market imperfections, which increases the need to complement revealed preference approaches with stated preference. In Ethiopia there are studies conducted by Abdisa (2018) focusing on estimating cost of power outage using revealed approach, via measuring cost of power backup to self-generate electricity in response to power outages. Study by Meles (2020) emphasized to estimate the impact of power outages on households in urban Ethiopia, whereas that of Hassen & Degu (2019) research investigated the effect of Power Outage on Micro and Small Enterprise Productivity in urban Ethiopia firms. Another study by Carlsson et al, (2020) investigated the cost of power outage for micro, small and medium- sized enterprises in Addis Ababa using stated preference approach. However, research that focuses only on Addis Ababa's SMEs may not be generalizable to the entire Ethiopian context. As our review underlined, there has been no previous empirical study that tried to investigate the impact of power outage on Small, medium and large-sized manufacturing enterprises operating out of capital city using stated preference method in Ethiopia. This study is, indeed, aimed to fill the gap in this aspect via considering the large sized manufacturing enterprises as same time enterprises operating out of capita city (Addis Ababa) facing different power supply situations. We expect that firms operating out of the capital city do have severe power outage and long-lasting duration of outage whose impact on firms is significant. Therefore, this study is aimed to answer the following research questions (1) what is the economic costs of power outage to manufacturing firms in Ethiopia? (2) Do Small, medium and large-sized sized manufacturing enterprises have willingness to pay to avoid power outage? (3) What are the factors that determines firms WTP for reliable power supply? (4) How much is the average marginal willingness to pay to avoid power outage? (5) Is there any difference in MWTP to avoid cost of power outage between Small, medium and large sized enterprises?

1.3. Objectives of the study

The general objective of this study is to measure the economic cost of power outage to manufacturing firms via willingness to pay for improved reliability of electricity supply among Small, medium and large-sized sized manufacturing enterprises in Ethiopia.

The specific objectives are;

- To estimate the economic costs of power outage to manufacturing firms in Ethiopia
- To estimate the extent of effect of power outage on firm's performance (sales lost due to power outage)
- To estimate average marginal willingness to pay to avoid power outage among small, medium and large-sized manufacturing enterprises
- To estimate if there any difference in MWTP to avoid cost of power outage between Small, medium and large sized enterprises

1.4. Significance of the study

Reliable power supply is crucial for economic and social development of countries, being a key factor in increasing economic growth and living standards. However, developing economies of Sub-Saharan Africa in general and Ethiopia in particular are experiencing a frequent and prolonged power outage. As a result, firms which are the main actors in an economic development are incurring unnecessary cost due to power outage. Therefore, this study would provide policy input for the government of Ethiopia concerning the economic cost of power outage on manufacturing sector of an economy. Thus, the study has significance for both government and industrialists in the country to develop strategy for means of reducing power outage (via increasing investment on power supply) and alternative mechanisms in order to ensure power supply reliability.

1.5. Scope of the study

This study is delimited to investigating the economic cost of power outage on small, medium and large sized manufacturing enterprises in Ethiopia. In order to do so, we have conducted survey from different industry sector such as Agro-processing (food and beverage industry), textile and garment, leather and leather product, metal and metal product, and wood and furniture industries, available out of the capital city. We selected industries out of the capital city (in Galan, Dukem, Bishoftu, Adama and Shashemene industries) due to the fact that the extent of power outage and duration of outage is severe in these areas compared to that of Addis Ababa. Thus, we collected data from these selected industries using stated choice experiment methods.

1.6. Ethical considerations

With regard to the ethical issues, we followed the following steps. Initially we communicated to those randomly selected industries manager or owners about the objective of the study in advance and scheduled for survey and face to face interview. Then, based on the schedule we met and informed them how to respond to the choice experiment questions providing them with some sample. Then we told them to ask what ever cases are unclear for them and we stayed around until they completed the survey. They were also informed that all of the information they offer would be kept confidential. In addition, there is nothing in the questionnaire that can expose them to any detriment since there is no personal information issues. Even they were given a freedom to the extent that they have rights not to participate in the study.

1.7. Organization of the study

The research is organized into five sections. Section 1 is introduction part which provides a brief background, justification, and the study objectives. A review of literature on cost of power outage and related issues are presented in Section 2. Research methodology including data collection mechanism and model specification were discussed in Section 3. Section 4 deals with empirical result, discussion and analysis. Conclusions and policy implications were discussed in Section 5.

2. Literature review

Research on the impact of power outage on industry has been conducted since at least 1948, the first perhaps in Sweden (Bental and Ravid, 1982). Unreliable and insufficient power leads to welfare losses (Kessides, 1993) and hinders economic growth (Eberhard et al., 2008). The lack of high-quality electricity significantly weakens the overall productivity of companies (Arnold et al., 2008; Sichone et al., 2016). Using data from the World Bank enterprise Survey of 1,000 firms in 10 sub-Saharan countries, including Ethiopia, Arnold et al (2008) found that firms in regions with more frequent power outages were less productive than others.

Power outages reduce productivity per worker since workers can be diverted to less productive activities. Outages lead to restart costs, loss of production and sales to electricity-dependent industries, equipment damage, raw material destruction, loss of product quality, and loss of reputation, such as a drop in ranking in export market reliability criteria (Beenstock). et al., 1997; Steinbuks and Foster, 2010). The latest business survey data from Word Bank shows that 41% of surveyed sub-Saharan African businesses cited electricity as the biggest obstacle to their business, while 26% cited transportation as the main constraint. Power outages were experienced by 77% of businesses, with an average of 9 outages per month and each outage lasting an average of 5.7 hours. Outages cost an average of 8.5% of annual turnover. 53% of firms owned generators. Where generators were used, the average share of produced energy was 28% (World Bank, 2018)[4].

Studies estimating the value of unsupplied electricity on the industrial sector come from aggregate macro data as well as from individual plants, forming a micro analysis (Bental and Ravid, 1982). Macro analysis examines the long-term impact of downtime on long-term growth through the neoclassical Solow growth model (Solow, 1956; Andersen and Dalgaard, 2013). Using outages as

[4] https://www.enterprisesurveys.org/en/data/exploretopics/infrastructure#sub-saharan-africa--7

a binary variable in a logarithmic regression model, Andersen and Dalgaard estimate that a 1% increase in power outage reduces GDP by almost 3% in 39 sub-Saharan countries, including Ethiopia. If all African countries experienced South Africa's electricity quality, they estimate that their GDP per capita would increase by 2 percentage points (Ahmed et al., 2019). However, the fault of the macro studies of Bental and Ravid (1982)[5] is that they estimate the average cost of unsupplied electricity, while the corresponding estimate would be the marginal cost.

Hashemi et al (2018) investigated the cost of power outages to industry using a contribution/toll approach. Contribution is the portion of sales revenue that goes to cover overhead costs and generate profit for the firms. This approach is used when a unit of output is not produced due to a power outage, saving all the variable cost components. That part of the opportunity cost that would have resulted in covering overhead and profit if the unit in question had been produced is lost. But in fact, the cost of power failure is not only an opportunity cost for firms, but also different costs, such as indirect and direct costs. An individual manufacturing firms can use this approach to estimate the true opportunity costs of power outages by assessing the benefits and costs of investing in potential mitigation strategies. The importance of the method is emphasized for industrial electricity consumers, where the effects of power failure are different for each firm.

Several studies have tried to estimate the costs due to power failure using different techniques. For example, (Bental and Ravid, 1982; Adenikinju, 2003; Steinbuks and Foster, 2010; Oseni and Pollitt, 2013) inferred outage cost from actions taken by firms. However, this method sometimes only provides upper or lower bounds on estimates of disruption costs (Balducci et al., 2002). Others by Pasha et al. (1989); Caverns et al. (1992) used survey methods where firms are asked to report losses due to outages. This approach is attractive because it allows the cost of downtime to be shared between customers. There are also studies that adopted a production function approach, such as Castro et al. (2016) to estimate the cost of power outages. This study combines the strength of the survey method with the production function approach by applying the translog cost function to firm-level survey data. Power outages affect business in several ways. However, its impact varies from firms to firms, depending on the degree of vulnerability and the relative generating

[5] Another pitfall of subjectively answered surveys is that they could be prone to loss aversion, and this may explain why a number of studies such as Pasha, Ghaus and Malik (1989) and Beenstock et al (1997) concluded that firms overstated their losses. For instance, as Thaler (1980) observed, people suffer from loss aversion: the loss of utility from giving up a valued good is greater than the gain in utility from acquiring the good. Similarly, perceived losses do not necessarily match actual losses if framed in a particular way, contrary to rational expectation.

capacity of a self-generating firm to its own required electricity (Oseni and Pollitt, 2015). The costs of power outages also vary according to the size of the firms and the a type economic activity a firm is engaged in. In this regard, (Moyo, 2012; Adenikinju, 2003) found that power outages are particularly harmful to small-scale businesses because they are unable to finance the cost of backup power. On the other hand, a study by Osen and Pollitt (2015) shows that larger firms have higher outage losses. They argued that this is largely because large firms use more machine-dependent production processes than small firms.

The cost of power outages also depends on the nature of the firm's power outages. Power outages can be characterized along several dimensions, including duration, frequency, outage timing, and advance notification. Few studies have investigated the impact of such features on outage costs. Billinton et al. (1982) and Ontario (1980) report that firms initially face high outage costs. However, the costs decrease rapidly as the duration increases. In terms of interruption frequency, business firms prefer infrequent long interruptions to frequent short interruptions (Billinton et al., 1982; Ontario, 1980). Scott et al. (2011) found a similar result indicating that frequent power outages are associated with lower firm productivity. Investigation of the effects of blackout time and advance notification is limited due to data limitations.

There has also been considerable empirical research on the mitigation measures taken by firms to reduce the costs of power outages. The most common strategy was found to be investment in own generation (Adenikinju, 2003; Steinbuks and Foster, 2010; Oseni and Pollitt, 2015). Steinbuks and Foster (2010) found that the probability of owning a generator is approximately 20% even where the electricity supply is fully reliable, and motivation to invest in a generator and capacity of generator installed are highly influenced by firm characteristics such as size, industry, firm structure and export orientation. A similar result was found by Oseni and Pollitt (2015). However, a firm's mitigation strategy depends in part on the firm's available options and the nature of power outages. According to Alam (2013), short-term power outages do not necessarily force businesses to own generators. Fisher-Vanden et al. (2015) also show that Chinese firms did not generate electricity themselves during power shortages, but instead optimized production inputs by substituting energy with materials.

Existing empirical studies of blackouts focused on evaluating the economic costs of blackouts. However, it is not clear from these studies whether power shortages due to power outages have a similar effect in different industries and whether or not the magnitude varies. Therefore, this study examines the economic costs of power outages for manufacturing firms of different sizes and industries in Ethiopia. Some studies have tried to estimate the costs of power outages using the stated preference methods, which have been used in particular to measure the willingness to pay among households for improvement in the reliability of electricity supply (e.g., Carlsson and Martinsson, 2007; Meles, 2017; Moeltner and Layton, 2002; Osen, 2017; Abdisa, 2018; Hassen and Degu, 2019). Two studies from abroad are Morrison and Nalder (2009) and Ghosh et al. (2017) and four domestic studies that are close to the current study on firms are those of Abdisa (2018), Meles (2020), Hassen and Degu (2019), and Carlsson et al. (2020). Morrison and Nalder (2009) analyzed the attitudes of service and manufacturing companies in Australia towards power outages. There, however, the problems related to power outages are significantly different from the context of a developing country, and the research focuses on reducing four power outages per year, which corresponds to the total number of power outages during the year. Ghosh et al. (2017) investigates the willingness to pay of micro and small enterprises in India to reduce power outages using a contingent valuation study. A study conducted by Abdisa (2018) in Ethiopia examines the cost of power failure using a revealed approach, measuring the cost of power backup to self-generate electricity in the event of a power outage. The results show that power outages had a negative impact on business productivity, increasing costs for businesses by 15% between 2011 and 2015. A study by Meles (2020) examined the impact of power outages on Ethiopian households using a generalized propensity score method expenditure approach mixing with the stated preference method to account for the non-monetary costs of disruptions. It found that the monthly willingness to pay $6.2 million for a better power supply, on top of the regular electricity bill. A study by Hassen and Degu (2019) investigates the impact of power outages on the productivity of micro and small businesses in Ethiopia. The result shows that a one percent increase in average blackout duration is associated with a 0.54%, 0.17%, and 0.19% decrease in TFP, labor productivity, and revenue, respectively. Carlsson et al. (2020) investigated the costs of power outages for micro and small businesses in Addis Ababa, Ethiopia using a stated preference survey. Consequently, existing empirical research on outages has focused on estimating the costs of power outages. However, it is not clear from these studies whether power shortages due to power outages have a similar effect in different industries and whether or not the magnitude varies. Therefore, this study examines the economic costs of power outages for manufacturing firms of different sizes and industries in Ethiopia. In addition, our research focuses on small, medium and large industrial enterprises located outside the capital, which have serious problems with reliable electricity supply. We use a stated preference method and focus on four broad aspects of outage attributes: number of outages per month, average duration of a typical outage, power outage time, and attitudes toward supplier ownership.

3. Methodology

3.1. Choice experiment study

Both the choice experiments (e.g., Carlsson and Martinsson, 2008; Ozbafli and Jenkins, 2016) and contingent valuation method (e.g., Carlsson and Martinsson, 2007; Moeltner and Layton, 2002) are stated preference methods used to investigate the willingness to pay for improvements in the reliability of electricity supply (Carlsson et al., 2020). In this study, we use a choice experiment that allows firms to measure their preferences in hypothetical situations using a stated choice survey (Green and Srinivasan, 1990; Louviere et al., 2000). Stated preference data is usually much richer than revealed preference data and thus opens opportunities to increase the behavioral capability of a mixed logit model in situations where there is little or no market data information (Hensher et al., 2005; Shin et al., 2014; Carlsson and Martinsson, 2008; Ozbafli and Jenkins, 2016). The questionnaire consisted of three parts: (i) general information about the firms, (ii) detailed questions related to the companies, and (iii) the choice experiment. The final questionnaire was created as a result of several focus group studies, followed by one pilot study with 25 companies. We have used stratified random sampling techniques based on industry sector and firm sizes. Industries considered in the survey were categorized in to food and beverage industry, textile and garment industry, leather and leather product industry, metal and metal work industry, wood and furniture industry treated as strata. Within each stratum different firm size (small, medium and large) were considered in the sampling. We sampled small, medium and large manufacturing companies located in Galan, Dukem, Bishoftu, Adama and Shashemene industrial areas. Finally, we randomly selected 600 companies from a list of more than 18,000 registered companies received from Oromia Industry and Investment Bureau. We then choose the owners or managers of these companies as respondents for our survey, because they make important decisions when it comes to investments in production capacity for which decision on energy sources is crucial.

In the introduction to the choice experiment, we first presented a general introduction of power outages and how power plants can reduce them by building new dams, upgrading grid networks, improving existing transmission and distribution lines, and improving customer service in the event of technical failures. This was followed by a description of the scenario (see Appendix A). The scenario focused on the firm's willingness to pay for reducing power outages, considering that the service provider (could be the incumbent, i.e., the Ethiopian Electric utility or potential entrant operator in the form of private or public private partner) could improve the reliability by making investments. The main effect of these investments would be to reduce the frequency, duration and time of the firm's power outages. Each respondent was asked to choose the most preferred option among five different choice set. Each set of choice includes the status quo, i.e., the current situation, and four alternatives with improvements in terms of duration, frequency, downtime and electricity supplier ownership. The attribute ownership of power operator is introduced in the choice set targeting to measure firms' attitude and trust towards the incumbent operators (owned by government) with regard to electricity service improvement compared for other potential operators (private or public private partnership) in a hypothetical situation. The trade-off for the firms would be a reduction in these four parameters and increased electricity prices. To facilitate understanding, we also presented an example of a choice set to the respondents after we had read the scenario. The attributes and levels used in the choice experiment are presented Table 1. The current situation (status quo) is obtained from the World Bank Business Survey (WBES) of 2015 for Ethiopia[6]. The fourth column of Table 1 shows the current situation during a typical month consisting of 11 outages, each lasting an average of 5 hours, with an electricity price of 0.67 Ethiopian Birr (ETB) per kWh, with random outage timing and state-owned operator. The attribute levels in the third column show the frequency and duration of blackouts after improvements. For time of outage and type of provider attributes column three consists multiple choice including other options to be considered. Considering five attributes, three attributes with four levels and one attribute with three levels and one attribute with two levels, the total choice set for an

[6] The utilities in Ethiopia use an increasing block price strategy. There are seven blocks. The lowest block covers consumption levels from 0 to 50 kWh per month with a price of 0.27 birr per kWh, while the highest block includes consumption levels above 500 kWh per month with a price of 0.6943 birr per kWh. Since most of the firms consume more than 500 kWh per month, motivating 0.67 birr per kWh as the average price in the current situation (Fredrik Carlsson, et al, 2018). Birr is the Ethiopian currency, and the exchange rate at the time of survey (January to February 2021) was US$1 = 43.2 ETB. A daily industrial worker's wage in out of Addis Ababa during the survey period was about 200 ETB. https://www.nationsencyclopedia.com/WorldStats/ESI-average-duration-power-outages.html

experiment becomes 384; and we used a fractional factorial design to an orthogonal array of hypothetical power supply package[7]. Using this method, the study ensures maximum efficiency in designing the experiment such as encompassing the principles of level balance, orthogonality, minimal overlap, and utility balance. Finally, the array is reduced to 16 choice sets and randomly blocked into five choice sets with four alternative services in each set, including the status quo (Table 1).

Table 1. Attributes and levels in the choice experiment

Attributes	Description	Levels	Current situation
Frequency	Number of outages in a typical month	5, 7, 9, 10	11
Duration	Length of a typical outage in hours	1, 2, 3, 4	5
Time of outage	The time of occurrence of the outage. Day time refers to (6 AM-6 PM) and Nighttime refers to (6:01 PM-5:59 AM)	Daytime Nighttime	Randomly
Power supplier	Entity who supplies and distribute power services to manufacturing firms due to perceived differences in efficiency and customer handling	Government Private Public private partner	Government
Cost (birr/kWh)	Cost of electricity per kWh	0.8, 0.94, 1.08, 1.22	0.67

The survey data was collected during October 2020 to March 2021. For the sake of reliability of the data the survey was conducted in the form of an interview, since some of the respondents might be not convenient in understanding the choice scenarios. We gave the respondents a card depicting each choice set to make it easier for them to make their choices (see Appendix) and we have assisted to clarify things based on their request.

3.2. Sampling and sample size

With regard to sampling and sample size, we used stratified random sampling techniques based on industry sector and firm sizes. Industries considered in the survey were categorized in to food and beverage industry, textile and garment industry, leather and leather product industry, metal and metal work industry, wood and furniture industry. Within each stratum different firm size (small,

[7] A fractional factorial design contains a sub-set of all combinations of levels of attributes. A fractional factorial design has the properties of being balanced and orthogonal.

medium and large) were considered in the sampling. The size of the firms is based on the number of permanent full-time workers reported and defined as: small (5 to 20 employees), medium (21 to 100 employees), and large (more than 100 employees). Accordingly, 160 small, 240 medium and 200 large sized manufacturing firms were considered in the sample (Table 2).

Table 2: sample distribution by sector and firm size

Sector	Number of registered industries	Small firms (27%)	Medium (40%)	Large (33%)	Total sample (3%)
Food &Beverage	7200	65	96	79	240
Textile &garment	2400	22	32	26	80
Leather & Leather products	3600	32	48	40	120
Metal & Metal products	2400	22	32	26	80
Wood& furniture	2400	22	32	26	80
Total	18,000	163	240	197	600

A total of 600 firms were surveyed from October 2020 to March 2021.

3.3. Theoretical models

The random utility theory (McFadden, 1973) is used as a theoretical basis for studying consumer preferences using discrete choice methods. The model assumes that respondents choose their preferred alternatives based on the greatest utility or benefit they perceive. Thus, this study assumes that each consumer/firm perceives the utility associated with each attribute of the options of improved power supply services and selects the one with the highest possible utility.

In the random utility model, the linear utility function is divided into a deterministic component and a stochastic part as follows:

$$U_{nj} = V_{nj} + \varepsilon_{nj} \qquad (1)$$

where the subscript n means the nth consumer/firms and j means the jth alternative of the choice situation. U_{nj} is the utility obtained from alternative j by the nth consumer. V represents deterministic utility, while ε represents unobservable utility, which capture excluded factors that may affect the utility of an alternative in V_{nj} and factors that are intrinsically unobservable (Ben-Akiva et al., 1985). In fact, there are various models, such as the generalized multinomial logit

(Fiebig et al., 2010), which can capture scale heterogeneity; However, in this study, in addition to capturing coefficient heterogeneity, we also used the mixed logit model due to the simplicity and computational efficiency of their estimation.

3.4. Mixed logit Model

The mixed logit model is used as a very flexible model to account for unobserved heterogeneity in estimates, any random utility model, and is widely used in modeling to improve power reliability using the stated preference method (Carlsson et al., 2010; Hensher et al., 2005; Whittington et al., 1990). In a mixed logit model, the unobserved factors can be divided into two additional parts $(\varepsilon_n = \eta_n + \delta_n)$: a stochastic (η_n) that is correlated over alternatives and heteroscedastic over consumers and alternatives and stochastic part (δ_n) , which is IID over alternatives and consumers (Train, 2009). We use simulated maximum likelihood using 500 Halton plots to estimate the model. In the estimates, we use a triangular distribution for the random parameters of all attributes, so that the upper end point is zero and the lower end point is twice the mean (Hensher and Greene, 2003)[8]. This constraint ensures that the cost, duration, and frequency attributes have a negative sign, meaning that increasing any attribute results in disutility. We also investigated the log-normal distribution as a way to limit the sign of the coefficients, but as is often observed in the literature, we have problems with the convergence of the distribution and fat tails. Thus, the utility of consumer/firm n from choosing option j can be defined as:

$$\mathrm{U}_{nj} = X_{nj}\beta_n + \varepsilon_{nj} \qquad (2)$$

If an unknown parameter β_n consisting of a vector of coefficients of explanatory variables X_{nj} allows variation across consumers in the tests. To allow the coefficients to vary with respect to consumers in the population β_n is assumed to have density $\mathrm{f}(\beta)$. The choice probability with regard to the random coefficient framework is:

$$\mathrm{P}_{nj} = \int L_{nj}(\beta) f(\beta) d\beta \qquad (3)$$

Where, $\mathrm{f}(\beta)$ is the density function and $\mathrm{L}_{nj}(\beta)$ is the logit choice probability at parameters β:

[8] If a normal distribution is assumed, then a subject is allowed to have both positive and negative effects on utility from an increase in any of the attributes, which is undesirable and unlikely

$$\mathrm{L}_{nj}(\beta) = \frac{e^{V_{nj}(\beta)}}{\sum_{k=1}^{K} e^{V_{nk}(\beta)}}$$

$V_{nj}(\beta)$, is the observed part of the utility. If utility is linear in β, $V_{nj}(\beta)$ becomes $\beta' X_{nj}$ and the choice probability takes the form of (Train, 2009);

$$\mathrm{P}_{nj} = \int \left(\frac{e^{\beta' X_{nj}}}{\sum_{k=1}^{K} e^{\beta' X_{nk}}}\right) f(\beta) d\beta \tag{4}$$

The analysis is based on the assumption that the respondent weighs all the features and alternatives and then chooses the best option from the set of options. However, research shows that respondents often use heuristics to make decisions and may not even consider all the features (e.g., Carlsson et al., 2010; Hensher et al., 2005; Scarpa et al., 2009), often referred to as attributes absence. This could be due to a number of reasons, such as unwillingness to pay for the planned improvements, reducing the weight of certain attributes or simply cognitive fatigue. Regardless of the reason, previous research has shown that if respondents do not consider these attributes when making a decision, it can lead to biased estimates. There are several ways to approach this, and here we use responses to a follow-up question that asked people to specifically indicate how much they considered each attribute when making their choice. For each attribute in which the respondent did not participate, we bound the coefficient of that attribute and the respondent to zero when estimating the model (Carlsson et al., 2010). We then estimate the marginal willingness to pay for the two attributes based on the coefficient estimates, which are calculated as the ratio of the attribute coefficient to the price coefficient.

There is a large literature that compares the mixed logit model with other discrete choice models, applying them to empirical studies in various fields. However, some studies argue that the choice of model depends on the contextual situation of the researcher. For example, if a researcher is interested in revealing the heterogeneity of individual firms to determine the preferences of decision makers, a mixed logic model is preferred.

4. Results and Discussions

4.1. Descriptive statistics

In Table 3, we present descriptive statistics about the sampled companies and their owners. We interviewed owners or managers of 600 firms operating in different parts of the country but out of Addis Ababa.

Table 3: Descriptive statistics

Variables	N	Minimum	Maximum	Mean	Std. Dev.
Firm characteristics					
Firm's age in years	600	2.00	20.00	7.13	3.93215
Number of working hrs. within a day	600	8	10	8.27	.680
Male employee size	600	2	146	75	59.891
Female employee size	600	3	187	92	73.090
Firms average monthly sales (in 1,000 ETB)	600	27	40000	2335.4	1729.23
Firms' average electricity consumption (in kwh per month)[9]	600	850	2500	1185	1023
Firms monthly profit lost due to power outage	600	2160	126000	4906.3	3854.527
Firms monthly cost due to power outage	600	21000	588200	350940	272910.8
Owner characteristics	600				
Age of respondent in years	600	25	50	44.5	6.635
Gender of respondent (=1 if owner/manager is male)	600	0	1	.87	.340
Education level at least college diploma (=1 if yes)	600	0	1	.67	.499
Business experience in in general (years)	600	10	34	23.7	7.412
Business experience in current business (years)	600	2	10	6.3	2.301
Trust in the current electric utility providers (0 if low and 10 if high)	600	4	7	5.7	.943

An average firm in our sample has been in operation for at least seven years and has on average 75 and 92 male and female employees, respectively. The average monthly revenue is 2,335,400

[9] According to information from the Ethiopian Electric Utility (EEU), the existing electric power generation, transmission, and distribution costs are, on average, about $0.09 per kilowatt-hour (kWh), while the current tariff for electricity lies between $0.04 and $0.06 per kWh. Using $ exchange rate of 52.81 birr by 1 USD, we have calculated 1kwh charge equal to 0.09$ or 4.75 ETB.

ETB. The average electricity consumption for the sampled enterprises is 1185 kWh per month. In addition, on average firms profit lost due to power outage is 4906.3 birr per month and general cost due to power outage is 350940 ETB per month. These overheads may include additional downtime costs such as fuel and generator maintenance costs and labor costs. This figure shows the extent of the impact of a power outage on the potential performance of companies in general. When comparing costs to monthly sales, businesses lose an average of 15.03 percent of monthly sales. According to owners/managers, the average age of the owner or manager of the firms is 44.5 years, and the majority of owners/managers are men (87%). About 67 percent of the owners or managers have at least a college diploma. Owners and managers in our sample have an average of 23.7 years of general business experience and 6.3 years of experience as an owner or manager of an existing business. When asked to rate their confidence in the current utility on a scale from 0 (not at all) to 10 (complete confidence), owners or managers' report a fairly average level of confidence, with an average score of 5.7. We have also gathered detail information about the business firms and electricity blackout experiences (see Table 4).

Table 4. General characteristics of firms and electricity blackout

Variables	Categories	Frequency and percentage in brackets	Remarks
Respondents	Manager	440 (73.3)	
	Owner	160 (26.7)	
Legal form of firms	Sole	560 (93.3)	
	PLC	40 (6.7)	
Firm size	Small	160((26.7)	
	Medium	240(40)	
	Large	200(33.3)	
Firm's production interrupted due to power outage	Yes	600(100)	
	No	0	
Measure taken to reduce problem of blackout	Backup generator	440 (84.6)	
	Shifting operation time	80 (15.4)	
Did the operation of firm interrupted due to other problems	YES	560 (93.3)	
	NO	40 (6.7)	
Reasons for interruptions	Lack of raw materials	200 (35.7)	

	Lack of foreign currency	160 (28.6)
	Shortage of water	200 (35.7)

Of our sampled firms, about 93.3 percent were sole-proprietor enterprises whereas about 6.7 percent were private limited companies (PLC). All sampled firms have faced production interruptions due to power outage. In order to mitigate these outages about 84.56 percent of firms have bought backup generator[10] whereas about 15.4 percent of the firms in our sample have been forced to adjust their operation times due to power outage.

Since we have considered different sector of industries, their level of power consumption and expenditure could be heterogenous. According to the survey the average power consumption in Kwh per month is depicted as below Figure 1.

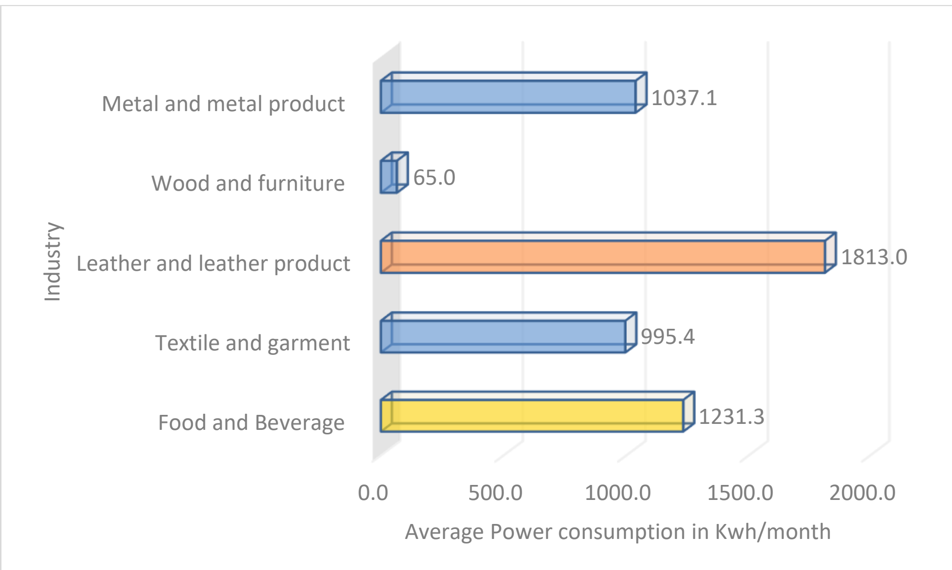

Figure 1: Current power consumption by sector

Even though firms are experiencing severe blackout, their current bill expenditure for power consumption varies from sector to sector which directly depends on the amount of power consumption (see Figure 2).

[10] Cost of diesel generator to produce a unit of kwh is estimated to be about 3.67 ETB.

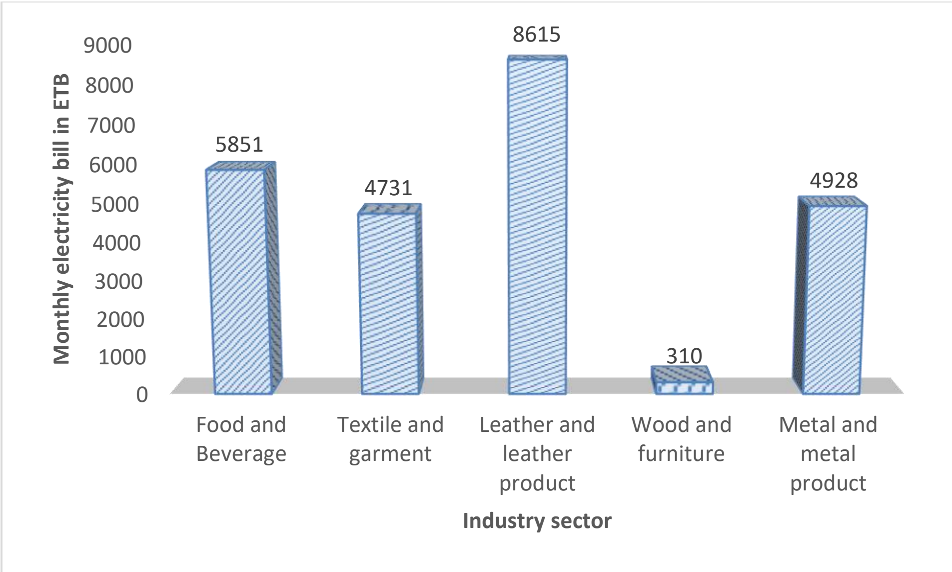

Figure 2 Monthly electricity cost/bill by sector

As explained in Table 3, the power outage has a significant effect on firms' performance (either on profit or monthly sales). But the effect of these power outage may vary and depend on the size of the firms. Based on the self-report data, the effect of power outage on firms' profit is summarized as below, see Table 5.

Table 5: Effect of power outage on firm performance

	Average Profit lost due to power outage (ETB/month)	Average Profit lost due to power outage (ETB/year)
Small enterprise	4214.02	50568.28
Medium enterprise	4935.68	59228.14
Large enterprise	5569.20	66830.38

Table 5 shows that the effect of power outage is large on large enterprises compared to that of medium and small sized enterprises. This could be due to the reason that since the large enterprises require high power consumption which even difficult to operate by generator backup, the effect of power outage seems severe compared to the others medium and small sized enterprises. By the current scenario, a given large enterprise average profit lost due to power outage is 5,569.20 ETB/month. For medium and small sized enterprises, the average profit lost due to power outage is 4,935.68 and 4,214.02 ETB/month, respectively. These amounts of profit lost could be improved and regained if the frequency and duration of power outage is improved.

4.2. Econometric Analysis

We estimated the Mixed Logit model (MIXL) since it was found to provide a better fit to the data using goodness-of-fit criteria such as consistent Akaike information criteria (CAIC), Akaike information criteria (AIC), and log likelihood (LL). The estimated result of the Mixed Logit model (MIXL) is shown in Table 6 below.

Table 6: Results of the Mixed logit model

Attributes	**Coef.**	**Std dev[11].**
Frequency	-.572***	.121*
	(.136)	(.059)
Duration	-1.708***	.861***
	(.290)	(.265)
Govt provider	-.0773	.778**
	(.274)	(.346)
PPP provider	-1.726***	.003
	(.487)	(.428)
Day Time	-2.025***	.054
	(.605)	(.399)
Night-time	.693	.798**
	(.626)	(.382)
Cost (in ETB/ kwh)	-.381**	.322*
	(.161))	(.168)
Log-likelihood	-213.38	
LR chi2(6)	39.81	
Prob > chi2	0.0021	
Observations	600	

Note: Standard errors in parentheses. ***, **, * denote significance at 1%, 5%, and 10% levels, respectively

The result reported in Table 6 shows that the majority of the attributes of power outages remain statistically significant with negative signs. Moreover, almost all the estimated standard deviations

[11] The sign of the estimated standard deviations is irrelevant: interpret them as being positive

of the coefficients are statistically significant, indicating that the model captures unobserved heterogeneity among the respondents. Literally the result shows that firms prefer less frequent outage, shorter duration of outage, prefer private provider compared to public and public private partner, dislike daytime outage and prefer to pay less cost for improvement.

With regard to power supplier attribute, we want to value firms' attitude and preference towards providers and check weather power provider ownership matter or not. This is because the level of confidence in the electricity provider might also explain the degrees of WTP for service improvement (Abdullah and Mariel, 2010). Our results show that firms prefer to get power supply from private operator compared to that of public and public private partner modality. This result reflects their attitude towards the existing power provider firms (public) related to the imaged private operator had it been in place to provide the services. This result is in line with the findings of Townsend (2000) which indicate that the WTP is lower in countries where the quality of service continues to remain poor after the price is increased. Given the chronic nature of outages in Nepal and North Cyprus, most people prefer to invest in coping measures than paying more for power service improvement due to the reason that majority of customers have low or very low confidence in their existing electricity provider. These negative attitudes towards the existing service provider and the level of confidence towards the electricity provider need to be considered when appraising the option of power outage service improvement and when considering an increase in tariffs to cover for the investment costs involved.

With regard to time of outage, firms dislike daytime outage significantly taking random blackout as a base. This also seems logical since most of the economic activities are carried out during day time including labor mobility, transportation, marketing and other services. Because of this, firms do not want to face power interruption during day time.

The main point of our interest lies in estimating the marginal willingness to pay for the four outage attributes: frequency, duration, time of outage and provider ownership. The marginal willingness to pay for all attributes is presented in Table 7.

Table 7: Marginal WTP estimates in ETB per kwh/month and Total cost of outages (ETB/month)

Attributes	Marginal WTP (ETB per kwh)[12]	Marginal WTP (ETB per month)	Total cost of outages (ETB/month)[13]
MWTP in ETB per kwh			
Frequency	1.50	1777.5	19553
Duration	4.48	5308.8	26544
Government provider	0.20	239.37	239
Public private partnership provider	4.53	5368.05	0
Day time	5.30	6280.5	5006
Evening time	1.81	2144.85	435

Table 7 shows the marginal willingness to pay and average monthly willingness to pay for each attribute. Companies are willing to pay an average of 1.5 ETB per kilowatt-hour for a unit reduction in the number of monthly outages. This amount corresponds to approximately 223 percent of the current kWh price of electricity. Regarding the duration attributes, companies are willing to pay an average of 4.48 ETB per kilowatt-hour to reduce the average outage by one hour. Compared to the current electricity tariff, it is 668 percent of the price per kilowatt hour of electricity. Regarding the attribute of downtime, companies are willing to pay an average of 5.30 ETB per kilowatt-hour to reduce a one-unit day time power outage. In terms of power provider ownership, companies are willing to pay 0.20 ETB/kwh to replace the current state energy source and 4.53 ETB/kwh to avoid a potential PPP supplier. This may seem that firm's attitude towards fully or partially government owned operators is not preferred compared to the private provider. We then calculate the marginal WTP of each attribute in ETB per month using the average monthly electricity consumption of the sampled firms (1185 kWh). The results of this analysis are shown in column 3. We also estimate willingness to pay for the total downtime cost per month. To do this, the total amount is added by multiplying the marginal WTP estimate by the total number of power outages, the marginal WTP estimate by the average duration, the marginal WTP estimates

[12] Calculated by stata command '*wtp price_kwh $randvars',* following random parameter logit estimation. In some cases, we have used (divides Coeff of attributes by coefficient of cost). In order to get Monthly MWTP for each attribute, we multiplied MWTP for each attribute by average cost of power in that sector in birr (from descriptive statistics)

[13] Total cost of power outage is calculated as multiplying MWTP estimates for each attribute per month by total number of current scenarios.

for provider ownership by the number of current providers, the marginal WTP estimates for time of outage by the average frequency of time of outage per month. This estimate is then multiplied by the average monthly electricity consumption (1185 kWh/month) so we have a measure in ETB per month. The total monthly cost of power outage for the average firm is ETB 51,777 ($976)[14]. This means a ninefold increase from the current average monthly electricity bill for firms. Outage costs estimated to be 2.22 percent of the firm's monthly sales.

This finding is in line with the finding of Carlsson et al., (2020) who have investigated the cost of power outage in the case of Addis Ababa. However, in the current study we have considered broader attributes of power outage including time of outage and ownership of provider and the area of the study is also out of the capital where we believe that the problem of power outage is severe for manufacturing firms. Thus, regardless of the time differences, study area differences and inflation issues, the firms' monthly cost of power outage on average is estimated to be 51,777 ETB/month whereas study by Carlsson et al., (2020) found that the average cost of power outage were 2293 ETB.

Mixed logit model relaxes assumption of coefficient distributions and hence the distribution of the individual-level coefficient for price per kwh is depicted as below density distribution curve. The density distributions seem rising as price per kwh increases for manufacturing firms (Figure 4).

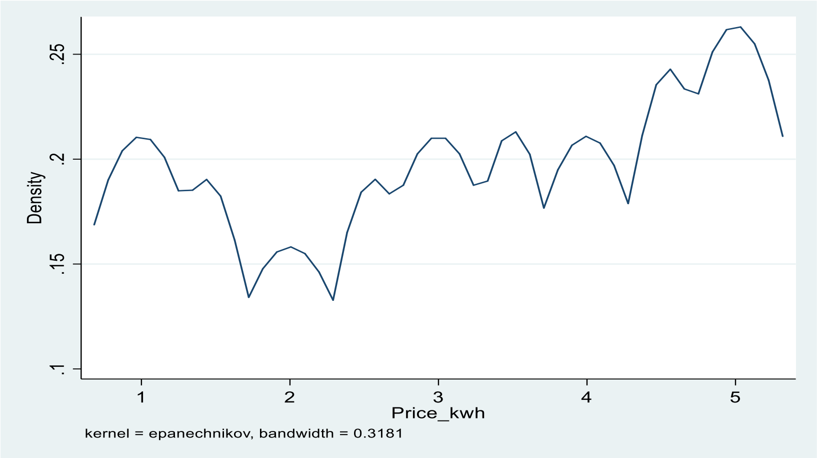

Figure 4: Density distribution of price level coefficient

[14] The summation of each product of marginal WTP coefficient by average monthly consumption of power in kwh (1185 kwh) times the current scenario of outage attributes

4.3. Observed heterogeneity in preferences

So far, we have focused on sample means. This gives decision-makers only limited insight into how to prioritize investments in the energy sector. Indeed, it is important that decision makers know and understand the heterogeneity, if any, in blackout costs depending on the different characteristics of firms. To shed light on this, we examine two important aspects of firm characteristics—size and sector type—to estimate separate models for different groups of firms

4.3.1. Firm size

Firm size is one aspect that can correlate with outage costs, and this criterion can be important for decision makers when planning investments. For example, small businesses (6-10 employees) may not have sufficient financial resources to invest in backup generators, while medium-sized (11-99 employees) and large (more than 99 employees) firms are more likely to have the financial resources. On the other hand, medium and large firms can be very dependent on electric service, so that even the use of backup generators will not meet their needs during a power outage. In this case, these groups may suffer higher downtime costs than small businesses. The estimated models for the three groups are presented in Table 8 and the corresponding MWTP estimates in Table 9.

Table 8: Results of the Mixed logit model for different firm sizes

	Small enterprises		Medium enterprises		Large enterprises	
	Coef.	Std dev[15].	Coef.	Std dev.	Coef.	Std dev.
Frequency	-.513*	.002	-.572***	.327*	-.834***	.224 *
	(.271)	(.221)	(.191)	(.178)	(.251)	(.103)
Duration	-1.388**	.741**	-2.017***	.218*	-1.398 ***	.915*
	(.623)	(.279)	(.234)	(.103)	(.381)	(.492)
Govt provider	1.585**	1.486*	-1.299***	.389**	-.628*	.075*
	(.763)	(.789)	(.473)	(.173)	(.360)	(.043)
PPP provider	-.549***	.857	-2.524***	.452	-1.906**	.025
	(.099)	(2.233)	(.621)	(.312)	(.925)	(.538)
Day Time	-2.837*	.027	-1.412**	.435	-1.822*	.005
	(1.720)	(.567)	(.575)	(.556)	(1.009)	(.616)
Night-time	.203	.0009	3.280***	.453	.691*	2.317***
	(1.192)	(.405)	(.623)	(.531)	(.345)	(.882)

[15] The sign of the estimated standard deviations is irrelevant: interpret them as being positive

Cost (in ETB/ kwh)	-.632* (.328)	.122* (.058)	-.189* (.094)	.214 * (.109)	-.296* (.160)	.256* (.140)
Log-likelihood	-55.88		-126.76		-73.64	
LR chi2(6)	24.99		286.32		34.62	
Prob > chi2	0.0001		0.0000		0.0051	
Observations	160		240		200	

Note: Standard errors in parenthesis. ***, **, * denotes significance at 1%,5% and 10% levels, respectively.

The mixed logit result for firm sizes shows that majority of the attributes of power outages remain statistically significant with negative signs for all firm sizes. Furthermore, almost all the estimated standard deviations of the coefficients are statistically significant, indicating that the model captures unobserved heterogeneity among the respondents. With regard to power provider attribute small firms prefer government provider unlike other medium and large enterprises. With regard to all other attributes the results seem similar and as expected with regard to sign.

Table 9: Marginal Willingness to Pay estimates by firm sizes

Attributes	Small	Medium	Large
MWTP in ETB per kwh			
Frequency	0.81	0.47	2.82
Duration	2.2	1.61	4.73
Government provider	2.51	1.43	2.12
Public private partnership provider	0.87	0.99	6.45
Day time	4.49	2.39	6.16
Night time	0.32	0.76	2.34
MWTP in ETB per month[16]			
Frequency	807.57	474.82	4122.84
Duration	2193.40	1616.80	6915.26
Government provider	2502.47	1432.88	3099.44
Public private partnership provider	867.39	996.30	9429.90
Day time	4476.53	2402.82	9005.92

[16] Average power consumption of small, medium and large manufacturing firms is estimated to be 997, 1004.5, and 1462.5 kwh per month, respectively. We multiplied this average power consumption by each attributes marginal willingness to pay to get MWTP in ETB per month for each attribute.

Night time	319.04	766.47	3421.08
Total cost of power outage per month in ETB	25985.3	16810.5	90899.18

Table 9 shows that small firms have the highest marginal willingness to pay in ETB per kwh for frequency, duration, government owner operator, day time outage attributes compared to medium sized enterprises. By the same fashion the total cost of power outage per month in ETB is highest for small firms (25985.3 birr per month) compared to that of medium sized enterprises (16810.5 birr per month). This may be due to the reason that small firms may not afford to invest in alternative energy backup while that of medium sized could able to invest on it. On the other hand, large sized enterprises do have highest marginal willingness to pay for all attributes compared to both small and medium sized enterprises. The average cost of power outage per month for large manufacturing enterprises is 90899.9 birr per month.

We tested the differences using *t*-statistics. For the duration, frequency, government ownership and daytime outage attributes, the MWTP differences are statistically significant at 5 percent, for all comparison between small, medium and large-sized enterprises. The differences in MWTP for the public private partnership as an operator and nighttime outage attribute are statistically significant only between medium and large enterprises.

The bottom panel of the table shows the estimate of MWTP in Birr per month for each firm size group. Since these values are obtained by multiplying the MWTP birr/kWh by the average monthly electricity consumption of each group, we observe a different pattern when we compare the groups. Contrary to the claims of Carlsson et al. (2020), medium-sized companies have the lowest monthly MWTP in Birr and the lowest monthly power outage costs in Birr for all indicators. On the other hand, large companies have the highest MWTP in Birr and the highest monthly downtime costs in Birr across all attributes. These differences in average electricity consumption between groups are the main driver of the pattern observed in the MWTP Birr months figure. Thus, power outage costs are significantly higher the larger the firm is, and relatively lower the medium the firm is, as opposed to the smaller the firms are.

4.3.2. Industry sector

The production process and electricity dependence can vary between industries, which in turn can affect downtime costs. We therefore divide our sample into five sectors based on the definitions of the Central Statistical Agency of Ethiopia: food and beverage; textiles and clothing; leather and leather products; metal and metalwork manufacturing product; and wood and furniture industry. The results of the mixed logit models are shown in Table 10 and the MWTP values in Table 11.

Table 10: Mixed logit model for different industry sector

	Food and beverage industry		Textile and garment industry		Leather and leather product industry		Metal and metal product industry		Wood and furniture industry	
	Coef.	Std dev.	Coef.	Std dev.	Coef.	Std dev.	Coef.	Std dev.	Coef.	Std dev.
Frequency	-.384** (.188)	.205* (.098)	-.019 (.192)	.192 (.204)	-.517* (.277)	.002 (.236)	-.667** (.263)	.212 (.203)	-.677** (.273)	.970* (.443)
Duration	-1.591*** (.362)	.555* (.295)	-2.086*** (.283)	1.208* (.674)	-1.298*** (.461)	.691 (.518)	-1.055*** (.225)	.228* (.112)	-1.065*** (.235)	.428* (.211)
Govt provider	.142 (.384)	.005 (.715)	2.653*** (.659)	.664* (.324)	.726 (.529)	.071 (1.431)	1.370** (.652)	.654* (.314)	1.360** (.642)	.753* (.374)
PPP provider	-1.108 (.707)	.004 (.411)	3.108*** (.766)	.312* (.163)	.026 (.785)	.669 (.948)	-2.363* (1.311)	.322* (.153)	-2.368* (1.308)	.319* (.159)
Day Time	-.877 (.834)	.016 (.395)	-1.511*** (.503)	.621* (.313)	-2.634*** (.925)	.32095 (.864)	-1.120 (.911)	.321 (.314)	-1.124 (.909)	.221 (.213)
Night Time	.989 (.907)	.968* (.498)	-2.827*** (.672)	.934* (.524)	.096 (.828)	.474 (.422)	1.861* (.960)	.635 (.587)	1.859* (.957)	.535* (.286)
Cost (ETB/kwh)	-.348** (.129)	.287* (.143)	-.671*** (.179)	.716** (.289)	-.393* (.188)	.235* (.117)	-.096* (.343)	.626* (.299)	-.295* (.142)	.426* (.199)
Log likelihood	-104.28		-111.58		-45.23		-52.33		-50.33	
LR chi2(6)	52.28		220.45		10.95		82.30		79.30	
Prob > chi2	0.0020		0.0000		0.0073		0.0000		0.0000	
Observations	240		80		120		80		80	

Table 10, shows results of mixed logit model for industry sector and it shows that attributes of power outage such as frequency, duration and cost per kwh are statistically significant with negative signs across all industry sector. Furthermore, most of the estimated standard deviations of the coefficients are statistically significant, indicating that the model captures unobserved heterogeneity among the industry.

Table 11: Marginal Willingness to Pay for attributes by industry sector measured in ETB/kwh

Attributes	Food and beverage industry	Textile and garment industry	Leather and leather product industry	Wood and furniture industry	Metal and metal product industry
MWTP in ETB per kwh[17]					
Frequency	1.1	0.028	1.31	2.29	7.13
Duration	4.6	3.109	3.3	3.61	11.21
Government provider	.41	3.95	1.85	4.61	14.32
PPP provider	3.18	4.63	.07	8.03	24.93
Day time	2.52	2.25	6.7	3.81	11.83
Night time	2.84	4.21	.24	6.30	19.57
MWTP in ETB per month[18]					
Frequency	1354.41	27.87	2375.03	149.17	7391.01
Duration	5663.92	3094.79	5982.90	234.66	11626.92
Government provider	504.83	3931.94	3354.05	299.66	14847.52
PPP provider	3915.49	4608.83	126.91	521.76	25852.15
Day time	3102.84	2239.71	12147.10	247.66	12271.04
Night time	3496.85	4190.75	435.12	409.61	20295.25
Total cost of power outage per month in ETB by sector	46905.79	22348.23	69163.45	3394.37	168183.16

[17] Calculated by stata command '*wtp price_kwh $randvars',* following random parameter logit estimation. In some cases, we have used (divides Coeff of attributes by coefficient of cost). In order to get Monthly MWTP for each attribute, we multiplied MWTP for each attribute by average cost of power in that sector in birr (from descriptive statistics)

By the same fashion here we also estimate both the marginal willingness to pay in birr per kWh and the marginal willingness to pay in birr per month for each of the industry sectors. Column 6 in the top panel shows that firms in the metal and metal processing sector have the highest MWTP per kWh for all the attributes. For instance, for the firms in the food and beverage sector, the MWTP per kWh corresponds to a 164 percent, 686 percent, and 376 percent increase in the electricity price to reduce the average number of outages from 11 to 10 in a month, to reduce the average duration of an outage from 5 to 4 hours and to reduce a daytime outage once per month, respectively.

In the bottom panel of the Table 11 shows the MWTP in birr per month for each of the sectors, where we multiply the MWTP per kWh values by the average monthly electricity consumption of the sectors. The result shows that the wood and furniture industry sector have the lowest cost of power outage in birr per month followed by textile and food and beverage sectors. On the other side, the metal and metal product industry and the leather and leather processing industry have the highest cost of power outage in birr per month considering all attributes.

5. Conclusion and Policy Implications

Firms in many developing countries suffer from blackouts, which are characterized by random, frequent and prolonged power outages that make it difficult to plan and execute production operations. Thus, understanding the costs associated with unreliable electricity supply is particularly important for policy makers and new investors planning to invest in the energy sector. In the past, a different approach was used to estimate the costs of power outages for businesses. Most studies to date have used the revealed preference method. However, in many developing countries, firms' expenditure on equipment to cope with outage (such as backup generators) may be limited by credit market imperfections, increasing the need to supplement revealed preference approaches with stated preference. To date, only a few studies have used stated preference. A detailed and in-depth analysis of the subject is lacking in sub-Saharan Africa, and especially in Ethiopia, where unreliable electricity service is one of the most important obstacles to economic growth and industrialization.

This study estimated the economic costs of power outages for industrial enterprises in Ethiopia, especially in the South eastern industrial areas (area where power outages frequently occur). The survey covers small, medium and large enterprises, including various industries such as food and beverages, textiles and clothing, leather and leather products, metal and metal products, and wood and furniture. To do this, we performed a choice experiment and estimated the mixed logit model. The electricity service improvement proposal implemented in our choice experiment included four different components: number of outages experienced per month, average duration of a typical outage, time of outage per month and ownership type of electricity producer. The study notes that manufacturing companies located outside the capital (south east industrial areas) incur significant economic costs due to power outages. The average cost of outages for a firm is ETB 51,777 ($976) per month, nine times the current average monthly electricity bill. Downtime costs also account for 2.22 percent of the firms' monthly sales. Our results show considerable heterogeneity by size and industry.

The following policy implications can emerge from the obtained results. The costs of power outages have been found to be significant and companies are generating their own electricity to deal with power shortages. In addition, firms are willing to pay to avoid disruptions. This shows that there is a market for an expensive and reliable energy source, suggesting the investment on more power plants and distribution system (allocation efficiency) to produce reliable electricity. This can be achieved in several ways. One could be to eliminate subsidies and establish optimal tariffs that are cost recovering for new grid investment. Because the electricity tariff rate of Ethiopia is too low (0.01 USD per kwh), compared to other African countries. It can also attract international and private investors to the sector. The government should also introduce incentive regulations that encourage the private sector to participate in power generation and distribution.

In addition to building more power plants and distribution system, the government should optimize diversification of source of electricity in order to liberate our industries from rainfed dependence and improve reliability. So far 90 percent of Ethiopia electricity generation is from hydro followed by 7.6 percent from wind. If there is no rainfall there will be shortfall of electricity that makes firms to stop production. This should be changed from the scratch in the long run.

The government should also make blackout schedule reliable (try to make it during night time since majority of firms are at shutdown at night time) as it may help firms to shift their productions from machinery dependent to manual methods and makes the necessary preparation.

At last, but not least in addition to self -investing on power-generating activities, firms should re-optimize among production inputs by substituting materials for energy. Firms should re-optimize among inputs by substituting materials for energy and shifts from make to buy of intermediate inputs due to a shortage of electricity in order to reduce economic cost of power outage.

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Appendix A: Choice Experiment Scenario

In the following, we describe the scenario we present to the respondents in our choice experiment. Now I will ask you about your firm's willingness to pay to reduce power outages. It is known that there are discussions in the country about improving the electricity service through the necessary investments. Ethiopian Electric Utility is considering investments such as construction of new dams (GERD), improvement of grid networks, improvement of existing transmission and distribution lines, decentralization and improvement of energy source and improvement of customer service in case of technical failures. In addition to the existing electricity service provider in Ethiopia, you can also think about possible private or public-private partnership formats entering the market to provide electricity supply. These investments are expected to reduce the frequency and duration of unexpected power outages during your usage period. If the power failure must be due to a shortage, the electric power provider may consider time of outage based on your choice. These investments are expensive and would lead to an increase in electricity prices. To find out what customers think about outages, we ask you several questions. First of all, we ask you to make rank or choice among different power supply alternatives. Each alternatives describes the frequency of outages, duration, time of outages and owner of the electricity supply during a typical month, as well as the cost of electricity in Birr per kWh. Click the options you are most likely to like (first) to least popular, including the status quo. I'll give you an example of choice/rank card.

Table: Rank /choice set 1

Power Alternatives	Frequency of outage / month	Duration of outage	Time_of _outage	Power supply owner	Price_per_kwh	Rank /choice (1st, 2nd ,3rd ,4th)
Alt 1	7 times	1 hour	Daytime	Public private partnership	1.08	
Alt 2	5 times	2 hours	Nighttime	Private	1.22	
Alt 3	9 times	3 hours	Daytime	Government	0.94	
Alt 4	Existing power service					

In Alternatives 1, 2 and 3, investments are made to affect power outages, which also means an increase in the cost of electricity. We discuss improvements to power outages and associated cost increases; a summary of each option follows. In the case of the 1st option, the frequency of power outages decreases 7 times, the average length of each outage is 1 hour. However, the outage is during the day time and the electricity supplier is a public-private partnership. With this investment, the price of electricity will increase to 1.08 birr per kilowatt hour.

Option 2 reduces the frequency of power outages to 5 times, the average duration of each outage is 2 hours, the outage is at night, and the power producer is a private firm. With this investment, the price of electricity will rise to 1.22 birr per kilowatt hour. In Alternative 3, the frequency of power outages is reduced to 9 times, the average length of each outage is 3 hours, the outage is a day time, and the power producer is a national operator (gov't provider). With this investment, the price of electricity will increase to 0.9 birr per kilowatt hour. For option 4, this describes the situation if no action is taken. If improvements are not made, you are predicted to experience an average of 11 blackouts per month, each averaging 5 hours of outages, black out randomly and provided by government operator. The price of electricity is the same as today (0.67 Birr per kWh).

We want to know what you like about these options/alternatives. We ask you to make five such choices or ranks. Remember that the choice you make affects only the frequency, length, time, type of service provider and electricity rate of power outages. everything else remains unchanged. The government is committed to ensure that funds from tariff increases are used only to improve electricity service. Experience from previous research shows that people often report that they do not want to pay to improve their current condition, not because they do not want improvement, but for other reasons. We believe that sometimes this may be due to the belief that they have the right to uninterrupted electricity or that resources are not being used for their intended purpose. However, please don't think like that when choosing alternatives. You may have other reasons for reacting this way. If you have any thoughts on this, please clarify after your selection.