Analysis of the cost of infrastructure failures in a developing economy: The case of the electricity sector in Nigeria

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AERC Research Paper 148
African Economic Research Consortium, Nairobi
February 2005

Published by: The African Economic Research Consortium
P.O. Box 62882-00200
Nairobi, Kenya

Printed by: The Regal Press Kenya, Ltd.
P.O. Box 46166-00100
Nairobi, Kenya

ISBN 9966-944-59-1

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Acknowledgements

I wish to express my deep appreciation to AERC for the financial support to carry out this research. I am also grateful to the resource persons and members of AERC's Group AT for various comments and suggestions that have helped the evolution of this study from its very beginning to this stage. Two anonymous referees who reviewed the paper provided perceptive comments that have been quite useful in improving the overall quality of the paper. I am, however, responsible for all the remaining errors.

Abstract

Infrastructure has been identified as the key constraint to private sector development in Nigeria. Hence, this study analysed the cost of power outages to the business sector of the Nigerian economy using both a survey technique and revealed preference approach. One strong outcome of the study is that the poor state of electricity supply in Nigeria has imposed significant costs on the business sector. The bulk of these costs relate to the firms' acquisition of very expensive backup capacity to cushion them against the even larger losses arising from frequent and long power fluctuations. Small-scale operators are more heavily affected by the infrastructure failures as they are unable to finance the cost of backup power necessary to mitigate the impact of frequent outages. The small-scale operators that could afford to back up their operations have to spend a significant proportion of their investment outlay on this. The study advocates for institutional reforms of the power supply sector in Nigeria.

1. Introduction

It is fairly settled in the literature that infrastructure plays a critical and positive role in economic development. Infrastructure interacts with the economy through multiple and complex processes. It represents an intermediate input to production, and thus changes in infrastructure quality and quantity affect the profitability of production, and invariably the levels of income, output and employment. Moreover, infrastructure services raise the productivity of other factors of production (Kessides, 1993).

The provision of infrastructure in most developing countries is the responsibility of the government. This is because of the characteristics of infrastructure investment. First, infrastructure supply is characterized by high set-up cost. Its lumpiness and indivisibility precludes the private sector from investment. Second, its indirect way of pay-off, coupled with its long gestation period, makes it generally unattractive to private investors. Moreover, provision also generates externalities that the producer may not be fully able to internalize in the pricing structure. Thus, in the face of other numerous competing, less risky and more familiar investment opportunities offering the promise of higher and quicker returns, few private investors are willing to embark on infrastructure investment (Ajayi, 1995).

However, the nearly exclusive concentration of infrastructure provision in the hands of the public sector, especially in developing countries, has led to failures in the supply of these services. Faced with declining economic fortunes and dwindling revenue, most governments in developing countries found it increasingly difficult to keep pace with adequate provision and maintenance of infrastructure. Moreover, the perception of government that economic infrastructure is a social service affected the pricing of its products and consequently the effectiveness of their provision. Besides these, the traditional inefficiency associated with public monopolies affects the quality and reliability of their services.

There are five main approaches used in the literature to infer the welfare losses from power outages. These are the production function approach, self-assessment analysis, economic welfare analysis, contingent valuation and, finally, the revealed preference approach. These methods have their relative strengths and weaknesses. They have been used widely in both developed and developing countries, especially the former, to infer outage costs. For the industrial sector, existing measure of outage costs vary between $1.27 to $22.46/kWh of unserved electricity. Residential outage costs vary between $0.02 and $14.61/kWh unserved (Caves, Herriges and Windle, 1992).

The rest of this study is organized as follows: Section 2 presents the problem statement, while Section 3 highlights the objectives of the study. Section 4 contains the literature review, Section 5 presents a review of the electricity sector in Nigeria and Section 6 contains the analytical framework for the study. The survey methodology and empirical models are presented in Section 7, followed by the analysis of survey findings in Sections 8 and 9, which contain the measurement and analysis of outage costs and regression results, respectively. The final section presents the policy implications and conclusions.

2. Problem statement

In Nigeria, poor electricity supply is perhaps the greatest infrastructure problem confronting the business sector. The typical Nigerian firm experiences power failure or voltage fluctuations about seven times per week, each lasting for about two hours, without the benefit of prior warning. This imposes a huge cost on the firm arising from idle workers, spoiled materials, lost output, damaged equipment and restart costs. The overall impact is to increase business uncertainty and lower returns on investment. For the aggregate economy, this has seriously undermined Nigeria's growth potential and the attractiveness of the economy to external investors.

The National Electric Power Authority (NEPA) is the public utility vested with the responsibility of electricity supply in Nigeria. However, the failure of NEPA to provide adequate and reliable electricity to consumers despite billions of naira of investment expenditure has generated a confidence crisis in the industry. Public confidence in NEPA's ability to supply uninterrupted and stable electric power is so low that consumers have coined a term for the organization's acronym NEPA as "Never Expect Power Always". The inefficiency of NEPA imposes a huge cost on the economy. In 1990, the World Bank estimated the economic loss to the country from NEPA's inefficiency at about N1 billion.

There are essentially five ways by which firms may respond to unreliable electricity supply. These are choice of location, factor substitution, private provision, choice of business and output reduction. While all these elements are presently observed among Nigerian firms, the most common approach has been through private provision. Electricity consumers have responded to NEPA's inefficiency through self-generation. Electricity users, both firms and households, now find it necessary to provide their own electricity in part or in whole to substitute or complement NEPA supply by factoring generator costs into the overall investment cost, thus raising significantly the set-up cost for manufacturing firms operating in the country. Incidentally, indigenous, small-scale enterprises are worse affected. Lee and Anas (1991) report that small-scale enterprises spend as much as 25% of the initial investment on self-provision of a generator. Banks also insist that firms seeking project loans must make provisions for investments in captive generating equipment (Ajayi, 1995). This affects the range of profitable investment available to budding entrepreneurs, raises cost of production, reduces cost competitiveness of local production and represents a loss of revenue to the electricity monopoly.

Electricity, strictly speaking, is not a private good. The sector is characterized by high set-up costs and increasing returns to scale that permit at most very few producers. However, the legislation setting up NEPA effectively bars private operators from the markets and thus prevents such possibilities as joint production and pooled supply, satellite behaviours by private firms that could have led to shared costs and guaranteed reliable supply of electricity. Thus, there are big firms with huge excess scale that are not allowed to sell their excess production to other firms.

One implication of the existing electricity market structure is that NEPA, by taking advantage of the huge economies of scale in the industry, is able to supply electricity at much lower cost than private provision. This cost differential is large, sometimes running to over four times. A 1983 joint UNDP/World Bank study estimated a cost differential of 16–30% for large industrial establishments in the country with auto-generation. In spite of this large cost differential, however, over 90% of Nigerian manufacturers make provision for auto-generation. The relevant question then is, Why are manufacturers willing to incur such a huge extra costs for self-generation? Is it possible that the manufacturers are perfectly rational agents who are willing to incur the extra cost of auto-generation as an insurance against the larger costs from power outage? An understanding of the behaviour of the firm is important in proffering policy recommendations to solve their energy problems. In addition, an analysis of outage costs may provide useful data for measuring the willingness of consumers to pay for reliable electricity supply, measure the inefficiency of NEPA and hence form a basis for reform of the public monopoly.

A few studies have tried to measure the cost of electric power shortages in Nigeria. These include Ukpong (1973), Iyanda (1982), Lee and Anas (1991, 1992), Uchendu, (1993) and Ajayi (1995). Our study is different from these studies in two important respects – the methodology and the scope. Our methodology combines the benefits of the revealed preference and survey techniques. The principle of revealed preference implies that the cost of an outage may be inferred from the actions taken by consumers to mitigate losses induced by unsupplied electricity. Investments in backup generators may then be used to impute the costs incurred by power outages. In addition, we also investigate the factors underlying the behaviours of consumers in the attempt to mitigate outage losses. We complement the results from the revealed preference methodology with those obtained from subjective valuation. The survey technique enables us to measure the impact of outage characteristics on outage costs. In terms of scope of coverage, the study focuses on a disaggregated analysis of the manufacturing sector of the Nigerian economy. This enables us to examine the differential impact of outages across the various subsectors of the manufacturing sector, and across sizes and locations.

3. Objectives of the study

The central purpose of this study is to examine the cost of infrastructure failures on the performance of the Nigerian manufacturing sector, using the case of the electricity sector, and to understand the behaviour of firms in adapting to the uncertain business environment.

The specific objectives of the study are to:

- Provide an overview of the structure of the electricity market in Nigeria especially as it relates to the manufacturing sector.
- Characterize electricity outages in Nigeria and the impact on the Nigerian manufacturing sector.
- Estimate the losses that firms would have incurred from total dependence on NEPA and compare them with costs of auto-generation.
- Determine whether the losses from electricity outages display any sectoral, size or locational differences across the various manufacturing subsectors.

4. Review of the literature on electricity outages

The poor state of infrastructure supply in developing countries has a negative impact on their economic performance. For example, Lee and Anas (1992) report that manufacturing establishments in Nigeria spend on average 9% of their variable costs on infrastructure, with electric power accounting for half of this share. Elhance and Lakshamanan (1988) show that changes in the stock of economic infrastructure have important implications for the cost structure of manufacturing firms in India. Even in the informal sector, infrastructure can be a major share of business expenses (e.g., in Zimbabwe, transport accounted for 26%, the largest single item, according to Kranton, 1991).

Similarly, a 1987 study focusing on the effects of power outages in Pakistan estimated that the direct costs of load shedding to industry during a year, coupled with the indirect multiplier effects on other sectors, resulted in a 1.8% reduction in GDP and a 4.2% reduction in the volume of manufactured exports. In India, a 1985 study concluded that power outages were a major factor in low capacity utilization in industry, and estimated the total production losses in 1983/84 at 1.5% of GDP (USAID, 1988). Similarly, power rationing in Colombia was estimated to reduce overall economic output by almost 1% of GDP in 1992 (Kessides, 1993).

Usually small firms bear a relatively higher cost of infrastructure failures. Lee and Anas (1992) in a 1988 study of 179 manufacturing establishments in Nigeria found that the impact of infrastructure deficiencies of all types was consistently higher for small firms. Private infrastructure provision (for generators, boreholes, vehicles for personnel and freight transport, and radio communications equipment) constituted 15% of total machinery and equipment costs for large firms (over 50 employees), but 25% for small firms. Small firms were found to generate a larger percentage of their power needs privately than larger firms and to pay a higher premium for doing so, as measured by the excess costs of privately generated power over that of publicly provided.

Other enterprise level surveys conducted in several countries have found that infrastructure costs and problems of unreliability rank high among issues in the business environment. A 1991 survey of small enterprises in Ghana cited power outages, transportation costs and other infrastructure problems among the top four problems of operations (behind taxes), with this response strongest among "micro" and small firms. Electricity outage was ranked by very small firms among their top four constraints to expansion (Steel and Webster, 1991). Thus, the issue of infrastructure supply – its adequacy and reliability – is very important for the overall performance of the business sector and deserves policy attention.

The theoretical basis for estimating electricity outages is that there is a consumer welfare loss when there is electric power failure. Quite a number of studies have examined the cost of outages using the various approaches noted earlier. However, until recently many of these studies focused on the developed countries, which have less actual experience of outage failures. Moreover, there are significant differences in the methodologies used, leading to highly disparate results regarding the cost of service interruptions. Finally, fewer studies have focused on the impact of the characteristics of outage cost such as the warning time, outage frequency and partial outages.

Table 1 provides a summary of the literature on outage costs estimates. These estimates vary significantly according to the choice of methodologies and reporting system used. The proxy methods have yielded estimates that are generally lower than those reported by the survey methods. For the industrial sector, existing studies put the cost of interruptions in the range of $1.27 to $22.46/kWh of unserved electricity. Residential outage costs vary between $0.02 and $14.61/kWh unserved.

In the case of commercial sectors of the economy, outage costs range from $5.02 in the retail service sector to $21.73kWh for office buildings. The evidence points to significantly lower outage cost for government agencies and institutions (Caves et al., 1992).

Table 1: A typology of selected previous studies

Study		Country	Sector	Methodology
1.	Bental and Ravid (1982)	USA and Israel	Industrial	Proxy method (generator)
2.	Bernstein and Heganazy (1988)	Egypt	Industrial (production)	Proxy method
3.	Billinton, Wacker and Wojczynski (1982)	Canada	Residential	Survey
4.	Caves, Herriges and Windle (1992)	USA	Industrial	Proxy method
5.	Matsukawa and Fujii (1994)	Japan	Financial & communication	Proxy method (generator and UPS)
6.	Ontario Hydro (1977)	Canada	Industrial	Survey
7.	Billinton, Wacker and Wojczynski (1982)		Canada	Industrial Survey
8.	Ontario Hydro (1980)	Canada	Industrial	Survey
9.	Doane, Hartman and Woo (1988)	Canada	Residential	Survey
10.	Ukpong (1973)	Nigeria	Industrial (production)	Proxy method
11.	Iyanda (1982)	Nigeria	Residential	Survey
12.	Uchendu (1993)	Nigeria	Industrial	Survey
13.	Lee and Anas (1992)	Nigeria	Industrial	Survey
14.	Beenstock, Goldin and Haitovsky (1997)	Israel	Business & public	Proxy method (generator)

Source: Compiled by author.

Another study reported by Billinton et al. (1982) and Ontario Hydro (1980) on the sectoral variation in outage costs yielded similar conclusion. Residential outage costs are found to be at the lower end of the spectrum, with costs less than one-third of those estimated for industrial and commercial consumers. Industrial outage costs are consistently lower than those in the commercial sector, but the differences are not large. However, government and institutional costs are consistently placed between those for residential and industrial sectors, while office buildings and large farms have outage costs well in excess of those for the commercial sectors.

Some studies have also considered the varied impact of outage characteristics on outage costs. Power outages can be characterized along a number of dimensions, including duration, frequency, timing, warning time and interruption depth. Each of these characteristics potentially alters the outage costs incurred by a customer. Billinton et al. (1982) and Ontario Hydro (1980) report that firms experience high outage costs initially. However, these average hourly costs diminish rapidly as duration increases, levelling off at about 50% of a 1-hour interruption.

Table 2: Estimated outage costs in selected previous studies (US$ per kwh)

Country	Cost	Source
United States	0.57	Telson, 1975
Israel	1.67	Telson, 1975
Israel	0.21	Bental and Ravid, 1982
USA	1.16	Bental and Ravid, 1982
Israel	7.20[a]	Beenstock, Goldin and Haitovsky (1997)
USA	11.20[a]	Caves, Herriges and Windle (1992)
Japan	118-149[b]	Matsukawa and Fujii (1994)

Notes: a. Measured at 1991 prices.
b. Measured at 1988 prices.

The relationship between outage costs and outage frequency has received less attention in the literature. The available results indicate that total outage costs are not proportional to outage frequency, but rather decline per interruption as frequency increases. This pattern suggests that customers may be able to adapt to more frequent outages. Customers also prefer infrequent outages to frequent outages. Studies by Billinton et al. (1982) and Ontario Hydro (1980) among industrial and commercial sectors reveal that these consumers prefer infrequent long duration interruptions (e.g., one 4-hour interruption) to frequent short duration interruptions (e.g., four 1 hour interruptions). However, the reverse result was reported for residential consumers. Similarly, outage costs have been found to vary with the timing of the power interruptions. Large industrial firms exhibit little variability in estimated outage costs, while small firms exhibit a definite seasonal pattern.

Virtually all of the industrial and commercial outage cost studies attempted to measure the variation in outage costs by industrial classification. Billinton et al. (1982) reported outage costs for 15 industrial classifications. One-hour outage costs range from $2.00/average kWh for mineral fuels and paper and allied industries to over $60.00/average kWh for leather industries. Ontario Hydro (1977) reports similar results for 12 industry groups with less variation in the outage costs among groups.

However, Caves et al. (1990) observed some limitations with these studies. First, industry specific outage costs are typically based on few observations (i.e., fewer than ten) so that differences between them may not be statistically significant. Second, much of the variation in outage costs by industrial category may reflect differences in load factors across groups.

Industrial firms with self-generation capabilities have lower outage costs. Self-generation is found to lower the probability that customers may assign positive costs to an outage, and to reduce costs by approximately 40% given outage costs are positive. Backup power is found to increase the probability of a positive outage cost, but to reduce the level of outage costs by 0.03% for each 1% of backup power capabilities.

Perhaps the earliest study on the costs of power outages to the industrial and commercial sector in Nigeria was carried out by Ukpong (1973). He used the production function approach to study power outage costs in the two years, 1965 and 1966. Using a sample of 38 firms, he estimated unsupplied electrical energy to be 130 kWh and 172 kWh in 1965 and 1966, respectively. The corresponding costs of the power outages to the industrial sectors in the two years were estimated at N1.68 million and N2.75 million, respectively.

The shortcomings of this study include: first, he used aggregated data for the manufacturing sector and thus omitted subsector effects of the power outages; second, the study focused on output loss for unsupplied electricity and thus ignored other important costs such as raw material and equipment spoilage and the cost of auto-generation.

Iyanda (1982) adopted the self-assessment methodology to estimate the impact of power shortages on the household sector. He focused on the high-income area of Lagos Island, Ikoyi, Victoria Island, Yaba and Surulere areas of Lagos state in Nigeria. He estimated an average electricity outage cost of N1.19 per hour for each household.

A similar framework of analysis was reported in Uchendu (1993), but the focus was on the industrial and commercial firms in Lagos state through a survey covering various industrial sectors. The study estimated several types of outage costs such as on material and equipment loss and value of unproduced output. The value of unproduced output was estimated at N1.3 million, N2.01 million and N1.32 million in 1991, 1992 and mid-1993, respectively. However, the study suffers from the methodological limitations of self-assessment data and was limited only to Lagos state.

World Bank (1993b) estimated the adaptive costs of electricity failure on the Nigerian economy at US$390 million, divided between consumer backup capacity (US$250 million), operating and maintenance costs of diesel auto-generators (US$90 million), and fuel and lubrication (US$50 million). The estimate of NEPA revenue lost to unserved consumer energy amounted to US$40 million. However, the short-term losses incurred by consumers such as raw material and equipment spoilage and lost output were not estimated.

Finally, Lee and Anas (1991) used the self-assessment survey to measure the adaptive costs to the business sectors in coping with infrastructural deficiencies in Nigeria. Their study shows that most firms in Nigeria adapt to the unreliability of publicly provided electricity by investing in backups. The huge investment costs of the backup increases the set-up costs of these firms and thus reduces their competitiveness and relative efficiencies. One important finding of this study is that small firms have borne the brunt of power failure in Nigeria because they cannot afford personal generators. The study shares the shortcomings of World Bank (1993b) in that the short-term losses incurred by consumers arising from raw material and equipment spoilage and lost output were not estimated.

Our methodology incorporates the strengths of both the revealed preference approach and the self-assessment approach. Also quite important is that we investigated the impact of outage characteristics on outage costs, an issue that was not considered in the previous studies.

5. Structure of the electricity market in Nigeria

There are four key players in the electricity market in Nigeria: NEPA, Rural Electrification Board (REB), private licensed producers, and self-providers. The National Electric Power (NEP) Plc is the organization responsible for providing electricity throughout Nigeria. By Decree 24 of 1972, which established it, NEPA is required to conduct its business (generating, transmission and distribution of electricity) in such a way as to recover all its costs. By Decree 25 of 1988 (the Privatization and Commercialization Decree), it became one of the public enterprises slated for commercialization.

In spite of its commercialization, the public monopoly operates under very difficult circumstances. Apart from the domineering control of the government, the public perception of the organization as a social services provider has not helped matters. The total installed capacity in the country, which stood at 5,876MW in 1996, was only one-fifth that of South Africa, which was 31,000MW. Even then, Nigeria's installed capacity is nearly twice the peak demand for electricity, which was 2,452MW. In spite of this, the supply of electricity is unreliable – from the public power supplier reliability is known to be less than 50% by time nationwide.

Available information indicates that only 34% of Nigeria's population has access to the public power supply, while consumed energy per capita is only 161kWh, barely enough to light ten 40-watt bulbs for one hour each day of the year (Vision 2010). Suppressed demand is of three types: those who are not covered by the public supply (some 66% of the population), those who supplement the public supply with private power, and those who are covered but prefer to use private power for reasons of quality and security.

NEPA currently operates 78 generation units with about 40 functioning at any one time. Several factors affect the quality of the power supply in Nigeria. These include power generation limitation, declining investment in the power industry, stagnating expansion to meet rising demand for electricity, and over-aged and tired hydro and thermal plants crying out for rehabilitation. The following facts are important to note about the age of the plant, which imposes a constraint on the available capacity:

- 36% of installed capacity is over 20 years old.
- 48% of installed capacity is over 15 years old
- 80% of installed capacity is over 10 years old.

Thus most of the plant is in dire need of rehabilitation.

The distribution network consists of about 80,000 km of overhead 33kv and 11kv, as well as 15,000 sub-stations that together supply electricity to about 2.6 million customers. As at 31 December 1997, the total registered customer population was 2.62 million: 2.2 million residential customers, 410,000 commercial and 33,000 industrial customers, and about 3,000 street lighting customers. Thus the power generated is essentially for residential purposes. While energy for residential consumption is 52% in terms of generation, in terms of revenue it accounts for only 27% compared with 32.9% for commercial and 33.3% for industrial. Street lightning accounts for only 0.28%.

Ordinance No. 15 of 1950 gave the following powers to ECN, now NEPA:

- To generate, transmit, distribute and sell electric power throughout the country.
- To acquire, hold and dispose of lands for purposes of effective operation and attainment of the objective of regular power supply.
- To suspend electric power supply to consumers for such periods as may be necessary for carrying out inspections, tests or repairs and also making new connections.

During such periods of power interruption, electricity consumers have no legal recourse for damages suffered. This provided enough cover for some electric power disruption by NEPA that might emanate from its gross inefficiency, which consumers might not be able to discern from those conditions laid down.

The Ordinance also made provision for situations under which authorization to generate, distribute and sell electricity by states, private companies and individuals in the country could be granted. Given such situations, clearance could be sought from the Head of State through the Federal Ministry of Mines and Power, but authorization is subject to NEPA's recommendation. The onus is on the applicants to prove that their area is too far away to be easily connected to NEPA's power network system.

To cover – or not to admit – its inefficiency, recommendations to grant licenses to other bodies to generate/distribute electricity were rarely and reluctantly made by NEPA to the Federal government. This suggests therefore that the provision for authorization to generate electricity by other bodies was in a way restricted and controlled by NEPA. In spite of these restrictions, however, licenses were granted to the following companies under the provision:

- The Nigerian Electricity Supply Company (NESCO) to operate in some restricted areas in certain parts of the former Northern Region of Nigeria. NESCO supplied electric power to the Jos mining areas from a number of hydro-electric power stations it had. The company later sold parts of its electricity to the ECN for distribution to its customers in Jos, Bukuru and Vom.
- The African Timber and Plywood Limited at Sapele.
- The Shell Petroleum Development Company of Nigeria operating at Bonny and Delta areas.
- Ajaokuta Steel and Rolling Mill.

Thus, while electric power production from NEPA accounts for most – over 97% – of the electricity supply in the economy, this has been supplemented at various times by a relatively small amount of purchases from the excess production of some privately owned companies. The share of the other electricity supply companies is not only small, but declined from about 19% in 1960 to less than 1% in 1996 (Table 3).

Table 3: NEPA energy output, 1997

Type	Output generated (MWH)	% of generation
NEPA:		
Hydro	5,970,368	38.54
Gas turbine	2,397,119	15.47
Steam	7,049,860	45.50
Diesel plant	-	0.00
Purchases:		
NESCO	73,392	0.47
Shell Bonny	2,381	0.02
Ajaokuta	-	0.00
Total	15,493,120	100.00

Source: NEPA Annual Report (1997).

Although NEPA is the main supplier of public electricity, the state governments have also participated in the provision of electricity, dating back to the Third National Development Plan period, 1975–1980. They are restricted to supplies in the rural areas, where there is no NEPA supply, through the Rural Electrification Boards (REB). The ultimate goal of these isolated supplies, based on fossil fuels, is that they would eventually be linked to NEPA's network when feasible. There are many REBs in several states but their performance has been abysmal. The state governments could not meet the high costs of operating and maintaining these small isolated diesel-fired generating plants. Only consumers lucky enough to be absorbed into the national networks experienced electricity supply for a larger fraction of the day.

Although the legal instrument establishing NEPA vested it with the sole responsibility of electric power production in Nigeria, in practice the situation has been different because of the poor performance of the organization in the provision of adequate and reliable electricity supply. The response of the private sectors to the poor quality of NEPA's electricity supply has been widespread use of private provision of electricity. Certainly, the need to minimize the enormous cost of frequent interruptions in public electricity supply as manifested in considerable loss of output, damage to machinery and equipment, and idle labour time has aided the sustenance of the de facto situation.

In recent years virtually all major new establishments, whether privately or publicly owned commercial or individual enterprises, have undertaken substantial investment in private supply of electricity. Obviously the impact of this is to increase costs and reduce the competitiveness of the country's production both locally and in international trade.

There are essentially five ways by which firms might respond to infrastructure deficiencies:

- Choice of location

- Factor substitution
- Private provision
- Choice of sector
- Output reduction

We found evidence of all five behaviours among the firms we surveyed. However, private provision is by far the strategy most widely adopted by Nigerian firms. Piqued by the extremely poor performance of NEPA, private providers have had to make alternative private arrangements to reduce their dependence on NEPA, with the attendant losses from infrequent electricity supply. Lee and Anas (1991) identify four different private response strategies pursued by firms:

- Self-sufficiency: In this case, the firm provides its own infrastructural services to the point where it does not need any public input.
- Stand-by private provision: Here, the firm has its own infrastructural facilities in place and switches to these facilities where the quality or reliability of the public service falls below a critical level.
- Public source as standby: The firm relies primarily on its own facilities but switches to the public supply during those times of the day when the public source delivers a high quality service.
- Captivity: The firm continues to rely on the public source exclusively despite the very low reliability of such services.

In Nigeria, government regulations in the supply and trading of infrastructural services prevent the possibilities of three other mechanisms: joint production, satellite behaviour or shared production.

The unreliability of NEPA has led most manufacturers to incur extra costs for private alternatives. The generator market is very vibrant. Most small gas-powered electric generating sets in use are Japanese products (e.g., Honda, Suzuki, Yamaha). Most of these products are imported from Japan, while some are assembled in Nigeria. Holt Engineering Limited, for example, is the company assembling Yamaha generators. Moreover, many small-scale industrialists now prefer locally fabricated generating sets, which are considerably cheaper than the imported brand names. The Federal Ministry of Mines, Power and Steel is empowered to register all electricity generating sets being used in the country, but few users register with them.

6. Survey methodology and models

Here we look at the various sources of data, the rationale for the chosen research methodology, and the methodology for the analysis in terms of marginal costs of power outages and determinants of costs.

Methodology of the survey

The sample framework of the Federal Office of Statistics (FOS) provided the basis for the selection of the firms used in the survey. The sampling frame contained 2,390 manufacturing establishments. The study used a stratified random sampling method to select specific firms. The stratification was necessary to reflect the following variation: size, industry and location. The study covers three main industrial zones: the Lagos/ Ibadan axis, the Kano/Kaduna axis and the Onitsha/Nnewi/Aba axis. Besides contributing over 90% of manufacturing output in Nigeria, these zones also represent more than 66% of electricity consumption in the country. In all, 300 manufacturing enterprises were included in the survey. These are distributed as shown in Table 4.

Table 4: Distribution of target and realized sample by location and size of establishments

	Target sample	Percentage	Realized sample	Percentage
Location				
Lagos/Ibadan	150	50	75	45
Kano/Kaduna	75	25	40	25
Anambra/Abia	75	25	47	30
Size				
Small-scale	120	40	74	44
Medium-scale	75	25	31	20
Large-scale	105	35	57	36

Table 4 shows a close link between the target sample and realized sample. This suggests that the realized sample may be considered an acceptable representation of the population.

The surveyed companies encompassed producers of a wide range of commodities, including capital goods, intermediate goods and final goods. Specifically, the sectors covered include:

- Food manufacturing
- Beverages and tobacco
- Textiles and leather
- Wood and furniture
- Paper and printing
- Rubber and chemicals
- Metals and products
- Others

Thus the firms eventually selected spread across sectors, scales of operations and the major industrial clusters of the country, and should therefore reflect a broad spectrum of the manufacturing firms in Nigeria.

The analysis of the survey data was carried out with the aid of two computer software packages designed for the analysis of qualitative data. These are: EPI-Info computer software developed by the World Health Organization (WHO), which is a very versatile tool for the analysis of qualitative data, and LIMDEP version 7.0, which is similarly versatile for solving limited dependent models.

Method of analysis

The data obtained from the survey were analysed using basically two complementary approaches – descriptive and econometric. The descriptive approach involves the use of the tools of percentages, frequency, cross tabulations and simple analysis of perception.

Two empirical models were adopted for this study in addition to the descriptive analysis of the survey data. The first model, which is very popular in the literature, allows us to estimate the marginal cost of outages or, alternatively, firms' willingness to pay for a reliable supply of electricity. The model we applied is based on the revealed preference approach. The second model, based on the production approach, allows us to estimate the potential losses to the firm from power outages. The beauty of this approach is that it enables us to infer the mitigated costs arising from the installation of private generators and thus provides a basis for understanding why, in spite of the high marginal cost of private generation, firms still invest in auto-generation. It also allows us to characterize the losses from power outages based on firm size, location and sector of operations.

Marginal cost of power outages

The model adopted for this study is based on the revealed preference approach (see Bental and Ravid, 1982; Beenstock, 1991; Beenstock et al., 1997). This model is premised on some assumptions about the behaviour of the typical firm. First, firms are assumed to be operating essentially to maximize their profits. Hence, a firm faced with frequent power outages will act to insure itself against (all or some of) the damage caused by the outages. Since insurance policies are in general unavailable, however, firms will acquire backup generating power. This generating capacity is expensive, and the firm has to choose the optimal amount of backup power in accordance with the damage that unsupplied power would cause. Thus, by observing firms' behaviour with respect to the acquisition of own generating power, we may infer the (marginal) cost of unsupplied electric energy.

A competitive risk-neutral firm therefore maximizes expected profits (taking into account the probability of power outages) by equating at the margin the expected cost of generating a kWh of its own to the expected gain due to that kWh. This gain consists of the continued production (even if partial) that the self-generated electricity makes possible, and the avoided damage to equipment that would have otherwise been caused by power failure. The expected gain from the marginal self-generated kWh is also the expected loss from the marginal kWh that is not supplied by the utility. Therefore the marginal cost of self-generated power may serve as an estimate for the marginal outage cost.

The cost to the firm of generating its own power consists of two elements. First is the yearly capacity cost of the generator and other capital outlay. This cost will be denoted by *b(Kg)*, where *Kg* is the generator's capacity measured in kw[1]. Second is the variable cost per kWh. This is mainly for fuel, maintenance, and wages and salaries. If the generator is used to capacity during power cuts, as we assume, the variable cost per year is given by *v.H.Kg*, where *H* is the expected total duration of outages, measured in hours per year.

The total expected yearly cost per kw of backup generating power is then

$$b(Kg) + v.H.Kg \tag{1}$$

The expected respective marginal cost is

$$b^{I}(Kg) + v.H \tag{2}$$

and the expected marginal cost of a kwh generated is simply given by

$$MC_{kWh} = b^{I}(Kg)/H + v. \tag{3}$$

The firm equates the marginal cost to the marginal benefit from a kWh generated, which is also the marginal cost of unsupplied electricity. MC pricing is a measure of the willingness to pay for reliable supply of electricity. Equation 3, then, is our estimate of the latter. Thus the cost of the generator and the reliability of power supply will affect the estimates. For example, if generators become more expensive, then firms will purchase less backup power, and hence the damage of any power outage will increase. Similarly, a change in the reliability of the system (i.e., *H*) will affect the estimated outage cost. The more reliable the system becomes, the higher the outage cost as a result of the decreased backup facilities purchased by the firms.

In the event of incomplete backup, however, or where due to generator failure, etc., the firm may be vulnerable to outage failure resulting in losses such as destruction of raw materials, equipment damage, output loss or other. These losses are inversely related to the percentage of backup and the reliability of the firm's backup equipment.

Determinants of outage losses

Losses from power outages can be estimated using the production function approach (Ukpong, 1973; Uchendu, 1993). This approach measures output losses in terms of output lost per kWh of outage. The equation can be stated as

$$OC_i = N_i{*}A_i{*}B_i{*}OH_I \qquad (4)$$

where:

OC_I	=	outage cost for industry i
N_I	=	number of firms in industry i
A_I	=	VA_i/kWh_i
VA_i	=	value added in industry i /
kWh_i	=	total kilowatt hour consumption of electricity by industry i
B_I	=	kWh_i/H_i = kilowatts consumed per hour in industry i
H_i	=	number of hours of operations of industry i
OH_i	=	hours of power outage faced by industry i

The determinants of losses from power outages can be established by assuming a simple linear relationship between outage losses and observed firm characteristics as:

$$OC_i = a_0 + S\ a_i X_{ij} + Sb_i Y_{ij} + Sg_i\ SectDum_i + Sy_i\ LocDum_i + Sl_i ZonDum + ei \qquad (5)$$

where:

X_{ij}	=	characteristics of the power outage, duration of outage, frequency
Y_{ij}	=	firm-specific observable features: -Electricity consumption per kWh -Set of dummies for the size of firm -Sales in N -Backup
$SectDum_i$	=	sectoral dummies
$LocDum_i$	=	geographical location dummy for Lagos, Kano and Enugu axes
ZonDum	=	a binary dummy =1 for firms located in an industrial estate, 0 otherwise

The impact of the outage costs on the output performance of the firm can be stated as:

$$Y_i = a_0 + a_1 Kap_i + a_2 Lab_i + a_3 OC_i + e_i \qquad (6)$$

where:

Y	=	gross output
Kap	=	capital input
Lab	=	labour
OC	=	outage cost

7. Analysis of survey findings

A total of 162 out of the 300 questionnaires (54%) were successfully retrieved. The distribution of the firms by sector, scale of production and location is shown in Table 5.

Table 5: Distribution of respondents by sector, scale of operations and location

	Frequency	Percentage
Sector		
Food manufacturing	22	13.6
Beverages & tobacco	15	9.3
Textiles and leather	26	16.0
Wood and products	9	5.6
Paper and products	16	9.9
Rubber and chemicals	46	28.4
Metals and products	22	13.6
Others	6	3.7
Scale of production		
Small-scale	74	43.6
Medium-scale	31	19.9
Large-scale	57	36.5
Location		
Lagos–Ibadan	73	45.0
Kano–Kaduna	40	25.3
Anambra–Imo	47	29.7

Source: Survey data.

For the purpose of the survey, firms that employed fewer than 50 workers were classified as small scale, and those with more than 100 as large scale. Hence firms that employ between 50 and 100 were regarded as medium-scale enterprises. A brief overview of the data used in the study is presented in Table 6, which shows that there was considerable variation in the data across the firms. For example, electricity consumption varied from a low 7kWh per day for a small firm to 10,000kWh per day for one of the largest firms in the sample. Similarly, payment to NEPA for electricity supply in 1998 ranged from the lowest amount of N4,000 for one firm to the highest value of nearly N14 million for another firm. Thus, the high standard deviation for most of the variables is an indication of the variation across the firms.

Table 6: Data description

Variable	Minimum	Maximum	SD	Mean
Electricity consumption per day at full capacity (kWh)	8.0	25,000	10,772.0	1,142.0
Actual electricity consumed (kWh) per day	7.0	10,000	11,311.0	975.0
Electricity consumption from NEPA in 1998 (’000kWh)	540.0	2,845	183.2	296.4
Electricity consumed from own generator in 1998 (‘000kWh)	70.0	7,701	1,133.1	264.5
Payment to NEPA in 1998 (N’000)	4.0	13,641	1,673.0	675.0
Cost of own generator (N’000)	7.1	22,680	2,745.7	1,318.0
Value of generator (N’000)	50.0	35,000	1,354.5	266.4
Generator capacity	1.5	1,300	322.0	150.0
Labour	3.0	1,642	181.7	125.0
Sales (N’000)	195.0	3,300,000	299,620.0	949,612.0
Investment in machinery and equipment (N’000)	55.0	430,000	75,242.0	2,7375.0
Fixed assets (N’000)	102.0	1,200,000	200,379.0	90,210.7
Fuel consumed (N’000)	6.8	24,530	2556.5	1076.5
Outage cost (N’000)	24.3	763,492	8,9084.6	34494.1

Source: Survey data.

Ranking of infrastructure problems in Nigeria

Respondents were asked to rank the severity of infrastructure problems in Nigeria on a scale of 1 to 3 – no obstacle, moderate obstacle, major obstacle (see Table 7 for the results). The responses we received show that a large percentage of the firm regarded power and voltage fluctuations as major obstacles to their operations (Table 8). Most of the respondents also ranked electricity as their number one problem. This is followed by telecommunication in a distant second. More small-scale firms ranked electricity as a problem (85.3%) compared with large firms (80.4%).

Table 7: Ranking of severity of infrastructure problem in Nigeria (per cent) Infrastructure

	No obstacle	Moderate obstacle	Major obstacle
Land	8.1	4.9	4.3
Electricity	1.9	10.5	82.7
Water	19.8	13.6	4.3
Telecommunication	1.2	14.8	34.0
Road	13.6	6.8	1.2
Petroleum shortages	22.2	48.1	2.5

Source: Survey results.

Table 8: Percentage of respondents ranking electricity as most important or second most important infrastructure in Nigeria, by sector (per cent)

Sector	Most important	Second most important
Food manufacturing	72.7	18.2
Beverages	50.0	42.9
Textiles and tobacco	92.3	7.7
Wood and products	77.8	22.2
Paper and products	87.5	12.0
Rubber and chemicals	91.3	4.3
Metal and products	95.0	5.0
Others	100.0	0.0

Source: Survey results.

Electricity consumption

The public monopoly, NEPA, remains the main source of electricity consumed by Nigerian firms. Table 9 shows the source of electricity consumption by the firms. There is a high rate of auto-generation, however, as only 6.2% of the firms rely exclusively on NEPA. The firms regard NEPA as unreliable and are willing to insure themselves against the expected fluctuations in publicly supplied electricity by maintaining private generators.

Table 9: Sources of electricity used in the manufacturing sector

Source of electricity	Percentage
NEPA only	6.2
NEPA main	17.0
Own generator only	19.1
Own generator main	3.7

Source: Survey data.

More than 93% of the firms surveyed own one or more generating sets, with the number of sets maintained varying across the firms. For example, one of the surveyed firms maintains up to 12 generators. Over the entire sample, the mean number of generators owned by the firms is two. While one is at use, the other is usually reserved as a backup to the main generator. The age of the generators varies from 1 to 24 years, with the mean age being 15 years. Quite a number of firms depend on imported used generators and locally assembled ones. This implies inefficient oil consumption and greater expenditure on maintenance. The current value of the generators varies from N50,000 to about N30 million. The mean value of the generator is N1.5 million, while the average capacity is 125kVa. The mean capital and operating costs of the generators are N2,137,792.22 and N1,451,693.61, respectively (see Table 10 for the breakdown of the cost items). The high fuel and grease cost was not unconnected with the chronic fuel shortages that prevailed in the country for the most part of 1998.

Table 10: Mean cost structure for auto generation for Nigerian manufacturers

Item	Value (N)
Capital item	
Capital cost (generator)	1,500,000.00
Generator house	273,863.04
Stabilizer	21,772.96
Oil tank	126,689.74
Others	235,466.48
Total	2,137,792.22
Operating cost	
Fuel and grease	1,076,460.02
Wages and salaries	112,688.64
Maintenance costs	323,508.91
Others	9,036.04
Total	1,451,693.61

Source: Survey data.

Table 11 further shows the share of total investment devoted by firms to their own provision of electricity facilities. This cost, as expected, varies inversely with the scale of operations of the firms. Small-scale firms spend on average between 10 and 20% of initial investment on self-generation compared with large-scale firms, which spend less than 10%. Across all the firms, however, the additional investment costs incurred to mitigate the unreliability of NEPA is an avoidable cost that simply increases the costs of business operations in Nigeria.

Table 11: Proportion of total investment at start up devoted to provision of own electricity facilities by firm size

Proportion	Small-scale	Medium-scale	Large-scale
0 to 10%	28.8	35.5	56.0
10 to 20%	35.6	29.0	20.0
20 to 30%	10.2	25.8	14.0
More than 30%	25.4	9.7	10.0

Source: Survey data.

Power outage costs

The poor reliability of publicly supplied power in Nigeria has imposed a lot of costs on manufacturing firms in the country. As a result of power outages firms lost an average of 792 working hours in 1998. Assuming a nine-hour working day, this translates to about 88 working days in 1998. Also, about 35% of the firms reported having to shut down production at one time or the other in the year as a result of power outages.

The dimension of the poor state of electricity supply in the economy can be seen in Tables 12 and 13, which confirm the seriousness of the power outage problem in Nigeria. On the average, firms experience outages between five and ten times in a week, with each outage lasting for over one hour. If these outages occur during the working period of the firms (which they do), then the potential losses would be so much and thus firms would need a form of insurance.

Table 12: Respondents' perception of the frequency of power outages per week

Frequency of power outages per week	Percentage of respondents
Fewer than 5 times	6.9
Between 5 and 10 times	52.2
More than 10 times	40.9

Source: Survey data.

Table 13: Respondents' perception of the average duration of outages

Average duration of outage	Percentage of respondents
Less the 30 minutes	5.1
From 1 to 6 hours	69.4
More than 6 hours	25.5

Source: Survey data.

Finally, the average cost for auto-generation and for Publicly provided electricity is presented in Table 14. While electricity from NEPA accounted for about 60% of total electricity consumption by the firms, the average cost per kWh is N5.28. Auto-generation accounted for only 40% of electricity consumption, but the average cost was N15.47 per kWh. The table shows that the 262 firms spent nearly N1 billion on privately supplied electricity in 1998.

Table 14: Electricity consumption and average cost

Source	Electricity consumption ('000kWh)	Cost of electricity (N'000)	Average cost (N)
NEPA	81,051	427,921	5.28
Auto-generation	56,305	871,139	15.47
Total	137,356	1,299,059	9.36*

* Weighted average.
Source: Survey data.

Perception of the causes of and solutions to inefficient supply of power

There is a sharp division in the perception of consumers and NEPA on the causes of the poor supply of electricity in Nigeria. While NEPA emphasized inadequate funding, low tariff rates, and technical problems arising from illegal connections and tampering with NEPA installations, consumers are convinced that the tariff rate has little or nothing to do with it. The general perception is that NEPA is corrupt and inefficient. Hence, the consumers' solution is to deregulate the sector.

Table 15: Firms' perceptions of the factors responsible for the poor performance of NEPA

Cause of problem	% Selecting option	Ranking
1. Low electricity tariff	9.1	6
2. Inefficiency of NEPA	97.4	2
3. Too much govt control	52.0	3
4. Poor funding	42.7	4
5. Corruption	96.7	1

Source: Survey data.

Table 16: Firms' perceptions of how to improve NEPA

Solution	% Selecting option	Ranking
1. Privatize NEPA	73.6	2
2. Increase funding	43.4	3
3. Introduce competition	98.6	1
4. Increase tariff	15.9	5

Source: Survey data.

8. Measuring the cost of power outage

To compute the cost of unsupplied power for the industrial sector in Nigeria using the revealed preference approach, we need to compute the MC of unsupplied electricity using the formulas in the methodology section. To obtain the MC, we calculate the values of b^I, H, l and v. Since the result is sensitive to the reliability level, we construct a schedule of MC for different levels of reliability and discount factors. b^I is the annual cost per generator-kw, including accessories like stabilizer, fuel tank, cables and synchronizers. b^I depends on price schedules for generators, on depreciation rules and on the interest rate. We obtained price schedules for one of the most popular industrial generators in Nigeria, Perkins, and we observed that these prices increase almost linearly with the capacity. The average price is N16,374/kVa, which translates to N13,099/kw (using power factor of 0.8kva=kw). The prevailing interest rate is 12% and if the generator's life span is 15 years, then the annualized cost of generator to the firm is N218.63 per kw. We also annualized other capital items like generator house (N182.57); stabilizer (N14.51); fuel oil tank (N84.46); and others (N156.98). Thus the capital cost of keeping a generator is N500 per kW.

The expected total duration of outages, *H*, is not officially available. However, our surveyed firms estimate an average of 796 hours in 1998. A World Bank study estimated outages in 1990 at about 240 hours (World Bank, 1993b), while Uchendu (1993) reported a mean of 380 hours.

The operating cost consists mainly of fuel and grease costs (N13.59 per kWh)[2]; wages and salary (N1.42 per kWh); maintenance cost (N4.08 per kWh), and others (N0.11 per kWh), which amount to N19.21 per kWh. Applying the formulas presented in the methodology section, we obtained the costs of unsupplied kWh. This is reported in Table 17.

Table 17: Marginal cost of generator or the willingness to pay for reliable electricity (in naira per kilowatt-hour)

Hours of power outage	MC (naira) per discount factor		
	10%	15%	20%
240hrs	65.83	65.20	64.88
380hrs	41.54	41.11	40.93
792hrs	19.95	19.74	19.66

Source: Author's estimates.

Table 17 shows that marginal cost estimates depend on *H*, the number of hours of power outages and the discount factor. However, MC is inversely related to the reliability of the public power system. As the reliability of power deteriorates, the incentive by a firm to insure itself against outages increases. Therefore, when an outage does occur, it tends to be less costly.

Characteristics of outage losses

Next we investigated the characteristics of the outage costs to find out whether the costs vary across sectors, scales of operation and even locations. The result is presented in Table 18. Among the sectors, textiles and leather, others (mainly electrical), and rubber and chemicals recorded the highest outage costs, while wood and products, beverages and tobacco, and paper and products recorded the least outage values. The table also shows that potential outage costs also vary with the scale of production. There is wide variation across the various groups, however, as reflected in the high standard deviation. As expected, losses vary proportionately with scale of production. Moreover, we found that firms in the Anambra/Imo axis suffered the least cost from power disruptions.

Table 18: Distribution of outage costs (N'000)

Sector	Mean	Minimum	Maximum	SD	N
Food manufacturing	17005.2	95.74	98507.4	26125.4	17
Beverage and tobacco	7500.3	67.5	31578.9	1174.8	13
Textile & leather	84423.4	242.3	763492.1	172562.7	25
Wood and products	1282.1	364.3	2612.9	949.6	6
Paper and products	13052.7	24.3	93333.3	23733.8	16
Rubber and chemicals	40530.8	118.7	329411.8	71856.0	35
Metals and products	16163.6	73.3	114000.0	26584.2	17
Others	43026.8	24.1	210000.0	93346.9	5
Scale of production					
Small-scale	5288.9	24.3	67500.0	11882.0	62
Medium-scale	21876.9	434.1	210000.0	42135.1	29
Large-scale	85113.2	766.3	763492.1	140554.3	43
Location					
Lagos-Ibadan	32212.0	24.3	444193.5	78408.4	58
Kano-Kaduna	49544.7	67.5	763492.1	134298.8	35
Anambra-Imo	24874.3	95.7	210000.0	44735.2	41

Source: Computed by author.

Table 19 provides a decomposition of losses by types. The table confirms our expectation that lost output is the major type of loss incurred by firms. This was followed by destruction of raw materials and damage to equipment. These losses totalled over half a billion naira in 1998.

Table 19: Decomposition of losses by type

Type	Amount (N)
Destruction of raw materials	46,696,694
Lost output	462,860,827
Restart costs	14,126,400
Damage to equipment	30,540,574
Total	554,224,495

Source: Survey data.

Table 20: Proportion of total output loss due to power failure in 1998

Proportion of output	Frequency	Valid per cent
Less than 10%	30	19.6
Between 10 and 30%	49	32.0
Between 30 and 50%	46	30.1
More than 50%	28	18.3

Source: Survey data.

Table 21 shows that the presence of backup power minimizes the expected outage costs. Thus, it is obvious that the mitigated outage cost is several multiples of the unmitigated costs. In fact, the presence of generators mitigated over 87% of potential losses from power outages. The presence of unmitigated costs is indicative of incomplete backup, the non-automation of backup, problems with the backup or other factors.

Table 21: Mitigated and unmitigated losses (N'000)

Sector	Potential outage costs	Mitigated outage costs	Unmitigated outage costs
Food manufacturing	17,005.2	15,025.1	1,980.1
Beverages and tobacco	7,500.3	3,991.9	3,508.4
Textiles and leather	84,423.4	74,000.6	10,422.8
Wood and products	1,282.1	466.7	815.4
Paper and products	13,052.7	11,476.1	1,576.6
Rubber and chemicals	40,530.8	37,069.2	3,461.6
Metals and products	16,163.6	10,653.7	5,509.9
Others	4,3026.8	42,618.2	408.6
Scale of production			
Small-scale	5,288.9	4,689.3	599.6
Medium-scale	21,876.9	19,586.2	2,290.7
Large-scale	85,113.2	73,875.6	11,237.6
Location			
Lagos-Ibadan	32,212.0	26,463.6	5,748.4
Kano-Kaduna	49,544.7	44,946.8	4,597.9
Anambra-Imo	24,874.3	22,618.4	2,255.9

Source: Computed by author.

9. Analysis of regression results

Tables 22 and 23 show the OLS regression results on the determinants of outage costs. Table 22 excludes the sectoral, location and scale dummies, while these are controlled for in the regression results presented in Table 23. In Table 22, column 1 reports the OLS estimates after controlling for labour and capital employed in the firm. These were not controlled for in column 2. However, in column 3, the dependent variable controls for size of electricity consumption by firm. The results show that the location of the firm (in terms of either being in an industrial zone or not) has significant negative effect on outage costs. Given the lower power outages experienced in the industrial zones, firms located there are able to minimize costs.

Table 22: Determinants of outage costs

Variable	Loutage (OLS)(1)	Loutage (OLS)(2)	L(Outage/elec) (OLS)(3)
Constant	7.66***	6.44***	-0.78
	(9.40)	(7.88)	(-0.69)
Locfirm	-0.46	-0.31	-0.71**
	(-1.63)	(-1.05)	(-2.71)
Backup	-0.054	-0.54	-0.38*
	(-1.20)	(-1.03)	(-1.79)
Frequency	-0.02	-0.03	0.014
	(-1.02)	(-0.02)	(1.93)**
Duration	0.02	0.003	0.003
	(1.52)	(0.27)	(0.24)
Lelec	0.486***	0.75***	
	(5.28)	(10.03)	
Llab	0.63***		
	(4.63)		
Lkapt	-0.002		
	(-0.72)		
Llabout			-0.43***
			(-4.8)
	R^{-2}=0.54F	R^{-2}=0.48F	R^{-2}=0.15F
	(7,139)=25.6	(5,141)=27.7	(5,141)=6.12

Notes: * figures in parentheses are t-statistics; ***, **, * implies significance at 1%, 5% and 10%, respectively. Variable definitions are as follow: lab is labour, kapt is capital; labout is labour/output; elec is electricity consumption, locfirm is dummy variable indicating whether the firm is located in an industrial area or not; L(outage/Elec) measures relative outage costs by firm size by deflating outage costs by electricity consumption; L before a variable indicates logarithm. For example, loutage is the log of outage costs.

Source: Computed by author.

Although not statistically significant, the characteristics of the outage-frequency and duration affect outage costs. Similarly, as expected the presence of backup has a reduction effect on outage costs. Column 3 of Table 22 also shows that on the average, large scale firms are able to minimize their outage costs relative to smaller firms. This effect is picked up by the variable labour–output ratio (Llabout), which has a negative and significant effect on outage.

In Table 23, after controlling for sector, location and scale effects, the basic results obtained in Table 22 are carried over, especially in terms of signs of the parameters. In most cases, however, the sectoral, locational and scale parameters are not significant[3].

Table 23: Determinants of outage costs, including sector, location and scale

Variable	Loutage (OLS)(1)	L(Outage/Elec) (OLS)(2)
Constant	10.59	0.44
	(8.72)***	(0.28)
Locfirm	-0.26	-0.63**
	(-0.89)	(-2.05)
Backup	-0.42	-0.37
	(-0.82)	(-0.68)
Frequency	-0.002	0.01
	(-1.29)	(0.72)
Duration	0.002*	0.005
	(1.76)	(0.47)
Food	-0.47	-0.86
	(-0.67)	(-1.13)
Beverages	-0.66	-0.33
	(-0.92)	(-0.43)
Textiles	0.07	-0.26
	(0.10)	(-0.34)
Wood	-0.90	-0.27
	(-1.06)	(-0.29)
Paper	-0.47	-0.51
	(-0.68)	(-0.68)
Chem-Rub	-0.07	-0.58
	(-0.10)	(-0.89)
Metals	0.13	-0.37
	(0.19)	(-0.42)
Smalldum	-1.03	-0.16
	(-1.07)	(-0.40)
Lagdum	0.99	0.27
	(1.26)	(0.41)
Lagodum	-0.09	-0.27
	(-0.29)	(-0.81)
Kandum	-1.00**	-0.86**
	(-2.88)	(-2.28)
Llabout		-0.40**
		(-2.28)
	R^{-2}=0.58F	R^{-2}=0.13F
	(15,130)=12.5	(16,139)=2.6

Notes: ***, **, * implies significance at 1%, 5% and 10%, respectively.
Variable definitions are as in the previous tables. However, additional variables are defined as follows: smalldum is small-scale dummy; lagdum is large-scale dummy; Lagodum is dummy for firms located in Lagos/Ibadan axis; Kandum stands for firms located in Kano/Kaduna axis.

Source: Computed by author.

Table 24 provides the regression results of the impact of outage costs on output performance of the manufacturing sector. The table shows that outage costs have significant reduction impact on output performance. This is broadly consistent with our previous findings.

Table 24: Impact of outage costs on output performance

Variable	Coefficient	T-statistics
Constant	13.20	5.27***
Lkap	0.75	2.45**
Llab	0.42	4.33***
LOC	-0.23	-2.01**
R^{-2}=0.82F(3,132)=25.8		

Note: ***, **, * implies significance at 1%, 5% and 10%, respectively.
LOC is the log of outage costs.

10. Conclusion and areas for further research

This study analysed the cost of power outages to the business sector of the Nigerian economy. The study applied both the survey technique and the revealed preference approach. The characteristics of the electricity market in Nigeria were also analysed. One strong outcome of the study is that the poor state of electricity supply in Nigeria has imposed significant costs on the business sector of the Nigerian economy. The bulk of these costs come in the form of acquisition of very expensive backup power. However, the decision to acquire a backup is actually a rational decision on the part of the firm in order to insure it from larger losses arising from frequent and long power fluctuations.

The continuation of the existing state of power supply will no doubt continue to have a negative impact on the attempt by the government to diversify the production and export base of the economy away from oil. A situation where firms spend as much as 20% to 30% of initial investment on the acquisition of facilities to enhance electricity supply reliability has a significant negative impact on the cost competitiveness of the manufacturing sector.

Furthermore, as the results of our analysis have shown, small-scale operators are more heavily affected by the infrastructure failures. In many instances they are unable to finance the cost of backup necessary to mitigate the negative impact of frequent outages. Hence, they have to bear the full burden of electricity failures. Small-scale operators that could afford to back up their operations have to spend a significant proportion of their investment outlay on this.

One important area of further research is to examine the institutional reforms that can enhance the public sector delivery of electricity. It is very obvious from the study that private generation is inefficient relative to that by the public sector. Private provision is, therefore, not the optimal way for the economy to go. There is a need for an in-depth study of the institutional structure of NEPA in Nigeria and how effective reforms could be carried out to ensure its effectiveness.

Notes

1. Capacity is usually measured by kva. At full capacity, 0.8kva=kw.

2. In Nigeria, a litre of diesel is N17.00 at the official price. This translates to N7.16 per kWh.

3. However, when we related outage to electricity consumption we found that location becomes significant.

References

Ajayi, G.A. 1995. *Cost-Benefit Analysis of Captive Power Generation by Manufacturing Industries in Nigeria*. Unpublished PhD thesis, Department of Economics, University of Ibadan, Ibadan.

Beenstock, M. 1991. "Generators and the cost of electricity outages". *Energy Economics,* 13(3): 283–89.

Beenstock, M.E. Goldin and Y. Haitovsky. 1997. "The cost of power outages in the business and public sectors in Israel: Revealed preference vs. subjective valuations". *The Energy Journal***,** 18(2): 39–61.

Bental, B. and S. Ravid. 1982. "A simple method for evaluating the marginal costs of unsupplied electricity". *Bell Journal of Economics,* 8(4).

Bernstein, M. and Y. Heganazy. 1988. "Economic costs of electricity shortages: Case study of Egypt". *The Energy Journal***,** Special Electricity Reliability Issue, 9: 173–88.

Billinton, R., G. Wacker and E. Wojczynski. 1982. *Customer Damage Resulting from Electric Service Interruptions*, Volume 1. Prepared for the Canadian Electrical Association, R&D Project 907 U 131, April.

Caves, D.W., J.A. Herriges and R.J. Windle. 1992. "The cost of electric power interruptions in the industrial sector: Estimates derived from interruptible service programmes". *Land Economics,* 68: 49–61.

Caves, D.W., J.A. Herriges and R.J. Windle. 1990. "Customer demand for service reliability in the electric power industry: A synthesis of the outage cost literature". *Bulletin of Economic Research,*42(2): 79–117.

Doane, M.J., R.S. Hartman and C.K. Woo (1988), "Household prefernce for interruptible rate options and revealed value for service reliability". *Energy Journal.*

Elhance, A.P. and T.R. Lakshamanan. 1988. "Infrastructure-production system dynamics in national and regional systems: An economic study of the Indian Economy". *Regional Science and Urban Economics,* 18, North-Holland.

Iyanda, O. 1982. "Cost and marketing implications of electric power failures on high-income households in Lagos". *The Nigerian Journal of Economic and Social Studies,* 24(2): 169–84.

Kessides, C. 1993. *The Contributions of Infrastructure to Economic Development: A Review of Experience and Policy Implications.* World Bank Discussion Papers No. 213. The World Bank.

Kranton, R.E. 1991. *Transport and the Mobility Needs of the Urban Poor*. Infrastructure and Urban Report No. INU 86. World Bank, Infrastructure and Urban and Development Department, Washington, D.C.

Lee, K.S. and A. Anas. 1991. "Manufacturers' responses to infrastructure deficiencies in Nigeria: Private alternatives and policy options". In A. Chibber and S. Fischer, eds., *Economic Reform in Sub-Saharan Africa*. A World Bank Symposium.

Lee, K.S and A. Anas. 1992. *Impacts of Infrastructure Deficiencies on Nigerian Manufacturing: Private Alternatives and Policy Options*. Infrastructure and Urban Development Department Report No. 98. World Bank, Infrastructure and Urban Development Department, Washington, D.C.

Matsukawa, I. and Y. Fujii. 1994. "Customer preferences for reliable power supply: Using data on actual choices of back-up equipment". *Review of Economics and Statistics*, 74: 434–46.

NEPA. 1997. "NEPA beyond the load schedding". Advertorial, *New Nigerian*, Wednesday, June 3, 18–9.

Ontario Hydro. 1977. *Survey of Power System Reliability: Viewpoint of Large Users*. Final Report No. RMA 76-5, April.

Ontario Hydro. 1980. *Ontario Hydro Survey on Power System Reliability: Viewpoint of Farm Operators*. Final Report No. R&U 78-5, December.

Steel, W.F. and L.M. Webster. 1991. *Small Enterprises under Adjustment in Ghana*. World Bank Technical Paper No. 138. The World Bank, Washington, D.C.

Telson, M. 1975. The economics of alternative levels of reliability. *Bell Journal of Economics*, Autum.

Uchendu, O.A .1993. "The economic cost of electricity outages: Evidence from a sample study of industrial and commercial firms in the Lagos area of Nigeria". CBN *Economic and Financial Review*, 31.

Ukpong, I.I. 1973. "The economic consequences of electric power failures". *The Nigerian Journal of Economic and Social Studies*, 15(1): 53–74.

USAID. 1988. *Power Shortages in Developing Countries: Magnitude, Impacts, Solutions, and the Role of the Private Sector*. United States Agency for International Development Report to Congress. March.

World Bank. 1993a.*The East Asian Miracle: Economic Growth and Public Policy*. New York: Oxford University Press.

World Bank. 1993b. *Energy Sector Management Assistance Programme Report on Nigeria*. Washington, D.C.

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