DIRECT ASSESSMENT METHOD FOR ESTIMATING THE ECONOMIC COST OF POWER INTERRUPTION

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ABSTRACT

This studyaimed at providing the approach to be followed by researchers when estimating cost of unserved utility service mostly electricity. It examined the different cost components that can be used to identify total direct cost using a typical direct assessment method. It was revealed that there are variations to direct cost assessment which involved production loss approach and systems outage customer cost approach. Direct Assessment method provides the richest source of information for tracking trends in interruption cost and had a number of weaknesses such as ignoring indirect cost, self assessment problem and non-consideration for makeup cost. The method can also be used in assessing direct cost for interruption in services such as water supply and telephone services.

Keywords: *Electricity outage, direct assessment, production loss, cost of electricity interruption*

INTRODUCTION

The methodology of the direct assessment approach uses direct loss by which it estimates the cost of power outages through lost production, lost materials and lost time or leisure. The direct assessment method is an economic appraisal tool that estimates the cost of power outages by allowing electricity consumers to express their losses in monetary terms (Bose, Shukla, Srivasta and Yaron 2006). The approach is based on the principle that the lost production, materials and time in each productive sector, or lost goods during an outage can be estimated directly, and this can be aggregated to a total (De Nooij, Kopmans and Bijvoet, 2006). The approach relies on the individual respondent's self assessment method of valuing the cost of electricity outage. Direct cost estimations, such as the direct financial evaluation approach, the gross economic indices approach (GNP divided by total electricity consumption), and the case study approach have been frequently employed in the past (Pollit, Jamasb and Yu, 2006).

The use of the direct assessment approach dates back to the Industrial Revolution when, firms experienced an energy (coal) crisis in production (Marshall, 1907), but it was not until the 1930s that direct assessment became widely applied. The methodology was employed in the formulation of the Federal Electricity

Regulation Commission (FERC) responsible for initiating reliable electricity supply in the United States in the 1940s. It was a period during which most privately owned electricity suppliers converted to public utilities (FERC, 1973). Under the Commission, US electricity utilities were required to supply reliable electricity in order to minimise the loss of production. The Commission's survey in the 1940s on the cost of unsupplied electricity to firms showed shocking results of lost production, revenue and profits (FERC, 1973). Based on these calculations, the direct assessment methodology was popularised (Ukpong, 1973; Beenstock, Goldin and Haitovsky, 1997). Since then, the method has been extended to estimating cost of poor telephone networks and the cost of unsupplied water, inter alia.

The direct assessment approach was adopted by Ukpong (1973) in Nigeria, which he referred to it as production function approach. Tishler (1993), Grosfeld-Nir and Tishler (1993) further refined the methodology by assuming that damage to materials was proportionate to the output loss during the outage and that factor demands for electricity and labour were adversely affected by the uncertainty of electricity supply. The latter raises the effective user cost of electricity. Outages cause sub-optimal technologies to be adopted, and thereby impose additional costs beyond the direct costs incurred at the time of the outage itself (Grosfeld-Nir and Tishler, 1993). The direct assessment method was the dominant methodology for estimating the cost of power outages in the early studies of this problem (Beenstock, Goldin and Haitovsky, 1997). Therefore, the purpose of this study is the application of Direct Assessment Method for estimating the economic cost of power interruptions.

VARIATIONS OF THE DIRECT ASSESSMENT COST ESTIMATIONS

Production Loss Approach: One application of the direct assessment cost is to calculate the value of the production loss that can be attributed to the interruption of power supply, that is, to estimate the 'cost of unserved energy' (CUE) (Ontario Hydro 1977, 1980; Caves, Herriges and Windle, 1990; Matsukawa and Fuji, 1994; Beenstock, Goldin and Haitovsky, 1997). In the agricultural sector, the production loss method derives the CUE from the incremental crop output not realised (opportunity cost) due to the non-availability of power for irrigation. The production loss method calculates the maximum amount that a firm or household will pay to avoid electricity outages.

The major problem with this approach is that, adjustment processes are not accounted for in the responses, with the result that the CUE is often overstated (Ross, Boyd and Kokkelenberg, 2000). For example, industrial enterprises that suffer from power cuts will seek to minimise the outage effects by rescheduling production to other periods, for instance, through the use of pump sets (Tiwari, 2001). These rescheduling possibilities are not incorporated into the estimates respondents make of their lost production (Oosterhaven, 1996). A further disadvantage of the method is its reliance on the recall ability of respondents - the firms (Yung, 2005). The value

of losses is overstated when the entire loss of production is attributed to the power cut (Bose, Shukla, Srivasta and Yaron, 2006). Frequently, firms can estimate the loss in revenue, but not the loss in value added (Ross, Boyd and Kokkelenberg, 2000). For these reasons, the production loss method provides an upper limit estimate cost of electricity outages from the perspective of the firm (Stern, 2000).

Systems Customer Outage Cost (SCOC) Approach: The Systems Customer Outage Cost (SCOC) approach has also been used to estimate the financial impact of an electricity supply interruption (OFGEM 1999). This method estimates the costs of outages from Sector Customer Damage Functions (SCDFs). These reflect the number of interruptions, interruption durations and the system customer mix. SCDFs are evaluated from the weighted Customer Interruption Costs (CICs) (Allan and Kariuki, 1999). This method determines the costs that customers would have incurred if their electricity supply were interrupted for a given duration of time from SCDFs.

On the basis of hypothetical scenarios, customers are asked to choose from a given list the actions they would take in order to minimise the impacts of such interruption (OFGEM, 1999). The hourly cost of each scenario is noted alongside the list of actions. A shortcoming of this type of estimation is that it equates the direct cost of an action incurred from a power interruption to the value of the interruption to customers (Pollit, Jamasb and Yu, 2006). Without considering the value of utility losses to consumers, OFGEM's approach (SOSC) is likely to significantly under-estimate the actual outage cost. To avoid the underestimation problem, a combination of the methods may be required.

APPLICATION OF THE DIRECT ASSESSMENT METHOD

The direct assessment method may be employed to ascertain the cost of interruptions of electricity supply or a reduction in its quality to productive sectors and households. Households and firms differ substantially in their valuations (De Nooij, Kopmans and Bijvoet, 2006). The main valuation approach of firms is output traded on the markets, whereas the main valuation method of households is well-spent leisure time. The cost of power outages vary from case to case and from sector to sector, depending on any or all of the following factors (Bose, Shukla, Srivasta and Yaron, 2006):

i The extent to which the consumer is forewarned about such interruptions.
ii The time of the day and the season during which the supply fails.
iii The coping strategies that the customer has in place.

STEPS IN DIRECT ASSESSMENT APPLICATION

A typical direct assessment method follows the steps detailed below:

Defining the scope of power outages estimation: The first stage of direct assessment is defining the proposed estimation of power outages cost (Hanley and Splash, 1993),

analysing how the proposed estimation is going to be achieved, who the affected are and the means with which the targets are to be reached. The anticipated challenges in achieving the targets have to be identified. At this stage, the researcher must decide, how important the targets are to the whole analysis and so determine the implications thereof. The reference against which the implications are determined is the base case, a scenario where there are no power outages.

Setting power outage scenarios: The second stage of the direct assessment is to list a set of power outage scenarios. The scenarios may vary considerably among sectors or targets or situations (Eto et al., 2001). For example, one scenario might ask for the cost of a one-hour outage, while another might ask two or twelve hours. In some cases, advance notice of outages might be presented as an explicit scenario, e.g. one hour outage with advance notice. In others, consumers might be asked if their costs would be reduced if they had advance notice of the outage. The person administering the questionnaire should get the respondents to understand their involvement and the nature of the transaction proposed (Hanley and Splash, 1993). Pre-testing of the questionnaire should be done before the actual survey takes place in order to determine the most appropriate way of asking questions and whether the respondents will provide sensible responses to the questions.

Defining the type of direct cost associated with power outages: The third stage of the direct assessment is the identification of direct costs associated with power outages. Power outages can impose direct costs on consumers in a number of ways, depending on the class of consumers. These costs have to be identified separately for each class of consumer. The identification is normally conducted by making reference to the direct costs associated with each sector.

Determining cost: The fourth stage of the direct assessment is to determine the cost for the firm and consumers.

a. *Determining cost for firms:* Firms suffer three kinds of damage in the case of an outage (Borenstein, 2001). First, they produce less. Without electricity, many production processes stop, some production is lost, for example, unsaved computer files take time to start up production again. Second, extra costs may be incurred, such as paying overtime bonuses to workers. Third, some goods and inputs may be damaged, for example, hot steel in a steel plant may cool down (making it difficult to process) and have to be reheated (the earlier input of heat is then lost). The damage caused by an electricity interruption in a firm is equal to the value it would normally have added during that period.

b. *Valuing cost for households:* Households face two kinds of cost: the lost possibility to use their leisure time as they want and the loss of goods, such as the contents of the freezer if an interruption lasts too long (De Nooij Kopmans and Bijvoet, 2006). In winter, households could experience cold discomfort because heating systems depend on electricity. Households enjoy

leisure by using time and money as inputs. The marginal utility of money decreases with the increasing amount of money one has, while the marginal utility of free time increases as the number of hours worked increases. There is an optimal amount of time for a person to work. At this optimum, the income generated with one hour of work equals the value of an additional hour of leisure time. Put differently, the value of a marginal hour of leisure time equals the income earned per hour.

Data Collection: The fifth stage is data collection. Data collection can be done by one of these two methods. The first is the survey method. Surveys are the principal source of information on customer outage costs (Caves, Herriges and Windle, 1990). Survey approaches require customers to identify their possible response to different power outage scenarios. The consumers are required to estimate how much it would cost them to adjust to a power outage. The second is the case study. This method involves asking the electricity consumers the cost they have incurred after an outage had occurred and the amount of value they place on the interruption of their activities.

The maginitude of consumers outage cost can only be estimated by making reference to similar past outages (Eto et al., 2001). Consumers face a lot of problems in trying to determine the different costs at different times, that is what differs the costs of power outages for 1 hour, 2 hours, or 4 hours. The cost of any power outage are both direct and indirect costs. In most studies, the indirect costs are ignored. However, the indirect costs may be higher than the direct costs and have long-term consequences, for example, deforestation. Other measures, such as the contingent valuation method (CVM) can also be used to estimate such costs.

Screening, Consistency Checking and Capturing: The researcher also needs to check on the consistency of the consumers' responses to questions, such that one hour outage cost should not be higher than a 12 hour outage. An important part of screening the data is the identification of valid and invalid responses. Refusal to state the cost, or incomplete questionnaires are normally identified and omitted from the calculations. A decision has to be made about how to identify the outliers as well as what to do with them. As an alternative to omitting outliers, the problem they cause is often addressed by weighting responses differently (Hanley and Splash 1993). It is also important that the researcher minimises double counting of costs, for example, the cost of lost production or cost of damage to equipment should not be added if replacement cost is also included.

RATIONALE AND CRITIQUE

The direct assessment method provides the richest source of information for tracking trends in interruption cost because it identifies specific components of economic losses, distinguishes among classes and types of customers bearing those costs and considers the costs associated with a range of electricity interruptions (Concept Economics, 2008). The direct assessment approach is not, however, without its

shortcomings. The following are its weaknesses:

Ignores indirect cost: The direct assessment method measures only direct cost of production (such as lost output) and not indirect cost (such as inconvenience) (Concept Economics 2008). Indirect cost may be more than direct cost.

No consideration for makeup cost: The direct assessment method makes no allowance for the fact that foregone production might be partially made up for after the outage and for this reason, overestimate the cost of electricity outages. Proponents of the method argue that this overestimation of direct cost compensates for the omission of indirect costs (Bose, Shukla, Srivasta and Yaron, 2006; Concept Economics, 2008).

Self assessment problem: Self assessments based on business surveys may be prone to strategic misrepresentation (Pasha, Ghaus and Malik, 1990). The reported outage cost may be exaggerated to impress upon the power company the need for more reliable electricity. Alternatively, the respondents may be unaware of the cost or unable to devote the necessary time to complete the questionnaire.

Typically, outage cost estimates are based on what customers say they will experience under different outage circumstances (Lawton, Sullivan, Van Liere and Katz, 2003). The key source of uncertainty in these estimates is the degree to which the cost that customers report, for hypothetical circumstances, correspond with the actual cost experienced (Woo and Pupp, 1992). No studies have attempted to validate the results obtained from these surveys, yet this is a significant source of uncertainty in the cost estimates to date (LaCommare and Eto, 2005). Another important source of uncertainty typically encountered in customer surveys is small sample size. This problem according to LaCommare and Eto (2005) undermines the scope for generalising information derived from the sample.

Limited information: The estimates are based on limited surveys of consumer groups (LaCommare and Eto, 2004). LaCommare and Eto (2005) found that the cost experienced by a non-surveyed customer group were 25-50 percent of the cost experienced by the surveyed population. Business losses are not always directly proportional to the duration of an outage (Eto, Divan and Brumsickle, 2004). In such cases, the key factor is the length of business or production downtime caused by an outage of any length. In some cases, partial loss of voltage or voltage sag can cause the same amount of downtime as a complete loss of power if machines need to be rebooted or production processes need to be restarted (LaCommare and Eto, 2005). This issue poses a major challenge in estimating the economic cost of power interruptions.

Nature of respondents: Assessing actual cost is complicated by differing impacts of events on different classes of customers, for instance, households, industrial, mining and farmers (LaCommare and Eto, 2005). The costs experienced by non-households customers or firms are (in principle) simpler to estimate than the difficult-to-quantify

"hardship" cost experienced by households. Basic accounting categories for firms, such as labour and materials costs and revenue losses, are straightforward (though not necessarily easy) to estimate. However, household-sector costs include elements such as the cost of consumable goods (flashlights and candles) and inconvenience costs (resetting clocks, changing plans, and coping with inconvenience, fear, anxiety, etc).

Presence of backup: The economic cost and perceived risk of unreliable power supply has led many electricity consumers to invest in a wide variety of technologies and measures to reduce their vulnerability to outages. Back-up or stand-by generators are probably the most well known of such investments (LaCommare and Eto, 2005). These investments mean that the direct cost of power outages will differ between those with the generators and those without. The presence of backup sources will also influence the perceptions and estimates of respondents (Eto, Divan, and Brumsickle, 2004).

ADDING THE COST COMPONENTS

In order to estimate the cost of outage by the direct assessment, it is important that total value lost by consumers due to power outages is ascertained by summing all direct cost experienced during outages. The direct costs incurred by firms go beyond production loss or output loss. In addition to output loss cost, other direct costs such as materials destruction cost (in stock), labour cost (payment of idle labourers and cost of overtime and bonuses to meet production and orders), damage to equipment cost, restart cost, time or opportunity cost per outage are part of the outage costs. Mathematically, it is express as:

$$TDC_i = OL_i + MC_i + LC_i + EDC_i + RC_i \quad \text{.....1}$$

Where: TDC_i is the total direct cost for the ith consumer

OL_i is cost of lost output (lost leisure for households)

MC_i is the material destruction cost

LC_i is labour cost

EDC_i is the equipment damage and maintenance cost as a result of outages

RC_i is restart cost

From equation 1, costs per unit of electricity (kWh) lost can be estimated as:

$$OC_i = \frac{TDC_i}{kWhlos_i} \quad \text{.....2}$$

Where: OC_i is the cost per kWh lost,

$kWhlos_i$ are the total units of electricity (kWh) lost or unsupplied due to outages.

CONCLUSION

The purpose of this study was the application of Direct Assessment Method in estimating the economic cost of power interruptions. The direct assessment method estimates the cost borne by the end users and producers of electricity as a result of outages, excluding backup costs. The costs include production loss and all direct losses such as material loss, idle labour cost, direct maintenance cost and lost leisure. The cost also includes the additional cost of covering lost production or sales as a result of outages. The flexibility of the direct assessment method and its link to observable market behaviour recommends its use in outage cost research.

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