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Estimating the willingness to pay for reliable electricity supply: A choice experiment study

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ABSTRACT

This research examines households' willingness to pay (WTP) for an improved electricity service. Households' stated WTP is estimated using the choice experiment (CE) method. The data used in the estimations come from 350 in-person interviews conducted during the period 5–22 August 2008 in North Cyprus. Compensating variation (CV) estimates for a zero-outage scenario are calculated using the parameter estimates from the mixed logit (ML) model; these are 6.65 YTL (Turkish lira) per month (3.02 USD) for summer and 25.83 YTL per month (11.74 USD) for winter. In order to avoid the cost of outages, households are willing to incur a 3.6% and a 13.9% increase in their monthly electricity bill for summer and winter, respectively. The WTP per hour unserved is 0.28 YTL (0.13 USD) for summer, and 1.08 YTL (0.49 USD) for winter. A preliminary cost–benefit analysis indicates that the annualized economic benefits are approximately 42.7 million YTL (19.4 million USD) for the residential sector. This would justify an investment in additional generation capacity of approximately 268 MW, which is far more than that which is needed to eliminate the service reliability problem.

1. Introduction

The reliability of a power supply is crucial for small island countries that depend heavily on tourism for their economic prosperity. Power outages, especially in the summer months when air conditioners are in almost continuous use, can have a deleterious effect on the tourism sector and are therefore of great concern to these countries.[2] Cape Verde in the Atlantic Ocean, North Cyprus in the Mediterranean, and several islands in the Caribbean, such as the Dominican Republic, live with almost daily blackouts (Clough, 2008; World Bank, 2006). Often, the reason behind these frequent and long-lasting blackouts is a lack of investment in electricity generation, transmission and distribution systems.

The objective of this research is to measure customers' willingness to pay (WTP) for electricity reliability using the choice experiment (CE) method. This study is on North Cyprus, which relies heavily on tourism for its economic well being. The results can be used by the government in their evaluations of alternative electricity improvement projects, as well as in setting appropriate tariffs that reflect opportunity costs once the best alternatives have been chosen.

Economic cost–benefit analysis (CBA) has become the approach preferred by many utilities around the world in determining the optimal system capacity and reliability of electricity supply (Chowdhury et al., 2004; Munasinghe and Gellerson, 1979; Sanghvi, 1983; Sullivan, 2009). This method incorporates into the decision making the customers' evaluation of the costs of shortages, which is reflected in their WTP, as well as the system costs. The approach results in a reliability target that is based on economic efficiency criterion rather than simply setting it at some arbitrary maximum value for the probability of an outage. CBA helps to determine the economically efficient level of investment in reliability, at which point the marginal investment cost in reliability equals the marginal social cost of not undertaking that investment.

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[2] When the term 'power outage' (or failure/interruption/blackout) is used in this paper, it refers to a complete interruption of electricity for a period lasting a few seconds or longer.

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1.1. North Cyprus and the electricity system

Cyprus, the third largest island in the Mediterranean (total surface area 9250 km^2) after Sicily and Sardinia, lies 65 km from the south coast of Turkey. The climate is characterized by mild winters and hot, dry summers. The island is divided into two communities. Turkish Cypriots live in the northern part (surface area 3355 km^2) and the Greek Cypriots live in the southern part of the island. North Cyprus has a population of 265,100 (25.1% of the total population of Cyprus) and a gross domestic product (GDP) per capita of 13,354 USD (2009 estimate).[3,4]

In 2012 the total installed electricity generation capacity in North Cyprus was 362.5 MW. The system has suffered from both insufficient generation capacity and a depreciated transmission and distribution network, which are frequent causes of outages.[5] Outages in North Cyprus date back to 1994. Over the years, population growth, an increase in the number of foreign students and tourists, and the exponential growth in the construction sector have worsened the power shortage problem in the north.[6] There are power cuts throughout the year, worsening during the summer months when the air conditioners are working, and during the winter months when more people rely on electricity to heat their homes (Ilkan et al., 2005). Water is very scarce during the summer months and electric water pumps are another major contributor to the increase in demand during this part of the year. The residential sector represented 38% of total consumption in 2008 and grew by an average of 9.3% per annum over the period 2001–2008.

Very few studies have been undertaken to estimate the WTP for improved electricity service reliability elsewhere in the world. Setting a price for a reliable electricity supply is challenging owing to the fact that, unlike water and other regular commodities, electricity cannot be stored in an economical way while its demand varies throughout the day and year. Teblitz-Sembitzky (1992) noted that power generation is a multi-product industry in which the outputs can be indexed by time of use and priority of service, and, in contrast with a single-product industry, the cost allocation and price setting across different outputs is analytically challenging.

To avoid power shortages during periods of high demand, the utility can choose to invest in more reserve capacity, use peak-load pricing, or, alternatively, control the demand for the available supply by load-shedding techniques. Electricity generation during peak periods is more costly because less efficient generators are brought online for a short time. Furthermore, it is the growth of demand at the peak that necessitates additional investment in generation capacity.

2. Previous research

There are many studies that survey the outage cost evaluation literature and categorize the interruption impact evaluation methods into various groups (Anderson and Taylor, 1986; Caves et al., 1990; Lawton et al., 2003; Lehtonen and Lemstrom, 1995; Sanghvi, 1982; Sullivan, 2009; TERI, 2001). The various methods of measuring the cost of unreliable electricity are also widely discussed in the literature on optimal reliability assessment (Billinton and Pandey, 1999; Chowdhury et al., 2004; Sanghvi, 1983; Telson, 1975; Tollefson et al., 1994).

Measuring the cost of unreliable electricity to consumers in the business sector is more straightforward, since these consumers produce an output that has a market value. Measuring the cost of unreliability to residential customers is more difficult owing to the intangible nature of the main losses. The models used for residential users are based on utility maximization subject to an income constraint (Sanghvi, 1982). Each household has a preferred order in which it performs certain activities in a day, each of which brings a certain benefit and increases the household's total utility. A power interruption disrupts this preferred order and results in a reduction of the utility enjoyed by the household. This reduction in utility expressed in monetary values is theoretically equal to the WTP to avoid the costs of the interruption, or alternatively, to the WTA (willingness to accept) of forgoing the benefits from the interrupted activities. In practice, it is measured by survey or market-based methods.

Valuation methodologies for WTP are generally studied under two main categories: revealed and stated preference. The revealed preference approach measures the WTP for a service using actual expenditure data on marketed goods related to the service of interest. The stated preference approach relies on survey-based methods and hypothetical scenarios to measure the consumers' WTP for an improvement in the service. The stated preference method includes the contingent valuation method (CVM), and the choice modelling method. Sometimes this is one of the few ways of quantifying the benefits of a good or service that is not purchased in the market.

While CVM gives a single figure for the WTP for a service improvement, choice modelling methods enable us to break down the service improvement concerned into different attributes at different levels and estimate the marginal willingness to pay (MWTP) for each service attribute. Although CVM is the most widely used stated preference valuation method, CE is increasing in popularity owing to its market realism, and has been widely used in various valuations in different areas, including health, environment and infrastructure. Fewer studies have been carried out on the valuation of electricity services (Abdullah and Mariel, 2010; Beenstock et al., 1998; Bergmann et al., 2005; Carlsson and Martinsson, 2006, 2008; Goett et al., 2000; KPMG, 2003; Morrison and Nalder, 2009).

3. Survey design and implementation

In devising the questions included in our study we benefited from previous questionnaires in the literature that were used to determine residential electricity customers' outage costs, as well as other studies on WTP for service improvement (Bose and Shukla, 2001; Carlsson and Martinsson, 2007, 2008; CIE, 2001; Hensher et al., 2005a; Korman, 2002; KPMG, 2003; Layton and Moeltner, 2005; Moeltner and Layton, 2002; RIC, 2005; Wacker et al., 1983). We ask attitudinal questions regarding the respondents' current electricity service. These questions are intended to reveal the respondents' attitudes towards the electricity system overall, as well as information on load shedding, and on tariff variations. As perceived quality is found to have a positive impact on WTP (Zeithaml et al., 1996), in addition to the attitudinal questions, we include questions on the duration and frequency of summer and winter interruptions (planned and unplanned) as perceived by the respondents. These data are used in determining the respondents' current service attribute levels in the CE analysis. WTP for a reliable electricity supply is expected to be related, among other things, to the household's dependence on electricity (Munasinghe, 1980). Hence, we also ask questions to determine the level of dependency on electricity.

3.1. Choice experiment design

In order to ensure that the important attributes are included in the CE, we first carry out a survey of the literature on the cost of power outages to residential customers. We follow this with six focus group interviews held in the five districts of the country, as well as interviews with officials from the electricity authority. The attributes of an electricity service that participants in general believe to be important and for which they are willing to pay are frequency of outages, duration of

[3] http://nufussayimi.devplan.org/index-en.html, 2006 census and http://en.wikipedia.org/wiki/Demographics_of_Cyprus#Population

[4] http://devplan.org/Frame-eng.html

[5] Kıb-Tek (Cyprus Turkish Electricity Authority — Kıbrıs Türk Elektrik Kurumu in Turkish) is the electricity authority of North Cyprus responsible for the generation, transmission and distribution of electricity in the north.

[6] Annual average growth rates for the period 1979–2008. TRNC State Planning Organization, http://devplan.org/Frame-eng.html