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Estimating the cost of improving quality in electricity distribution: A parametric distance function approach

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HIGHLIGHTS

► We estimate the implicit cost of outages for the main distribution company in France.
► For this purpose, we make use of a parametric distance function approach.
► Marginal quality improvements tend to be more expensive as quality itself improves.
► The cost of preventing one interruption varies from 1.8 € to 69.2 € (2005 prices).
► We estimate that, in average, it lays 33% above the regulated price of quality.

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ABSTRACT

The quality of electricity distribution is being more and more scrutinized by regulatory authorities, with explicit reward and penalty schemes based on quality targets having been introduced in many countries. It is then of prime importance to know the cost of improving the quality for a distribution system operator. In this paper, we focus on one dimension of quality, the continuity of supply, and we estimated the cost of preventing power outages. For that, we make use of the parametric distance function approach, assuming that outages enter in the firm production set as an input, an imperfect substitute for maintenance activities and capital investment. This allows us to identify the sources of technical inefficiency and the underlying trade-off faced by operators between quality and other inputs and costs. For this purpose, we use panel data on 92 electricity distribution units operated by ERDF (*Electricité de France - Réseau Distribution*) in the 2003–2005 financial years. Assuming a multi-output multi-input translog technology, we estimate that the cost of preventing one interruption is equal to 10.7€ for an average DSO. Furthermore, as one would expect, marginal quality improvements tend to be more expensive as quality itself improves.

1. Introduction

The frequency and the duration of power outages are the two key measures of quality that electricity distribution utilities pay particular attention to. Other than the direct costs of outages, represented by opportunity costs and repair expenditures, there is also a regulatory cost as regulators more and more impose bonuses and penalties based on service quality performance. This is for instance the case in France, Germany, Italy and the UK. To prevent outages and these related costs, operators have two main possibilities, either to increase maintenance or to make new investments, e.g. replace overhead lines by underground lines.

In this paper, we estimate the marginal cost of preventing an outage for a distribution system operator (DSO), what we call hereafter the shadow price of quality. This shadow price represents the additional operational or capital expenditure that the DSO must incur in order to reduce the number of outages by one. This information is of particular importance for regulatory purpose as both the marginal benefit and the marginal cost of supplying additional quality are necessary to determine the welfare-maximising level of service quality (Sappington, 2005).

To estimate the shadow price of quality, we make use of the parametric distance function approach. We apply the same approach as Färe et al. (1993) but instead of considering outages as an undesirable output, we assume that they enter in the firm

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production set as an input i.e., that outages are an imperfect substitute for maintenance activities and investment. Therefore, following Growitsch et al. (2009), we postulate that the corresponding distance function is input oriented. This allows us to identify the underlying trade-off faced by operators, between quality and other inputs and costs.

We estimate a flexible translog multi-output multi-input technology. On the output side, we chose a specification that takes into account the main output dimensions of the electricity distribution activity: (i) the number of customers; (ii) the surface area served and; (iii) the GWh of electricity distributed. On the input side, the three dimensions retained are: (i) operational expenditures; (ii) capital; and (iii) quality, represented by the number of interruptions (longer than 3 min in duration). We use for computation purposes, a stochastic frontier approach (SFA) as well as a parametric (deterministic) linear programming approach (PLP). Both approaches give similar results, on average. With the SFA approach we can take into account the influence of random noise—but we find that the monotonicity requirements are not satisfied for all observations. We have thus developed a methodology to integrate the monotonicity constraints in a simple and convenient way using the deterministic PLP approach. To estimate the parameters of the production function, we use panel data on 92 electricity distribution units operated by ERDF (*Electricité de France—Réseau Distribution*) in France in the 2003–2005 financial years. Compared with similar studies, we have access to very comprehensive and comparable data, in particular on the value of capital.[1]

We derive from the underlying production technology the shadow prices for the quality (outages), that is the marginal rate of substitution between quality and the other inputs. For France, the average shadow price of quality is estimated to be 10.7€, meaning that it costs the DSO an additional 10.7€ to prevent one interruption. Our results show that the estimated shadow price of quality varies substantially: from 1.28 € to 69.2 € among the DSOs. Furthermore, as one would expect, marginal quality improvements tend to be more expensive as a network approaches 100% reliability i.e. the cost of quality function is a convex function.

We also estimate the distance function elasticities with respect to inputs and outputs for each DSO. These elasticities can be used to determine the main cost drivers of the operators. Results indicate that, when customer density is low, the main cost driver is the number of clients while electricity delivered can be increased at little cost. When customer density is high, increasing the number of clients and the electricity delivered requires both a substantial input expansion. Finally, our models completely benchmark the French DSOs taking the quality into account, an important exercise since the regulators have now started to use explicit benchmarking methods to regulate the energy distribution companies (see Farsi et al., 2007 for a description).

The remainder of the paper is organised as follows. In Section 2 we survey the literature on benchmarking analyses in electricity distribution including service quality while Section 3 describes the electricity distribution sector in France. Sections 4 and 5 present the methodology and the data used in estimation, respectively. In Section 6 we report the main results of this study and in Section 7 we draw some conclusions.

2. Related literature

Most benchmarking analyses in electricity distribution have involved models that incorporate standard output characteristics, such as energy supplied (in GWh), number of customers and network size (e.g., service area or network length). For example, see the literature review in London Economics (1999) and Jamasb and Pollitt (2001). Very few studies have included quality of service measures in these models. Some exceptions are the studies by Giannakis et al. (2005), Growitsch et al. (2009), Coelli et al. (2007) and Jamasb et al. (2010).

Giannakis et al. (2005) use data envelopment analysis (DEA) methods to measure technical efficiency (TE) and total factor productivity growth (TFP) in 14 UK distribution companies over the 1991/1992 to 1998/1999 period. The DEA method is used to estimate a non-parametric input distance function that involves three output variables (energy supplied, customers and network length). Four models involving different input sets are considered: (i) operating expenditure (OPEX); (ii) total expenditure (TOTEX); (iii) number of interruptions (NINT) and total time lost due to interruptions (TINT); and (iv) TOTEX, NINT and TINT. They find that the TE scores of the various models are positively (but not perfectly) correlated, and that the TE scores rise when the NINT and TINT quality variables are added to the TOTEX model (a result that is to be mathematically expected when variables are added to a DEA model).[2]

Growitsch et al. (2009) use stochastic frontier analysis (SFA) methods to estimate an input distance function using data on 505 electricity distribution utilities from eight European countries in the 2002 financial year. Their models contain two output variables (energy supplied and customers) and either one input variable (TOTEX) or two input variables (TOTEX and TINT). They use the Battese and Coelli (1995) SFA model to investigate the effects of customer density (customers per network km) and country (using dummy variables) upon technical efficiency scores. They find that the inclusion of the quality variable reduces TE for all but the large firms, plus they find that the TE scores from the two models are significantly negatively correlated, both findings being in contrast to those of Giannakis et al. (2005).

Jamasb et al. (2010) estimate the marginal cost of quality improvements of 12 UK distribution companies for the period 1995–2003. For that, they run fixed-effect estimations of the link between the cost of electricity distribution (identified with TOTEX, OPEX or CAPEX) and a series of cost drivers including the energy delivered, the network length, the network energy losses, the customer minutes lost and a time trend. They found that the marginal cost of quality is positive and, on average, equal to 25.6 pence per minute lost. This estimated marginal cost of improving quality is larger than the penalty set by the regulator for lower delivered quality. Consequently, the UK quality of service regulation does not provide enough incentives to increase the quality as the firms are better off paying the fine. Finally, the marginal cost of improving quality increases with the quality delivered, as expected.

The above studies are to be commended for introducing quality variables into these benchmarking models. However, these studies contain some shortcomings. First, they all make use of TOTEX measures which contain capital expenditure (CAPEX) measures which need not reflect the actual amount of

[1] O'Donnell and Coelli (2005) proposed a Bayesian approach which also allows imposing regularity conditions on distance function estimations. Other than the difficulties, in terms of statistical skills and computational challenges, implied by the Bayesian approach, the deterministic PLP approach is appropriate when data are of high quality; as it is the case of the homogeneous information on ERDF units studied here.

[2] This is also seen in a DEA study by Korhonen and Syrjänen (2003) of Finnish electricity distribution operators, where the inclusion of a TINT variable into the DEA model led to increases in technical efficiency for a number of firms. For example, see their Fig. 3. However, note that these results need to be treated with caution because their DEA model did not include a capital measure, which could lead to substantial biases.