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Quality frontier of electricity distribution: Supply security, best practices, and underground cabling in Finland

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ABSTRACT

Electricity distribution is a prime example of local monopoly. In most countries, the costs of electricity distribution operators are regulated by the government. However, the cost regulation may create adverse incentives to compromise the quality of service. To avoid this, cost regulation is often amended with quality incentives. This study applies theory and methods of productivity analysis to model the frontier of service quality. A semi-nonparametric estimation method is developed, which does not assume any particular functional form for the quality frontier, but can accommodate stochastic noise and heteroscedasticity. The empirical part of our paper examines how underground cabling and location affect the interruption costs. As expected, higher proportion of underground cabling decreases the level of interruption costs. The effects of cabling and location on the variance of performance are also considered. Especially the location is found to be a significant source of heteroscedasticity in the interruption costs. Finally, the proposed quality frontier benchmark is compared to the current practice of Finnish regulation system. The proposed quality frontier is found to provide more meaningful and stable basis for setting quality targets than the average practice benchmarks currently in use.

1. Introduction

The last two decades have witnessed a widespread implementation of incentive regulation in the European electricity distribution sector (see, e.g., Jamasb and Pollit, 2001; Haney and Pollitt, 2009, 2011). In this sector the firms are natural monopolies, and their pricing policies are usually regulated by some government agency. The traditional cost-of-service or rate-of-return regulation is known to provide insufficient incentives for distribution system operators (DSOs hereafter) for cost efficiency. A number of European regulators have introduced benchmarking approaches such as data envelopment analysis (DEA) or stochastic frontier analysis (SFA) in order to create incentives for cost efficient operation (see e.g. Jamasb and Pollit, 2007; Kopsakangas-Savolainen and Svento, 2008; Bogetoft and Otto, 2011). The emphasis on cost efficiency has however created adverse incentives for DSOs to decrease the quality of their services (Joskow, 2008). Recently considerable interest has been placed on studying how incentive regulation affects the quality related investments and the quality of service in network industries (e.g., Ai et al., 2004; Cambini and Rondi, 2010; Reichl et al., 2008). Empirical evidence suggests that incentive regulation focusing only on operational costs can reduce the quality of service unless regulation is amended with some quality incentives also (Hafner et al., 2010; Ter-martirosyan and Kwoka, 2010). Thus it seems clear that the regulatory models must be complemented with quality regulation in order to maintain an acceptable level of supply security (see e.g. Jamasb and Pollit, 2008).

The quality of service is seen an important objective by the customers, industry and the regulator alike. Poor service quality such as supply interruptions often leads to losses for industry and households in terms of lost production or the lost utility that customers can obtain from the energy services (de Nooij et al., 2007). As the task of the government (regulator) is to guarantee stable conditions to operate for industry and households, the service quality is a concern for the regulator also.[1] Consequently it needs to be examined how firms can improve their quality of service. Investments on network are one of the more direct ways to affect security of supply as older equipment is replaced with newer one. The most pronounced investment type on how firms can affect their quality of service is underground cabling. For example Fenrick and Getachew (2012) identify underground cabling as a highly important factor in reducing interruptions. Less emphasis however has been placed on how underground cabling affects the variability of interruptions. Since customers (and regulator) can be viewed to be risk averse, they view not only the small level but also

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[1] Customers' valuation of the interruptions of course partly depends from the customer type. See for example Sullivan et al. (1996) for an early discussion and de Nooij et al. (2007) for more recent study.

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the low variability of interruptions as a sign of good quality. Given a certain expected level of interruptions, the scenario with less variability would be favored by most customers over a scenario with high fluctuations in the duration and the frequency of interruptions as the former scenario would guarantee a more stable planning horizon. Risk aversion could be argued to be especially high in countries with highly variable weather conditions, such as Finland. Thus quality regulation should aim to reduce also the risk of interruptions in order to meet the customers' expectations of low variability. However, as Fenrick and Getachew (2012) state, the decision to invest on underground cabling is not straightforward as these investments incur extra costs compared to over-headlines. These costs include for example higher installment costs, costs due to longer repair times, and higher material costs (Hall, 2013). Thus the managers have to weigh the benefits of underground cabling against its extra costs. If the managers perceive the cost to be greater than the benefit, the level of quality may not be at the socially optimal level as managers probably do not consider the consumers' valuation of supply security when making investment decisions. There is large body of literature that discusses about the optimal *level* of quality in electricity distribution sector (Ajodhia and Hakvoort, 2005; Jamasb et al., 2012; Sappington, 2005). The variability of quality is however often neglected from these discussions. This study aims to shed light on how this variability can be affected by underground cabling investments. Our results suggest that underground cabling does not have a significant decreasing effect on the variability of interruption costs. In fact, the effect may be even risk increasing. From policy perspective this implies that firms may need to be given further incentives to undertake underground cabling investments.

Another issue is the practical implementation of quality regulation. Setting the target quality level is one important part of the implementation. In general regulation is challenging as firms usually have an informational advantage over the regulator about their true costs (see Holt, 2005; Kopsakangas-Savolainen and Svento, 2010; Sappington, 2005). Similarly to Shleifer's (1985) classic yardstick model of regulation, already Alexander (1996) discussed using the performance of comparable firms as a way to set the targets. However it may be difficult to find such comparable firms (Pollitt, 2005). Benchmarking methods are considered to overcome the problem of asymmetric information and finding an objective comparison point (see e.g. Ajodhia and Hakvoort, 2005). These methods however have not been used in the regulation of service quality as extensively as in the regulation of costs. For example in Finland the quality targets are set by averaging the own previous performance of the companies. Thus, if a DSO currently operates at a low quality level, it only needs to maintain its current low quality level without any need to improve its performance over time.

In this study we suggest that the best practice benchmarking methods could be utilized in setting the quality targets. We argue that the best practice is preferred to the average level, as the latter approach can create undesired incentives (see Ajodhia and Hakvoort, 2005). The industry wide performance is also likely to be improved more by using the best practices. We introduce a best practice method to be used in setting the quality target and compare it to the current practice of Finnish regulator. Our results indicate that the targets produced by the proposed method are more stable for DSOs of similar sizes than the targets obtained with the current approach of Finnish regulator. These findings seem to be in line with the DSO hopes of developing the foreseeability and stability of the regulatory model and improving the incentives for better performance found by Tahvanainen et al. (2012) in their survey (see also Kinnunen, 2006).

Methodologically both of the above aims, the examination of underground cabling effects and setting the quality targets, can be met by utilizing a recently developed StoNED method for frontier estimation (Johnson and Kuosmanen, 2011; Kuosmanen, 2012; Kuosmanen and Kortelainen, 2012). This estimation method non-parametrically estimates a frontier of quality performance what we call as a *quality frontier*. It also readily incorporates the effects of operational environment of DSOs into its estimation framework. It is generally well acknowledged that the operational environment of DSOs should be taken account in a typical benchmarking process. Network operators are subject to different weather conditions, geographical conditions, and consumer densities which affect their costs and service quality (see e.g. Growitsch et al., 2009, 2012; Simab and Haghifam, 2012; Yu et al., 2009a). In this work we consider the amount of underground cabling as measuring these operational conditions (see e.g. Kuosmanen et al., 2013; Kuosmanen, 2012). DSOs operating in a dense city areas have different underground cabling levels than DSOs in the rural areas. Thus the quality frontier presented in this study accounts for these differences in determining the proper quality targets.[2]

This paper is organized as follows. Section 2 briefly discusses the measurement of service quality and describes the theoretical quality frontier model framework and the empirical estimation method associated with it. Section 3 summarizes the data. In Section 4 we examine the effects of underground cabling on the level and the variance of interruption costs. Section 5 moves to examine the practical implications of using the estimated quality frontier instead of the current Finnish practice in quality target setting. This section also briefly describes the overall Finnish regulatory system. Section 6 then concludes.

2. Quality frontier model

This section introduces the quality frontier model and the necessary terminology and notation. The purpose of this section is also to address the questions of why a frontier model of quality is interesting and what type of information it can provide for the regulators. We also briefly discuss about the measurement of quality at this junction.

2.1. The measurement of quality

In this study, we use the costs of interruptions as the quality indicator (see e.g. Ajodhia, 2010; Growitsch et al., 2010). In Finland the interruption costs are calculated by the Finnish Energy Market Authority (*Energiamarkkinavirasto* (EMV)). The calculation takes into account the duration and number of interruptions. Thus in this study we are only concerned about the continuity of supply aspect of quality. Consequently we do not consider for example commercial or technical aspects of service quality, such as the quality of billing services and voltage variations. The estimates of customers' willingness-to-pay (WTP) to avoid interruptions or the valuation of lost energy are then used to transform the technical measures into costs (see e.g. Reichl et al., 2013; McNair et al., 2011; Growitsch et al., 2010; Yu et al., 2009b; de Nooij et al., 2007).[3] In Finland the customer valuation is based on the survey made by Silvast et al. (2005). The formula on how interruption costs are calculated by the Finnish regulator can be found from EMV (Finnish Energy Market Authority) (2011a) and from Appendix A of this study.

Alternative approach would be just to use technical measures common in the literature such as frequency and duration of outages, customer minutes lost or the loss of energy delivered (see e.g. Fernandes et al., 2012; Simab and Haghifam, 2012). Such technical measures can

[2] In Norway, a large set of environmental and operational condition variables are used in a traditional regression model to estimate an expected level of interruption cost which is then used as a reference value (see Langset et al., 2001). Kopsakangas-Savolainen and Svento (2011) consider load factor variable as a variable describing the operational environment.

[3] Alternative to WTP is willingness-to-accept (WTA), that is, how much customer should be compensated in order to accept an interruption of a certain size. Generally there is large disparity between WTP and WTA measures as the latter is often measured to be much larger than the former. WTA is heavily driven up by the loss aversion of the customers (see e.g. Beenstock et al., 1998). WTP on the other can be subject to underestimation (see e.g. Linares and Rey, 2013).