Quality, Regulation and Benchmarking – An Application to Electricity Distribution Networks

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Introduction

Monopoly and Quality

As opposed to price, relatively little attention has been devoted to the issue of quality regulation of monopoly firms. It is well known from economic theory that the welfare loss of monopoly is not only related to prices and outputs, but also to quality. In general, the monopolist's choice of quality will not coincide with the social optimum. Naturally, the regulator will aim at inducing the regulated firm to provide its consumers with a price and quality level that is as close as possible to the socially optimal one. Reaching this superior outcome is, as has been noted by different authors[1], severely limited by informational problems. When considering the problem of quality regulation, these information problems may be grouped under three headings (Spence, 1975). Firstly, there is the problem of measuring quality levels. Secondly, we generally face the problem of lacking information on consumer demand for quality. Finally, there also exists substantial lack of information on the (efficient) costs required to produce optimal quality.

From the conceptual premise that it is important for utility regulators to induce efficient behaviour but also to obtain socially optimal price and quality levels, this paper investigates the three above-mentioned informational problems in the context of regulating electricity distribution networks. As we will show, the third informational problem, measuring the relation between costs and quality, is the most difficult one. On the one hand, theory provides clear guidelines on how to determine optimal quality levels. The theory on efficiency analysis is well developed and there is substantial practical experience so that benchmarking is now widely accepted as a powerful tool in improving the regulator's informational disadvantage relative to the regulated industry. Nonetheless, little progress has been made so far in the field of simultaneous cost-quality analysis. Efficiency measurement techniques are usually just applied without including the quality element at all. This ignores the fact that rather than only price, regulators should aim to consider both price and quality – preferable within an integrated framework. The objective of this paper is to first provide an overview of the theory and state of the art with respect to the informational problems encountered under quality regulation for electricity distribution. Secondly, we describe practical application of quality regulation in a selected number of countries. Finally, we present the results from an integrated price and quality benchmark analysis based on Data Envelopment Analysis (DEA), which we carried out using an international sample of electricity distribution firms[2].

Paper Structure

In this paper, we extend the traditional benchmarking models by incorporating quality into the analysis. Through this approach, we show that a degree of information can be disclosed on the firm's cost and quality performance to the regulator, thus enhancing the regulator's ability to choose a more effective regulatory portfolio[3]. The present paper shows how to possibly achieve this and is structured as follows. In Section 2, we provide a review of the literature on price, quality, and regulation under monopoly. In Section 3, we

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[1] See in particular Laffont and Tirole (1993).

[2] Quality of supply in Germany is regarded as one of the highest in Europe. In Germany quality of supply regulation has not yet been discussed explicitly and has mostly been connected with the issue of liability payments as part of the "Allgemeine Versorgungs-Bedingungen (AVB)". In the future regulatory framework, additional methods for quality regulation schemes and methods for comparative analysis of quality performance will also need to be addressed. In that regard, the conceptual approach and quantitative analysis presented in this paper can be valuable for the upcoming economic regulation of German electricity distribution firms.

[3] We do not argue that benchmarking can fully solve the informational problem, but rather that it is a useful tool to – at least partly – improve in this regard. See, for example, Ajodhia, Petrov, and Scarsi (2003) for an analysis of the international experience with benchmarking in electricity distribution.

review some of the international experience with quality regulation of electricity distribution networks. In Section 4, we evaluate the three informational problems identified by Spence (1975), namely quality measurement, consumer demand for quality, and the relationship between costs and quality. In Section 5, we present the DEA model to be used for the benchmarking of costs and quality levels, and discuss the results. Finally, in Section 6 we conclude by discussing some conclusions and the possible way forward in integrated cost and quality benchmarking analysis of electricity distribution.

Price, Quality and Regulation

Quality Regulation

Early work by Swan (1970) and Lancaster (1975) study the level of product variation by a monopolist and find that – similar to perfect competition - an optimal range of varieties will be produced. However, White (1977) shows that this result is driven by the (too strict) assumptions made in their analysis. The Swan-Lancaster results only hold true if the monopolist is able to almost perfectly price-discriminate, i.e. to force some buyers of some good variety to pay higher prices than other buyers of the same variety. If the monopolist cannot discriminate – which is generally the case – s/he will not, in general, offer an optimal range of varieties to everyone but, instead, s/he will produce non-optimal varieties for some consumers or may even refuse to provide any satisfactory varieties to some customer groups. Thus, market structure does matter with respect to the range of product varieties that is made available to end-users. The early literature, however, does not connect the problem of suboptimal quality under monopoly with the policy implications in terms of regulation. This issue is examined first in the seminal papers by Spence (1975) and Sheshinski (1976) who independently analyse price, quantity and quality under monopoly and the impact of regulation. In their models, they assume that a single product is produced and quality is uniformly supplied to all consumers. They find that the monopolist will provide either higher or lower quality than the optimal level, depending on demand conditions. If consumers' willingness to pay for quality decreases (increases) at higher demand levels, then quality will be lower (higher) than the social optimum. The source of this failure is, as Sheshinski (1976) puts it: *"When the monopolist extracts from each consumer his value of an upgraded quality, the equilibrium quality level is socially optimum, but when all consumers are equally assessed by the marginal consumer's evaluation, decisions are distorted."* The monopolist provider decides on the basis of the demand of the marginal consumer whilst for social welfare, it is the *average* consumer that matters. As the marginal consumer is not likely to represent the average consumer, the monopoly choice of quality will not generally coincide with the social optimum (if known at all).

Mussa and Rosen (1978) analyse the case when a spectrum of products is produced. In their model, consumers are heterogeneous in their demand for quality, but the producer cannot distinguish among buyers prior to an actual sale and therefore cannot price discriminate. Instead, he offers a price-quality menu to allocate consumers along the quality spectrum by a process of self-selection – thereby permitting partial discrimination among consumers of varying intensities of demand. Assuming that buyers purchase only one unit of the good and that there are constant cost of production, Mussa-Rosen find that the monopolist almost always reduces the quality sold to any consumer compared with what would be purchased under competition. Consumers with low demand intensities for quality are priced out of the market, while a broader range of quality varieties (at an unnecessarily high price) is offered than in the competitive case. The Mussa-Rosen model is extended further by Gal-Or (1983), who finds that when there is a uniform distribution of the willingness to pay of consumers, market entry will decrease quality and only increase quantity. Kim and Kim (1996) find that spillover effects of quality development lead to lower costs, and the monopolist may offer a higher quality than socially optimal. Acharyya (1998) shows that the Mussa-Rosen result depends on the specification of the demand equation, and that the monopolist will not even always find it optimal to offer several qualities. Gabszewicz and Wauthy (2002) find that, if consumers are allowed to buy several units of the product, this is likely to induce the monopolist to select a quality for his product which is not the highest one, even if no cost of any sort is attached to quality. The main result of the Mussa-Rosen model and its subsequent extensions is that quality differentiation enables the monopolist to indirectly discriminate among purchasers of different characteristics. Mussa and Rosen point to this as the essence of their analysis: "*Different marketing [..] costs provoke a distribution of the attribute valuation..[ ]… that allows the monopolist to engage in a form of price discrimination*."

The monopoly outcome, in terms of both quality and quantity, is socially suboptimal. On the one hand, consumers are induced to purchase quality that is lower than the socially optimal level, and on the other hand some consumers might be excluded from the market altogether. Possible remedies to these undesirable consequences are explored by Besanko, Donnenfeld, and White (1988)[4]. They analyse the properties of three regulatory actions: minimum quality standards (MQS), maximum price regulation (MPR), and rate or return regulation (RORR), and find out

[4] See also Besanko, Donnenfeld, and White (1987).

that all three can increase social welfare. Both MQS and MPR raise the quality offered to consumers who prefer low-quality goods, thus reducing the distortion faced by these consumers. As regards RORR, they find similar results as Spence (1975), namely that if higher-quality goods are relatively capital-intensive, RORR will increase the quality options being offered to both high-valuation and low-valuation consumer groups. This reduces the distortion faced by those consumers who prefer low-quality goods, but distorts the quality offered to consumers who prefer high-quality goods. If lower-quality goods are relatively capital-intensive, RORR causes quality to be distorted downward to both consumer types. In both cases, RORR causes sub optimal high capital usage.

Price Regulation and Quality

In the monopoly and quality literature, the question at stake is: what is the optimal quality level and which problems are encountered in achieving it? A related – but fundamentally different – issue studied in the literature is how a change in existing price regulation adversely affects quality levels. Stricter forms of price regulation – as can be noticed in many countries currently reforming their electricity supply industries - aim to incentivise monopoly network companies to improve efficiency and eventually increase social welfare. But, as generally recognised, this also increases the risk on the quality front, since the regulated firm may reduce costs through undesired quality reductions. In electricity, too, not only is the price dimension important, but also the combination of prices and qualities is the factor that will eventually drive social welfare. Spence (1975) already analysed the case when the firm is regulated via a fixed price, and finds out that the firm will always undersupply quality. Under a RORR scheme on the other hand, the firm will tend to oversupply quality if quality is a capital-using attribute. RORR is biased in its inputs towards capital, and forces the capital stock up. This improves quality when quality is capital using, and partially compensates for the firm's tendency to undersupply quality.

Fraser (1994) examines the relationship between price cap regulation and the reliability of supply of a private monopoly. In his analysis, the X factor in the price cap represents the extent to which the firm is permitted to pass onto consumers any specific cost increases in the form of higher prices. He finds that when the firm has increasing costs and is allowed to pass onto consumers a proportion of the costs increase that is sufficient to maintain expected profits, then the associated level of reliability will be increased. However, if the firm is forced to absorb the cost increase to the detriment of its level of expected profits, then the firm's response will be to minimise the loss of expected profits by lowering reliability. Thus, if consumers under the price cap are protected from the cost increase, this protection will be at the expense of lower reliability. There will be some minimum level of price adjustment that is required to maintain reliability. Fraser's conclusions are important to consider in a regulatory setting. Often, regulators impose a price cap with a gradual price decrease (through the X factor) reflecting the regulator's expected improvement in efficiency. Fraser's results imply that if the X factor is set too high and the firm cannot achieve the regulatory cost targets, its strategic response to maintain sufficient profits will be to lower reliability. To solve this problem, Fraser proposes to include a reliability element into the price cap. This benefits consumers in a situation where the firm is required to absorb a cost increase because it can no longer protect profits by reducing its existing reliability level. On the other hand, if costs increase and the firm is allowed to pass on these costs, the resulting price will be proportionally larger than the cost increase, but it will also be associated with an increase in the reliability level. Such effects could be limited by lowering the relative weight of reliability in the price cap constraint.

Kidokoro (2002) focuses on the effects of a regulatory shift from RORR to price cap regulation on quality and welfare. He finds that if quality is capital using, the regulatory shift lowers both price and quality. In the reverse case, when quality is effort-related, the shift to price cap regulation will lower price and raise quality. In this case, an increase in effort lowers price but also raises quality. Kidokoro argues that price cap regulation is not suitable to regulated industries in which the amount of investment is crucial for the outturn level of quality. In this case, some cost-of-service amendments may increase the total social surplus: in other words, a hybrid form of price-cap and cost-plus regulation may enhance social surplus. When applied to the electricity network industry, Kidokoro's results suggest that a shift to price cap regulation will lead to quality degradation as quality (reliability) is capital-related. For effort-related quality, a reverse tendency may be expected. This suggests that it would be preferable to price-cap regulate only those activities that are primarily effort-related, and maintain a RORR system for capital-related activities. In practice, this would mean that investments and maintenance activities would be regulated outside the price cap. Remarkably, this resembles – partly - the features of new style price regulation employed today in the real world. Efficiency targets usually do not apply to capital expenditure; the latter are generally included on a pass-through basis in the downstream prices, albeit after a few non-trivial screening procedures.

In line with the previous authors, Weisman (2002) finds that, under price regulation, the regulated firm's incentive to invest in service quality increases with the level of the price cap. Secondly, Weisman shows that the incentive to reduce investment in quality under price regulation may be tempered by the regulated firm's participation in complementary, competitive markets. A reputation of poor quality in the provision of monopoly services can spill-over to adversely affect sales in the competitive markets the firm is also engaged in. This effect is also empirically confirmed in a recent empirical study for the Italian electricity distribution industry (Ajodhia 2003). Weisman then analyses the effect of different regulatory measures on quality. Under revenue sharing, the revenue is reduced by a revenue-share parameter. The firm bears all costs associated with investment in quality, while it retains only a fraction of the corresponding revenues [Sappington and Weisman (1996)]. Such schemes may actually provide the regulated firm with incentives to reduce investment in service quality. Under profit-sharing penalties, the regulated firm has unambiguous incentives to increase investment in service quality. Finally, Weisman studies the effect of increased information dissemination actions, i.e. exposing the firm's performance to its consumers. Increased dissemination provides the regulated firm with incentives to increase investment in quality without distorting the efficient investment in cost-reducing effort.

Theory suggests that whether or not the monopoly firm will over- or undersupply quality depends on the specific demand conditions. The effect of a shift in regulation (in particular, from RORR to price caps) is likely to induce degradation in quality if quality is capital using. In the case of electricity network businesses whereby a trend towards stricter forms of price controls is noticeable, one may therefore expect a decrease in reliability levels – which is the main dimension of electricity distribution quality, and a primarily capital-using aspect. Empirical studies of this effect are unfortunately scarce in the case of electricity. For the telecom industry, Ai and Sappington (1998) find that the introduction of cap regulation did not reduce quality levels. But Vickers and Yarrow (1988) note that although British Telecom's quality of service has not deteriorated since privatisation, it has not improved much either: "*Given the rate of advance of telecommunications technology this record is poor*". Sappington (2002) provides the examples of Idaho and Oregon where a revenue-sharing system for the telecommunications industry was abandoned due to problems with service quality. According to Ter-Martirosyan (2003) the State Public Utility Commission of Oregon terminated performance-based regulation plans for Pacific Power in 1995 because of the low quality of service, and reintroduced it in 1998 after incorporating strict quality standards for reliability. The first empirical analysis of the effects of the shift from rate of return regulation to incentive-based regulation for electricity utilities is only recently provided by Ter-Martirosyan (2003). She analyses a sample of 78 utilities in 23 states of the U.S. during the period 1993 to 1999. She finds that incentive regulation is associated with an increase in the average duration of electricity outages, although the implementation of explicit quality benchmarks reduces the average duration of outages per customer. Also, incentive regulation reduces the firm's operational and maintenance expenses at the distribution level, which may trigger an increase in the duration of outages.

International Experience

In a competitive environment, suppliers always try and adapt to the quality preferences of customers. In the end, products of different price and quality combinations will emerge, and customers will select those which best match their budgets and preferences. Suppliers do so because the cost of delivering low quality is internal to them, i.e. supplying too low quality will result in a profit decrease because demand will fall. In the case of electricity networks, customers have no choice and ultimately bear the costs of quality being too low. By internalising the costs of low quality to the company, an outcome similar to that of a competitive environment can be reached. Different regulators have tried this to different degrees. In the U.S., a number of regulators have adopted systems that are known as Performance Based Regulation (PBR). Under these systems, usually a part of the allowed revenues is made dependent upon performance on the quality front. Relative to some target, lower performance results in higher penalties while higher performance is rewarded. The maximum amount of penalties and rewards is usually restricted to a few basis points return. In Europe, similar systems have been adopted, for example, in the UK and Italy.

England and Wales

In England and Wales, there are 12 network companies that are regulated by Ofgem by hybrid revenue caps. Operating costs are checked for efficiency on the basis of simple regression analysis, and capital expenditure is reviewed separately. The UK approach is very similar to the US system in that penalties and rewards are based on actual performance. There are a number of minimum standards in place, including direct compensation for customers if power is not restored within 18 hours.
In 2001, Ofgem started up a project (Information and Incentives Project - IIP) that aimed to improve the quality of information from network companies and to strengthen financial incentives with respect to quality (Ofgem 2001). The project sought to find a trade-off between service quality and cost at the margin, and to provide the companies with a reasonable assurance that allowed revenues will be consistent with delivering the level of quality preferred by customers, in order to ensure continuity of service in the longer term. The Quality Incentive Scheme designed under this project consisted of four elements:

- A mechanism that penalizes companies annually, up to 1.75% of revenue, for not meeting their quality of supply targets (as measured by the number and duration of interruptions to supply);
- A mechanism for rewarding companies who exceed their quality of supply targets for 2004/05, on a one-off basis by up to 2% of revenue, based on their rate of improvement in performance up to that date;
- An intention to reward frontier performance in terms of quality and cost in the following price control period; and
- A mechanism for rewarding or penalizing companies annually, up to a maximum of 0.125% of revenue, for the relative quality of their telephone response to customers, and a proposal to introduce targets for the speed of telephone response from April 2003.

Ofgem has also announced that it will investigate whether the current scheme can be taken further to include customers' valuation of outage costs and the costs of making improvements in performance.

Norway

The Norwegian system includes more than 200 small network companies that are regulated by NVE. On 1st January 1997, the Norwegian regulator introduced an incentive-based regulatory model. The basic element of the new regulatory system is that the allowed (for recovery) network costs (i.e. allowed revenue) are, to some extent, separated from actual costs. Through incentives, NVE strives to encourage network owners to reduce costs and improve efficiency. Under the new system, network owners are no longer guaranteed full cost recovery. By establishing a system whereby each network owner is allowed to receive a predetermined maximal revenue, profits will in principle be equal to the difference between allowed revenues and actual costs.

Starting 2001, a link was introduced between allowed revenues and the level of performance – the so-called CENS arrangement. Based on estimates of energy not supplied (ENS) and average specific interruption costs for each customer category, interruption costs (IC) were calculated for each company annually. The expected level of ENS is also calculated for each company, and hence the expected level of IC. At the end of the year, the regulator calculates the difference between expected and actual IC. This difference is then cumulated to the allowed income for future years (Langset et al., 2001).

The Netherlands

The Dutch regulator DTe uses a price cap regime (tariff baskets) to set network tariffs. Under this approach, both capital and variable costs are benchmarked. Under such a system, the risk of under-investment increases and quality regulation becomes crucial. The Dutch regulator has issued a set of technical codes that detail some responsibilities for network companies. However, compliance with these codes is difficult to monitor and enforce. In 2001, the regulator therefore adopted a first quality code. This code obliges network companies to report and publish their performance levels. It also introduces further quality standards and individual standards in combination with penalties. In case of outages longer than 4 hours, customers are entitled to an automatic compensation payment from the network. The compensation should ideally reflect the value of reliability for the customer. Secondly, the payment scheme should minimize undesirable side effects. In the Dutch case, network companies might focus on avoiding outages longer than 4 hours, whereas shorter outages may be neglected. The new regulatory model of DTe (initially planned to be implemented from 2004, and then postponed) envisages yardstick regulation with respect to both quality and price. Under this system, companies will receive either a penalty or bonus depending on the difference between their own performance and that of the average of all (other) companies.

Italy

There are about 195 network companies in Italy, most of them being owned by ENEL. Network operators are regulated on the basis of a price cap by regulator AEEG (Autorità per l'Energia Elettrica ed il Gas). In Italy, the focus has been on improving reliability and attaining more uniform reliability levels between North and South. So far, only long unplanned outages (duration longer than 3 minutes) have been regulated. This is done through an incentive mechanism under which each company is assigned an improvement target, based on its current performance and customer density. A distinction is made between urban, suburban, and rural areas. For the future, AEEG is planning to complete the quality regulation scheme through the introduction of individual guaranteed standards at least for HV and MV users, and some overall regulation for short (duration longer than 1 second and shorter than 3 minutes) and transient outages (duration shorter than 1 second) for which zonal measurements are required (Lo Schiavo and Malaman, 2003).

Victoria, Australia

Victoria has gone further than the other Australian jurisdictions in regulating the quality of supply. This may be related to the fact that Victoria privatized many utilities over the 1990s. Experience suggests that consumers demand higher quality of supply and are less accommodating of service faults when utilities are privately owned than when they are owned by government. In any case, Government in Victoria has extended much more regulatory oversight over aspects of quality of supply in the electricity, gas and transport sectors than is apparent elsewhere.

The regulatory arrangements established for the electricity networks in 1996 set minimum standards for reliability. These standards differentiated between short and long feeder, but were generally seen to be too conservative and easy to achieve. The Regulator (Essential Services Commission or ESC) has prepared annual reports on quality of supply and financial performance of the electricity distribution businesses. These reports provide time series data on the reliability of supply and are considered to have put pressure on poor performers that has been translated into improved performance in subsequent years. In its 2001–2004 electricity determination, the Victorian Regulator has adopted a framework including two financial incentives for service reliability:

- The addition of a new term, ‘S’, to the CPI-X price controls that will adjust the annual price caps for each distributor to reflect actual service performance outcomes relative to the targets. The targets cover total minutes off supply, interruption frequency and duration - for both planned and unplanned outages - defined separately for each distributor and for each of the four major feeder network types. To the extent that the distributors can achieve or exceed the set reliability targets at a lower cost than implied by the expenditure benchmarks, they can keep additional revenue within the regulatory period. If they under–perform the targets, their revenue will be reduced over that period; and
- The requirement to make ‘Guaranteed Service Level’ payments to customers who experience reliability that is worse than specified performance thresholds. Standards have been set by consultation, monitoring and consumer liaison, and will be measured against a year 2000 baseline. The impact of momentary interruptions has been excluded from the incentive scheme due to lack of reliable and comprehensive measurement.

The general goal of the ESC is to ensure that the regulatory control delivers sustained incentives for the distribution licensees to increase their efficiency and reduce costs while maintaining and improving the reliability and serviceability to customers of their distribution systems. In economic terms, the price control should enable efficient distribution licensees to raise sufficient revenue to meet their operating costs, to finance necessary new investment, and to provide an adequate return on past investment that was efficiently undertaken. At the same time, in the context of the 2001 price review, the ESC clarified the standards of service reliability and quality that are to be delivered by the distribution licensees in return for the revenue streams provided under the price control.

Information problems

Measuring Quality

In general, a distinction can be made between three quality aspects: voltage quality, commercial quality, and network reliability (CEER, 2001). Firstly, voltage quality, sometimes called power quality, covers a variety of disturbances in a power system. It is mainly determined by the quality of the voltage waveform. The relevant technical phenomena are: variations in frequency, fluctuations in voltage magnitude, short-duration voltage variations (dips, swells and short interruptions), long-duration voltage variations (over- or under-voltages), transients (temporarily transient over-voltages) and waveform distortion (Dugan et al., 1996). Secondly, commercial quality is related to individual agreements between the network company and their customers. Examples of such agreements are the conditions for (re)connection of new customers, installation of measuring equipment, regular transactions such as billing and meter readings and occasional transactions such as responding to problems and complaints. In this paper, we will be primarily concerned with the third quality aspect i.e. network reliability. This is generally considered the most important aspect of network quality as it lies at the heart of the network service. Network reliability is a measure for the ability of the network to continuously meet the demand from customers. This aspect can be divided into two elements: The first one relates to guaranteeing sufficient capacity in the long term (adequacy) so that the network service can be delivered. The second one relates to whether the network service can actually be delivered in the short run i.e., customers do not experience interruptions in the supply of electricity. In practice, such outages may be caused by network failures or by system balance deficits. In this article we only consider network causes.

Several indicators are used to evaluate the reliability in distribution networks. The most common measures at the system level are the so-called SAIFI, SAIDI, and CAIDI indicators that measure reliability over a pre-defined period, usually of one year (IEEE, 1999):

- SAIFI stands for System Average Interruption Frequency Index and measures the probability that a customer will experience an outage. It is calculated by dividing the number of customer interruptions by the total number of customers served. The number of customer interruptions is the total number of interrupted customers for each outage.
- SAIDI stands for System Average Interruption Duration Index and provides a measure for the average time that customers are interrupted. It is calculated by dividing the total customer interruption duration by the total number of customers. The customer interruption duration is defined as the aggregated time that all customers were interrupted. SAIDI is a high level indicator representing the overall performance of the network.

- CAIDI stands for Customer Average Interruption Duration Index and is a measure for the average time required restoring service to the average customer per outage. It is calculated by dividing the total interruption duration by the total number of outages.

The Demand for Quality – Outage Costs

When measuring consumer demand for quality in electricity networks, it is common to use the indirect concept of "outage costs". The underlying reason for using outage costs is the difficulty in deriving direct information for the perceived value of reliability. Outage costs are the costs that consumers incur because of reliability being less than perfect. These costs can be divided into two components – short-term outage costs and long-term "adaptive response" costs (Sanghvi 1982). Short-term outage costs are costs that are incurred by consumers, either directly or indirectly, as a result of an outage. These costs can take different forms and are, broadly speaking, either economic or social. Direct impacts are those resulting immediately from the cessation of supply, while indirect impacts result from a response to an interruption. Examples of direct economic impacts are lost production, process restart costs, spoilage, etc. Direct social impacts include inconvenience, loss of leisure time, and personal injury or fear. Indirect impacts can be civil servant disobedience or looting during a blackout. The second category, long-term adaptive response costs, is associated with the changes in consumers' capital stock resulting from mitigating actions to reduce potential outage costs. Examples of such actions are installing emergency equipment (e.g. candles or flashlights), protective switchgear, Uninterruptible Power Supplies (UPS) or backup generators. Total outage costs are the sum of short-term and long-term costs. In theory, a consumer will invest in outage cost mitigating measures until the point where these two are equal at the margin i.e., total outage costs are minimized. Obviously, the consumer will only be able to make this optimal trade-off if s/he can estimate future reliability levels accurately enough.

The costs of an outage can be driven by many factors, some or even all of which may not be observable at all. In general, these factors can be grouped into outage characteristics, and consumer characteristics. An important element of the former category is outage duration. As an outage prolongs, outage costs increase. Research shows that there is a large initial fixed cost component, plus a variable component that decreases with duration (Caves et al., 1990). Outage costs will also vary with the time of the year, day of the week, and time of the day. For residential consumers, winter outages lead to higher costs than in the summer, while morning or late evening outages are less costly than afternoon ones (Woo and Pupps, 1992). For non-residential consumers, the amount of costs is closely related to the level of output. For example, Billinton et al. (1982) find that for retail consumers in Canada, the outage costs during the Christmas season and on Saturdays are significantly higher[5]. For large industrial consumers, the timing of outages tends to have little effect; this reflects the constant output delivered in these industries (Gates et al., 1999). If an outage is planned, e.g. in case of energy shortages or maintenance activities, advanced notice may be provided to consumers of the occurrence or duration of the outage. Such actions tend to decrease outage costs as consumers may take preventive actions or appropriately reschedule their activities. Note that this is in line with the previous observation that consumers experiencing frequent outages exhibit lower costs due to increased preparedness. A Scandinavian study report that planned outages can significantly reduce instantaneous outage costs (Lehtonen and Lemstrom, 1995). Similar results have been reported in other countries, including the U.S., Canada and Nepal, with a reduction in perceived outage costs varying between 20 and 50 percent [Billinton et al. (1982), Gates et al. (1999), Dialynas et al. (2001)].

Consumer characteristics also play a role in the valuation of outage costs. Doane et al. (1988) find a positive correlation between the presence of electric equipment in a household, and the level of outage costs. Consumers' dependency also increases over time: Sullivan and Sheehan (2000) report a doubling in the real economic quantification of reliability by households in the U.S. over a 10-year period. Andersson and Taylor (1986) report an increase in real outage costs from 1969 till 1980 in Sweden. These results are attributed to the increased reliance of consumers on electricity supply. Specific consumers may be more dependent than others, e.g. the elder and/or sick may be more vulnerable to outages. The perception of consumers may also influence outage costs. A study in Nepal showed that 38 percent of residential consumers considered the number of outages to be "low" or "very low", although the average number of outages was four per week (Pandey and Billinton, 1999). Similar results were found in a Brazilian study where more than half of the residential consumers interviewed valued the quality of service provided as "good", although half of these consumers had experienced at least one outage per month (Gastaldo, 2001). In most Western countries, such outage frequencies would not likely have delivered too positive outcomes in terms of customer satisfaction. A possible explanation for this is that as the frequency of outages increases, consumers can make a better trade-off between expected outage costs and adaptive response costs, thus minimiz-

[5] An interesting result reported is that, for retail and commercial consumers, the least costly hour of outage during working hours is lunchtime (arguably, unless the outage event directly affects their lunch's enjoyment).

ing total outage costs. Also, daily dependency on electricity may not be as high in the developing world as in Western countries, thus resulting in lower perceived outage costs.

Outage Cost Measurement Techniques

The literature presents a large number of methods to measure outage costs; in this section, we present some of these methods. A general distinction can be made between indirect (or proxy) methods and direct (or survey) methods. *Proxy* methods analyse factors that may act as a proxy for outage costs experienced by consumers. Under *survey* methods, this information is acquired directly from consumers themselves. In recent years, different proxy methods have been developed. Examples include the ratio of Gross National Product (GNP) to electricity consumed (this roughly represents the upper bound for outage costs), the ratio of the electricity bill to energy consumption, the wage rate, the value of lost production for a firm during an outage etc. Another proxy method is to derive outage cost information from electricity demand curves. The idea is that the willingness-to-pay for electricity depends on the degree to which the consumption of each energy unit can be deferred to (i.e. substituted for) another hour. When the elasticity of substitution is low, then the consumer surplus loss increases. The consumer surplus loss minus the bill savings resulting from foregone electricity consumption will then provide an indicative measure for the outage cost (Sanghvi 1982). For industrial consumers, the live cost of backup supply could be used as an outage cost proxy (Bental and Ravid 1982).

Similar to proxy methods, a series of survey methods exist. Blackout studies collect information about outage costs from actual outages. This method is usually applied in case of large-scale outages, e.g. the 1977 New York or 2003 North America blackouts. Direct cost surveys request outage costs directly from consumers. Consumers are requested to identify the different costs categories in case of an outage such as lost sales or production, spoilage, damage, after which an economic value is attached to each category. The outage costs are then the sum of all these individual costs. Optionally, a list of possible measures and associated costs can be provided and consumers are asked to indicate which measure they would employ for different outage scenarios. Under the "contingency-ranking" method, consumers are asked to indicate either willingness-to-pay (WTP) for higher reliability, or the willingness-to-accept (WTA) lower reliability levels. Conjoint analysis is similar to contingency-ranking valuation, with the difference that the WTA and WTP figures are derived indirectly. With conjoint analysis, consumers are requested to rank different (mutually exclusive) combinations of price and reliability levels – the price range is already determined ex ante by the researcher.

Cost and Quality Relationships

Several empirical studies have reviewed the social desirability of investments in power system reliability and have found that, in general, there is an oversupply of reliability. These conclusions are in line with the theory that rate of return regulation will be biased towards higher than optimal quality if quality is capital using. In the theoretical models that we discussed in our introduction, the issue of optimal quality was approached from the point of view of demand and costs. It was found that the monopolist's profit-maximising quality level is, in principle, not equal to the socially optimal quality level. Another stream of literature analyses the optimal quality choice under the assumption that the monopolist is a benevolent social planner, i.e. it maximises social welfare. Strategies for optimally balancing costs and quality in power systems have been proposed and applied in the utility industry. For electricity generation, a rich theory on peak-load pricing and optimal reliability was developed in the 1970s[6]. For distribution network planning, Munasinghe (1981) proposed a network-planning framework under which the firm chooses a quality level such that social welfare is maximised. This condition is met if the marginal costs of increasing reliability are equal to the marginal benefits that consumers gain from this increase. In practical terms, this means that the firm will invest in such a way that quality is optimal, and that the firm itself will be able to recoup these costs entirely, either from consumers or through a government subsidy[7]. In line with the Spence-Sheshinski models, optimal quality would require that – given the level of output – both costs and average demand for quality are equal at the margin. As noted earlier, it is very difficult – if not impossible – to extract information on the demand-quality relationship from consumers. Therefore, the indirect concept of "outage costs" is used. The standard optimality condition, then, turns into the requirement of finding the quality level where the cost to supply quality and the cost incurred by consumers as a result of outages are jointly minimised[8]. This well known "optimal reliability concept" has been widely promoted as the preferred approach for quality decisions in the electric utility industry.

There are, however, a couple of problems attached to the assumption of the network planner being a benevolent social planner. First, as widely argued for in the regulatory literature, leaving the firm with full discretion to choose

[6] See Crew and Kleindorfer (1982) for an overview of this discussion.

[7] As marginal cost will, in general, be lower than average cost, pricing at marginal cost will not fully recover the firm's full costs under economies of scale.

[8] See, for example, Munasinghe (1981) for a more theoretical assessment of this condition.

the quality level can lead to over-investment as a legitimate profit-maximising strategy. The well-known overcapitalisation thesis of Averch and Johnson (1962) predicts that, in its choice of inputs, the firm will be biased towards over-utilisation of capital. In turn, as quality is general capital using in the case of electricity networks, this would result in sub-optimally high quality levels ("gold plating"). Therefore, it is likely that - instead of ending up with a socially optimal quality level - monopoly firms being left free to tilt the balance of their inputs towards excessive capital intensity may deliver quality levels that are too high relative to the social optimum. There is general agreement that traditional forms of regulation have resulted in low productivity and inefficient high quality levels in the electricity utility industry. Indeed, as Alfred Kahn (2002) noted:

"*But there is reason to believe that it [high reliability] has come at too high a price. There is substantial evidence that the [quality] standards were selected by engineers to make their lives easy rather than to save customers money*."

The second problem is the lack of incentives for productive efficiency. The traditional regulatory approach is to leave the discretion to set quality levels to the firm, and set the prices on the basis on underlying costs. This, however, creates little incentive for productive efficiency in terms of input usage. Baumol and Klevorick (1970) argue that RORR helps keep inefficient firms in business. Since under RORR all profits in excess of the predetermined return are disallowed, this "*precludes extraordinary rewards for extraordinary entrepreneurial accomplishment*". They propose the instrument of the "regulatory lag" – keeping prices fixed between two price reviews - as a means to induce efficiency. Similarly to what happens with the Schumpeter innovation process, firms under a regulatory lag can (temporarily) retain the profits resulting from cost reductions and thus face strong(er) incentives for efficiency improvement. Excess profits can be earned during the lag, since through research and innovation the firm can reduce its costs below the level prevailing at the time when prices were set (at the beginning of the regulatory period). The additional earnings are, however, only a temporary benefit. At the next regulatory review, prices will be readjusted to take into account the firm's improved technology and the process will begin all over again. Baumol and Klevorick's proposal to pre-set a formal lag between price reviews indeed can be considered as the first historical step in the change from a RORR system to a price-cap scheme.[9]

An important issue when designing price-cap systems is the determination of the efficiency factor (X). In recent years, the theory on efficiency analysis has been developed to a great extent[10]. In addition, numerous studies have been performed of efficiency in electricity networks[11]. An area that has, however, received very little attention is the incorporation of quality into efficiency analysis. Some studies that do this include those by Korhonen and Syrjänen (2002), and CEPA (2003), who respectively analyse a sample of Finnish and U.K. distributors. They both find an improvement in efficiency scores after including the interruption time (as a proxy for quality) in the DEA benchmark. Korhonen and Syrjänen find that quality drives efficiency scores. In contrast, CEPA (2003) find no statistically robust relationship between the change in scores and the quality level. There are a number of factors that can explain these diverging results. Both studies only consider operational expenditure (opex), which only captures the short-term cost aspects of the electricity distribution business. However, reliability is strongly capital-related[12]. Therefore, incorporating reliability into an opex-only benchmark is not likely to fully capture the quality aspect. On the other hand, there is some evidence that U.K. distributors have perversely substituted between opex and capex. Whereas UK distributors are tightly regulated on the opex side, they do have a lot of room for manoeuvre on capex. As a result, there seems to be a bias towards capitalisation of what normally would be considered an opex activity. This effect may also explain the low correlation between efficiency scores with and without quality included as a variable. A benchmark analysis that assesses both short- and long-term cost elements (total costs: TOTEX) may well provide more insight into the cost-quality relationship, a task we embark on in the next section.

Benchmarking price and quality

Modelling aspects

In this Section, we present a benchmark model based on Data Envelopment Analysis (DEA), which we use to carry out integrated analysis of cost and quality for distribution firms. For quality, we use annual minutes "not served" (Customer Minutes Lost or CML). We make use of a multi-national cross-sectional sample of distribution operators from the Netherlands, the UK, Hungary, and Malaysia. The data was gathered from publicly available sources including regulatory publications and company accounts. We analyse the sensitivity of different parameters and perform crosschecks with other, statistically based benchmarking techniques to test the significance and validity of

[9] Subsequent articles have echoed and confirmed the advantages of fixing the regulatory lag. See Train (1991) for an overview.

[10] See for example Ajodhia, Petrov and Scarsi (2003) for a review.

[11] See for example Jamasb and Pollitt (2002) for an overview of such studies.

[12] We do not argue that reliability is only capital-related. For example, the number of repair crew staff (which is an element of opex) has a significant impact on outage duration.

Table 1: Model specifications.

	Model 1	Model 2
TOTEX	Input	Input
CML		"Negative Output" (minimising)
KWH	Output	Output
CUSTOMERS	Output	Output

our linear programming (DEA) outcomes.

Data Envelopment Analysis (DEA) takes, as its starting point, that - for any production process - there is an output frontier linking the maximum combination of outputs attainable with a given set of inputs, or, equivalently, for any set of outputs, there is an input frontier linking minimum combinations of inputs that are needed to produce those outputs. Production units that lie on this frontier are said to be "technically efficient". Technical efficiency is measured by comparing each production unit's actual combination of inputs and outputs with a relevant point on the frontier. For cost-minimising DEA, input price information would be required. In the absence of reliable information on input prices, we will here use a hybrid form of DEA whereas cost is treated as a - physical-like - input, and therefore the program is run as a technical efficiency DEA. We are aware of the theoretical problems caused by the usage of cost as a minimisable "input" in DEA, and we refer the reader to DTe's paper on cost-based benchmarking for more information on this hybrid DEA methodology and the theoretical justifications for it (DTe, 2000).

There are different ways of carrying out cost-based DEA, and these may lead to different results. We opted for a cost minimising technical efficiency model, because of the unavailability of data on input prices and thus the practical difficulty of separating out technical and "allocative" inefficiency. As regards scale assumptions in DEA, it is good to include the option between "constant" and "variable" returns to scale. As opposed to econometric techniques, DEA's application is easier in relating efficiency scores to non-economic features. This is mainly due to the fact that DEA computes scores rather than estimating them, and that no functional form is imposed upon technology. The absence of restrictions entails the "encompass" effect typical of DEA, leading to the absolute reliance of this technique on any single data point available, without any statistical smoothing. The use of DEA, therefore, makes quality analysis possible once quality is quantified in a reliable way, without the imposition of any functional form at all on the cost/quality relationship.

A standard DEA specification is the one considering total expenditure (TOTEX) as an input, both without (Model 1) and with quality (Model 2). The Model 2 variation on the basic DEA specification (Model 1) is the one using Customer Minutes Lost (CML) as a 'negative output', i.e. a fictitious input to minimise. The CML model is useful as a sensitivity variation on the standard totex specification. In all cases, we have two conventional distribution DEA outputs (to be held fixed in input-minimisation mode), i.e. kWh being distributed and the number of connections (approximated by the number of customers). The two models we envisage for our analysis are reported below in Table 1.
TOTEX is calculated as the sum of OPEX and Depreciation[13], at PPP-adjusted (April 2003) exchange rates normalised to the US Dollar (USD) in thousands. CML is defined as the cumulative minutes of interruption for all customers in any given year[14]. Energy delivered and customers are as reported in regulatory accounts by the utilities. All variables are re-scaled in natural (base e) logarithms for the purposes of econometric estimation, whereas they enter DEA as natural values.

Companies included in the dataset come from the UK, the Netherlands, Hungary (all of which are EU member states in 2004), and Malaysia from the ASEAN group. The data are for 2003 and the cross-section is internationally pooled. It excludes one UK utility for which depreciation data were not computable – thus bringing the number of UK distribution firms (DNOs) to thirteen from the fourteen making up mainland Britain (Northern Ireland is subject to a different industry and regulatory structure, and is therefore excluded). Otherwise, the sample is made up of six regional Hungarian utilities (distribution only), twelve Dutch territorial distributors (this number continuously decreasing due to merger activity), and thirteen Malaysian federate states from the territorial split of Tenaga Distribution, the distribution arm of Malaysia's lead electric utility TNB.

DEA models are run under both a constant and variable returns to scale assumption (CRS and VRS, respectively, and Models 1 and 2). This is to accommodate the debated issue of scale efficiency and responsibility for scale optimisation on the utilities' side, an issue that contributed to cripple the first DTe (NL) electricity distribution benchmarking exercise of 1999-2000.

Econometric cross-checking models are run in natural-logarithm mode taking cost as the endogenous (dependent) variable, and all other variables as explanatory (exogenous) factors. The functional form chosen for the econometric cross checks is the standard, log-log Cobb-Douglas cost function that is, on most occasions, a valid nested approximation to, and an acceptable statistical restriction of the more general, but much more data demanding, "Translog" cost function. A nice corol-

[13] We ignore here the return on assets (equal to RAB times WACC) for reasons of lack of comparability, in particular for non-EU countries.

[14] In our analysis, CML was calculated as the product of SAIDI (System Average Interruption Duration Index) and the total number of customers.

Figure 1: Graphical Presentation of Efficiency Scores without Quality

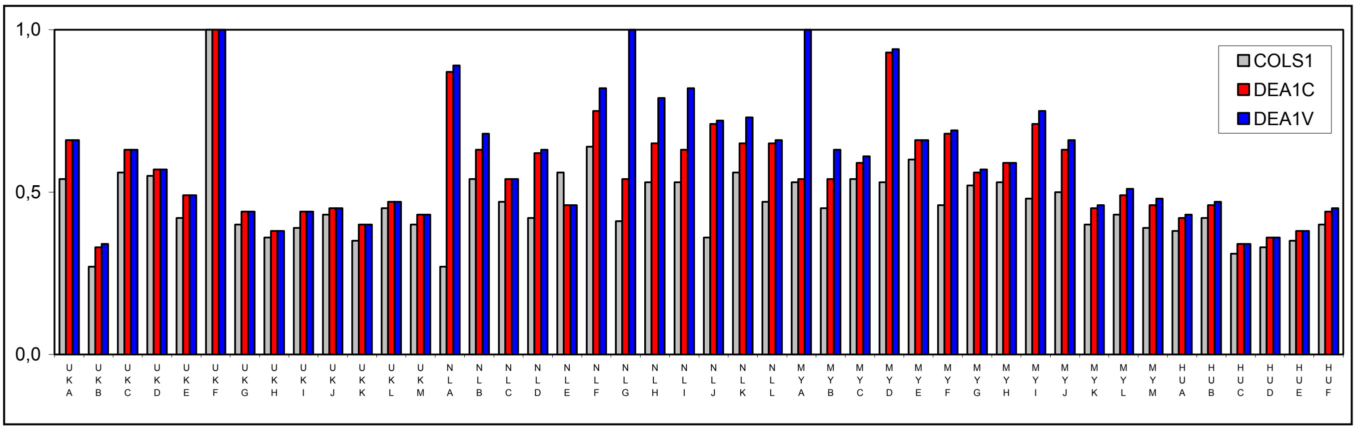
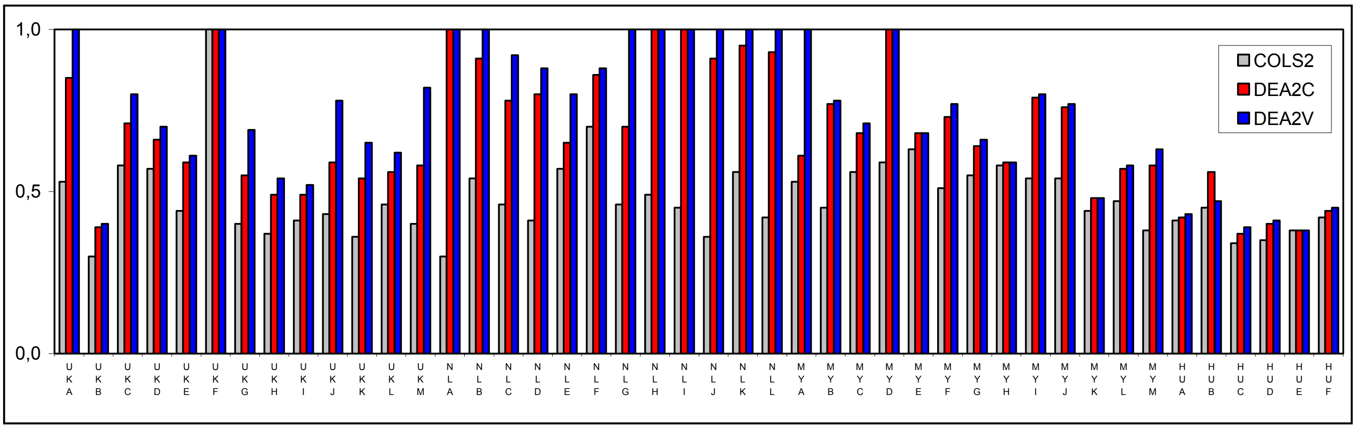


Figure 2: Graphical Presentation of Efficiency Scores with Quality



lary of this choice is that the estimated parameters from the cost function can directly be interpreted as (cost-output) elasticities.

DEA and econometric results (efficiency scores) are readily comparable on a statistical basis by means of both parametric (t) and non-parametric (distribution-free) tests. Efficiency scores are censored at 100% and cannot be lower than 0%. Under these conditions the usual testing procedure for statistical comparisons across score series would have to be non-parametric, as score series will sometimes fail to be normally distributed. However, normality can be tested in advance in order to select the preferred statistical cross-checking methodology.

Modelling Results

The models we ran, Models 1 and 2, gave DEA and COLS (Corrected Ordinary Least Squares) scores to cross-check. The total sample of 44 cross-sectional observations is too small to guarantee acceptable results in the presence of more complex statistical assumptions such as those underlying Stochastic Frontier Analysis (SFA). We tried to calculate SFA scores, but these were all clustered towards full efficiency, thus losing any discriminatory power in terms of efficiency ranking. This often happens to SFA with relatively small samples. The uselessness of SFA results led us to drop this technique from the modelling exercise.

On the other hand, COLS is a relatively accepted and unambiguous modelling technique to cross-examine DEA results. It is based on conventional OLS estimation, which is corrected by moving the regression line either back or forward by a horizontal shift in order to encompass the whole dataset. By so doing, COLS heavily relies on the position of the single most efficient observation in the dataset, and is in a sense similar to DEA in terms of extreme data dependence. However, COLS and DEA efficiency scores are calculated on the basis of completely different assumptions otherwise, and therefore they do not easily agree with each other in statistical terms. This introduces a degree of uncertainty in the benchmarking exercise if the latter is used by regulatory authorities for price control purposes.

Efficiency scores (bounded by zero and one) from both Models 1 (no quality) and 2 (CML) follow for all of the (anonymous) 44 utilities making up our cross section (Figure 1).

Regarding DEA, our Models are split according to the assumption made on scale efficiency (CRS or Constant Returns to Scale for absolute scale effi-

Table 2: Efficiency Scores

Number	Company	COLS1	DEA1C	DEA1V	COLS2	DEA2C	DEA2V
1	UKA	0.54	0.66	0.66	0.53	0.85	1.00
2	UKB	0.27	0.33	0.34	0.30	0.39	0.40
3	UKC	0.56	0.63	0.63	0.58	0.71	0.80
4	UKD	0.55	0.57	0.57	0.57	0.66	0.70
5	UKE	0.42	0.49	0.49	0.44	0.59	0.61
6	UKF	1.00	1.00	1.00	1.00	1.00	1.00
7	UKG	0.40	0.44	0.44	0.40	0.55	0.69
8	UKH	0.36	0.38	0.38	0.37	0.49	0.54
9	UKI	0.39	0.44	0.44	0.41	0.49	0.52
10	UKJ	0.43	0.45	0.45	0.43	0.59	0.78
11	UKK	0.35	0.40	0.40	0.36	0.54	0.65
12	UKL	0.45	0.47	0.47	0.46	0.56	0.62
13	UKM	0.40	0.43	0.43	0.40	0.58	0.82
14	NLA	0.27	0.87	0.89	0.30	1.00	1.00
15	NLB	0.54	0.63	0.68	0.54	0.91	1.00
16	NLC	0.47	0.54	0.54	0.46	0.78	0.92
17	NLD	0.42	0.62	0.63	0.41	0.80	0.88
18	NLE	0.56	0.46	0.46	0.57	0.65	0.80
19	NLF	0.64	0.75	0.82	0.70	0.86	0.88
20	NLG	0.41	0.54	1.00	0.46	0.70	1.00
21	NLH	0.53	0.65	0.79	0.49	1.00	1.00
22	NLI	0.53	0.63	0.82	0.45	1.00	1.00
23	NLJ	0.36	0.71	0.72	0.36	0.91	1.00
24	NLK	0.56	0.65	0.73	0.56	0.95	1.00
25	NLL	0.47	0.65	0.66	0.42	0.93	1.00
26	MYA	0.53	0.54	1.00	0.53	0.61	1.00
27	MYB	0.45	0.54	0.63	0.45	0.77	0.78
28	MYC	0.54	0.59	0.61	0.56	0.68	0.71
29	MYD	0.53	0.93	0.94	0.59	1.00	1.00
30	MYE	0.60	0.66	0.66	0.63	0.68	0.68
31	MYF	0.46	0.68	0.69	0.51	0.73	0.77
32	MYG	0.52	0.56	0.57	0.55	0.64	0.66
33	MYH	0.53	0.59	0.59	0.58	0.59	0.59
34	MYI	0.48	0.71	0.75	0.54	0.79	0.80
35	MYJ	0.50	0.63	0.66	0.54	0.76	0.77
36	MYK	0.40	0.45	0.46	0.44	0.48	0.48
37	MYL	0.43	0.49	0.51	0.47	0.57	0.58
38	MYM	0.39	0.46	0.48	0.38	0.58	0.63
39	HUA	0.38	0.42	0.43	0.41	0.42	0.43
40	HUB	0.42	0.46	0.47	0.45	0.56	0.47
41	HUC	0.31	0.34	0.34	0.34	0.37	0.39
42	HUD	0.33	0.36	0.36	0.35	0.40	0.41
43	HUE	0.35	0.38	0.38	0.38	0.38	0.38
44	HUF	0.40	0.44	0.45	0.42	0.44	0.45

ciency, similarly to what hypothesised by the Dutch regulator DTe in its actual benchmarking exercises, and VRS for Variable Returns to Scale assuming that firms may not be necessarily operating at optimal scale at the time their overall cost efficiency is assessed). In the absence of input prices in input-minimising DEA, efficiency scores would in theory only reflect 'technical' efficiency, not 'allocative' efficiency. This means that any inefficiency deriving from non-optimal input mixes would not be calculated by a technical DEA exercise. However, in our case we are using total expenditure as the overall DEA "input", and therefore our 'technical' DEA problem turns into a hybrid whereby efficiency scores may reflect both technical and allocative inefficiency, with no possibility whatsoever to separate out the two effects due to the practical unavailability of any reliable information on the relative price of production factors.

In Model 2, average DEA efficiency scores increase. This is a normal consequence of the insertion of extra variables in the DEA program. By cross-checking DEA models against COLS ones, we noticed that the insertion of CML in the cost equation was statistically sensible with a 10%-significant CML coefficient. However, the relative significance of CML in the TOTEX equation somewhat obscured the effect of electricity delivered (KWH) and led us to believe that the 'true' model might only contain customers and CML as the actual determinants of TOTEX.

In Model 2, the presence of CML as a benchmarking variable greatly enhances the relative efficiency of Dutch utilities, especially the smaller ones operating in 'easier' environments. These utilities are generally more cost-efficient than the UK ones on a TOTEX basis, especially when CML is part of the modelling. Generally speaking, the winners from the relative comparisons are the smaller utilities from the Netherlands, even under CRS DEA, and especially in Model 2 once quality of supply is taken into account. With the exception of a notoriously efficient big UK utility, the Dutch ones are relatively better positioned. This may be related to the higher customer density levels in the Netherlands leading to the design of mostly underground and highly meshed networks. In turn, this is associated with fewer outages and shorter outage duration leading to relatively better quality performance.

Interestingly enough, Malaysian and Hungarian distributors do not react to the insertion of CML to the same extent as the British and Dutch firms do. This suggests that British and Dutch firms have been more concerned with producing high quality than their Malaysian and Hungarian counterparts. We may speculate on a number of possible explanations for this. One is that British and Dutch customers have historically demanded higher reliability and this has resulted in higher (regulatory) pressure to deliver high quality. Another explanation may be the relative lower capital costs and associated higher level of investments in these countries. Reliability, which is strongly capital-related, is likely to improve at higher investment levels[15]. However, these are only speculations and further research is needed on this issue.

Another interesting aspect of the results is that Dutch companies gain more than anyone else from the VRS DEA assumption, especially in Model 2. This is due to the fact that many of the Netherlands' utilities are locally owned and based, and that some of them are extremely small, and enjoy a favourable customer density and mix (although this is now changing because of merger activity). CRS DEA will then be harsher to "limit-size" companies, for instance very small ones, which would otherwise obtain much nicer results under a VRS assumption. Interestingly enough, VRS DEA was rejected by the Dutch regulator in 1999 on the grounds that all firms are in fact free to determine their own scale by either merging or de-merging.

A final word should be spent about Hungarian and Malaysian firms.

[15] For example, in Italy reliability levels have improved strongly mainly as a result of intensified investments in the network (Ajodhia, 2003).

Whereas the latter positively react to the introduction of a quality variable in the benchmarking and become more efficient on average (thus highlighting a cost-quality relationship), the former only marginally improve in Model 2 as opposed to cost-only Model 1. This might be due to the fact that, whereas Peninsular Malaysia has a form of public active quality control and monitoring enacted by the Regulator, the development of quality standards in Hungary is now only beginning, although the Regulator is determined to introduce incentivised quality any time soon. The unimpressive quality performance of Hungarian utilities, in spite of private ownership, can only be tackled by means of strong quality regulation, especially in the presence of regulatory caps imposed on prices and a series of private monopolists.
The Peninsular Malaysian situation is institutionally different from Hungary's in that quality performance levels are monitored and published by the Regulator. Moreover, Malaysian local utilities are nothing else than divisions of the state utility TNB, and as such their quality performance is centrally monitored. This sometimes helps quality standards be kept at acceptable levels, albeit at the price of possible gold plating.

Finally, performing statistical testing on matched pairs of COLS and DEA score series highlights a fundamental average difference in the efficiency scores. This outcome is not unusual, and it just confirms that the assumptions on which the statistical and DEA analyses are based differ to such an extent that reaching consistent results is not always viable. For regulatory purposes, the statistical divergence among different efficiency score series – even in the presence of the same data set and the same basic model specification – cannot be understated, and may sometimes cast a shadow upon the actual practical applicability of alternative benchmarking techniques for straight regulatory usage.

Annex: Regression Results

Dependent variable: LTOTEX
Current sample: 1 to 44
Number of observations: 44

				EQ 1	Variable	Estimated Coefficient	Standard Error	t-statistic	P-value
Mean of dep. var.	11.3928	LM het. test	1.15434 [.283]						
Std. dev. of dep. var.	1.39387	Durbin-Watson	1.90478 [<.481]						
Sum of squared residuals	2.42217	Jarque-Bera test	6.28455 [.043]		C	-2.56873	0.404851	-6.34487	[.000]
Variance of residuals	0.059077	Ramsey's RESET2	1.99601 [.165]		LKWH	0.053669	0.095597	0.561416	[.578]
Std. error of regression	0.243058	F (zero slopes)	686.565 [.000]		LCUST	0.98883	0.104787	9.43656	[.000]
R-squared	0.971007	Schwarz B.I.C.	-2.64151						
Adjusted R-squared	0.969593	Log likelihood	1.35626						

Dependent variable: LTOTEX
Current sample: 1 to 44
Number of observations: 44

				EQ 2	Variable	Estimated Coefficient	Standard Error	t-statistic	P-value
Mean of dep. var.	11.3928	LM het. test	1.43626 [.231]						
Std. dev. of dep. var.	1.39387	Durbin-Watson	1.78305 [<.387]						
Sum of squared residuals	2.27497	Jarque-Bera test	5.50491 [.064]						
Variance of residuals	0.056874	Ramsey's RESET2	1.2032 [.279]		C	-2.65543	0.400869	-6.62417	[.000]
Std. error of regression	0.238483	F (zero slopes)	476.302 [.000]		LKWH	0.146591	0.110154	1.33078	[.191]
R-squared	0.972769	Schwarz B.I.C.	-2.61821		LCUST	0.789232	0.161132	4.89804	[.000]
Adjusted R-squared	0.970727	Log likelihood	2.7356		LCML	0.073967	0.045977	1.60878	[.116]

Dependent variable: LTOTEX
Current sample: 1 to 44
Number of observations: 44

				EQ 3	Variable	Estimated Coefficient	Standard Error	t-statistic	P-value
Mean of dep. var.	11.3928	LM het. test	0.78744 [.375]						
Std. dev. of dep. var.	1.39387	Durbin-Watson	2.01961 [<.630]						
Sum of squared residuals	2.37569	Jarque-Bera test	8.09472 [.017]		C	-2.45189	0.374014	-6.55562	[.000]
Variance of residuals	0.057944	Ramsey's RESET2	1.67088 [.204]		LCUST	0.988007	0.061005	16.1955	[.000]
Std. error of regression	0.240715	F (zero slopes)	700.398 [.000]		LCML	0.041885	0.039516	1.05995	[.295]
R-squared	0.971563	Schwarz B.I.C.	-2.66089						
Adjusted R-squared	0.970176	Log likelihood	1.78252						

Conclusions

General theory

An appropriate regulatory approach would provide the regulated firm with such economic incentives as to constrain the firm's private profit-maximising strategy towards an outcome that is compatible with socially optimal quality. Complying with this "incentive compatibility" constraint is, however, difficult in practice – in particular, when the quality dimension is included. There are three main informational problems at work. They are discussed in the paper and are briefly reproduced to sum up. Firstly, there is the problem of quality measurement. Secondly, consumer demand for quality needs taking into account. Thirdly, the relationship or 'trade-off' between cost and quality needs proper consideration. Starting from these three problems, we have argued that the solution to the latter is the most difficult to obtain. Until now, integrated analysis of cost and quality in electricity distribution has been very limited. Indeed, the results of such an analysis have not (yet) been formally used and applied for regulatory purposes.

Relative efficiency analysis

In order to test the third proposition, we performed DEA and COLS analysis on a sample of PPP-adjusted international utility cost and technical/quality variables for 2003, summing up to 44 observations from the UK, the Netherlands, Hungary, and Malaysia. Our findings confirmed that the utilities that are more cost-efficient tend also to better perform on the quality front. The cost-quality trade-off is a dynamic one, so it cannot be captured by cross-sectional analysis. On the contrary, what is more likely to happen in a cross-sectional setting is that the best-efficient utilities will still be best practice once quality comes into play. Moreover, quality-oriented utilities will take the lead in the rankings once a quality output kicks in (the Dutch case), and especially when scale need not influence cost efficiency (VRS DEA). Finally, Malaysian utilities perform better that Hungarian ones in the presence of stronger quality reporting requirements by the Regulator, which makes TNB somewhat closer to Western Europe in this respect than to an accession country such as Hungary. For all the four countries examined, however, higher cost efficiency generally means better quality performances too, which is a consistent result in the presence of a 'snapshot' (cross-sectional) sample. However, when the time dimension comes into play, results may be likely to change and, over a range of – say – five to ten years, the cost-quality trade-off might start to become visible. This is, however, matter for further data research and efficiency analysis.

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