

# DESIGN FRAMEWORK FOR ELECTRICITY QUALITY REGULATION

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## Abstract

Many European countries have, after restructuring their electricity market, adopted incentive based schemes for network regulation. In order to provide an optimal incentive, the regulator needs to internalise consumer interruption costs into the firm's decision-making process. However, two informational problems must be faced: Firstly, in acquiring information about interruption costs, the regulator does not only face an informational asymmetry between itself and the firm, but also one between itself and the consumers. The second problem is concerned with the cost-quality relation since costs and quality can vary both in the spatial and in the temporal dimension. The spatial problem leads the optimal quality level to vary as a function of the location in the network. If the firm were to optimise accordingly, then potentially large variations in quality levels may arise. The occurrence of a time lag between cost decisions and quality creates uncertainty whether quality levels will be optimal in the long-term.

Two approaches may be identified for integrating quality into the price-cap. Under the totex approach, quality integration takes the form of an integrated assessment of previous performance of the firm. Rather than only basing the X-factor on past cost performance, the X-factor is now set on the basis of combined price and quality performance as featured by the total social costs resulting from the firm's cost and quality decisions. Firms that manage to make a better price-quality trade-off will incur less sotex and therefore gain a higher efficiency score. Under the building blocks approach, integrated regulation takes the form of a combined price-quality assessment of proposed investments. Here, the regulator should make sure that investments that are allowed into the firm's capital base – and that will therefore ultimately be reflected in the allowed price – are those associated with least levels of sotex i.e. are implemented at a cost level that reflects an efficient mode of production and that provides a level of quality that is optimal.

## **1. Introduction**

### **Background**

An increasing number of countries have made or are currently making the move towards price-cap regulation. At the same time, there is a growing concern as well as empirical evidence that this change – or more specially the stronger focus on cost reduction – may create adverse effects on quality. In their seminal contributions, Michael A. Spence (1975) and Eytan Sheshinski (1976) already predicted and discussed the potential problems of quality under price-cap regulation. Subsequent authors have further studied the relations between price regulation and quality (see references in section two). For electricity distribution, the literature suggests that a move to stricter price controls, such as those based on price-cap regulation, leads to reduced network quality.

Quality regulation is not a new topic. Concern about quality under monopoly has always been there, but only after the introduction of price-cap regulation, attention for it has become widespread. The main reason for this is the perceived danger of degrading quality under price-cap regulation. This problem was already acknowledged by Professor Stephen Littlechild in the 1980s in his pioneering contribution that paved the way for the introduction of price-cap regulation in Britain as well as other countries (Littlechild 1983). More recently, the importance of quality provisions under price-cap regulation were also pointed out by the National Association of Regulatory Utility Commissioners (NARUC 1997) and the Council of European Energy Regulators (CEER 2003).

### **Paper outline**

This paper provides an overview of the state-of-the-art regarding the integration of quality into price-cap regulation. Quality, in the context of this paper, is defined as the reliability of the distribution network, as measured by the frequency and duration of interruptions occurring in the network.

This paper is structured as follows. Section 1 starts with a closer look at the quality problem under price-caps. Both the theoretical and empirical evidence regarding the need of quality under price-caps is studied. Sections 3 and 4 discuss two main approaches for integrating quality. Section 3 considers the more traditional approach, which is to separately regulate quality through the use of one or more quality controls. This is referred to as the partial approach. Section 4 explores the relatively new fully integrated price-cap approach for quality regulation under price-caps. Fully integrated price-caps are based on the idea of integrated price-quality benchmarking. Section 5 provides some conclusions to this paper.

## **2. Quality under Price-Caps**

### **Theoretical Concerns**

Rate-of-return regulation provides incentives to overuse capital inputs (the so-called Averch-Johnson effect, see Averch and Johnson 1962) and this, given that quality is capital-based, results in high quality. In contrast, price-cap regulation gives firms an incentive to cut costs which raises the concern that (part of the) cost reductions may be achieved through adverse

quality reductions. Theory confirms this concern. Spence (1975) and Sheshinski (1976) already showed that where price is fixed or taken as given, the monopoly firm will always set quality too low.

Subsequent publications have studied the quality problem under price-cap regulation in more detail. For example, Fraser (1994) examines the relationship between price-cap regulation and the reliability of supply of a monopolist. 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 its expected profits, then the associated level of reliability will be increased. This, effectively, would resemble a situation of rate-of-return regulation. 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 are protected against the cost increase, this protection will be at the expense of lower reliability.

### **Empirical Evidence**

Anecdotal evidence points out the problems of quality under stricter price regulation. Weisman (2002) provides the examples of Idaho and Oregon where an incentive 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 resulting low quality of service, and reintroduced it in 1998 only after incorporating strict quality standards for reliability. In Hungary, a large increase in the number of interruptions was noticed after the introduction of price-cap regulation of electricity distribution firms which accelerated the introduction of explicit quality regulation schemes (Tersztianszky 2003). These examples tend to confirm the concern with quality decline under price-cap regulation. Unfortunately, there are only a few studies available that collected empirical evidence of quality effects under price-cap regulation. For the telecom industry, Sappington (2003) compares different empirical studies on the effects of incentive regulation on quality to retail telephony consumers in the US. He finds that these studies produce diverging results; the hypothesis that quality declines with stricter regulation cannot be unambiguously proved for the case of US telecom. This, as he argues, reflects in part the limited success of the existing studies in capturing all relevant aspects of regulatory policy.

For the electricity industry, as far as known, there is only one empirical study by Ter-Martirosyan (2003) that looks at the effects of price-cap regulation on reliability. She found that price-cap regulation indeed led to worse quality performance in terms of an increase in the SAIFI and CAIDI indicators. In her study, she analysed a pooled sample of 78 electricity firms from 23 states of the US during the period 1993 to 1999. Her econometric model takes into account the type of regulatory regime, the presence of quality standards, the per capita income in the state, the average length of line per consumer, the share of underground lines, the share of self-generation by the firm, and the damage caused by severe weather conditions in the territory served by the firm. Her analysis supports the hypothesis that price-cap regulation has a negative impact on quality if no precautions are taken to safeguard quality. This is particularly true for the duration of interruptions. However, incorporation of quality

standards appears to reduce this effect. Then, the interruption duration remains the same or even improves in some instances. In contrast, price-caps do not seem to have significant impact on the frequency of interruptions. Possible explanations given for this are the absence of data and the different causes that contribute to the frequency of interruptions. Ter-Martirosyan refers to a study conducted by the Oregon Public Utility Commission showing that the main cause of interruption occurrence is equipment failure, whereas the interruption duration is mostly affected by storms and the time it takes to repair the damage. Thus, she argues, if price-cap regulation affects the cost structure of the firm, the impact on equipment is a long-term effect and related changes in reliability may not be noticed in the short run. The appropriate model to be used for interruption frequency would be one with lagged values of regulatory regimes. The short history of incentive regulation, however, does not allow the testing of such models yet.

Ter-Martirosyan also considered the potential problem that price-cap regulation and quality standards may be endogenous: They are more likely to be applied when the firm has a poor performance. After adjusting her model to capture this effect, she found that price-cap regulation still negatively affects reliability performance and that quality standards help to mitigate this problem. Another issue studied by Ter-Martirosyan is how incentive regulation affects the firm's spending on operational and maintenance. In principle, incentive regulation is designed to promote efficiency and therewith reduce spending levels. But, as discussed at length in previous sections, it also comes with the risk of adverse cost reductions at the expense of quality. Ter-Martirosyan analysed reductions in spending for firms with and without quality standards. In line with expectations, she found that in both cases, spending levels have fallen which suggests that the firms have operated more efficiently. However, she also observed that firms with quality standards have reduced costs less than those without. In the former case, spending levels were reduced by 17 percent since 1993 while for firms without quality standards this decrease has been about 37 percent. This is a substantial difference, which seems to support the hypothesis that price-cap regulation without quality measures generates perverse incentives to under-spend on quality.

In conclusion, Ter-Martirosyan's empirical study proves that the problem of quality degradation under price-cap regulation is a real one and needs to be dealt with appropriately.

### **3. Partially Integrated Price-Caps**

One approach to regulate quality is by choosing a partially integrated approach. In such a system, separate quality controls are implemented to complement the financial incentive scheme. Overviews of quality controls are contained in Rovizzi and Thompson (1995), Arblaster (1999), IPART (2001), Williamson (2001), DTE (2002b) and Raza (2003). In an integrated approach, a price-cap system is accompanied by additional regulatory measures that aim to mitigate any perceived negative effect of the lack of proper quality incentives in the financial incentive regime itself. Two classes of quality controls can then be distinguished: indirect controls put external pressure on network companies to pay sufficient attention to network quality, while direct controls attach financial incentives to attaining a certain quality level.

### **Indirect Controls: Performance Publication**

Firstly, indirect quality controls aim to provide consumers with information about the firm's quality performance and create institutions through which these better-informed consumers can demand or pressurise the firm to deliver an appropriate quality level. A widely applied type of indirect quality control is performance publication. Here, the regulator requires the firm to disclose information about (trends in) its quality performance to the public. Overviews of the firm's quality performance are then provided, for example, in the firm's annual reports, in dedicated regulatory publications, or on the firm's or regulator's website. Additionally, the regulator can oblige the firm to take into consideration the views of consumer representation groups or include consumers in the advisory or supervisory boards of the firm. Alternatively, consumers can be offered increased possibilities to express their quality concerns by establishing complaint handling bodies (e.g. consumer hotlines) or institutions where conflicts between consumers and firms can be handled (e.g. an Ombudsman). The complaint handling function may also be carried out by the regulator himself, as is for example the case in Italy.

### **Direct Controls: Minimum Standards**

The second class of quality controls are direct controls. Here, the regulator provides the firm with direct financial incentives (penalties or rewards) in order to provide an appropriate quality level. Such direct controls come in the form of minimum standards or incentive schemes.

Minimum standards dictate a minimum level to be achieved for a certain performance aspect. In case of not meeting this standard, the firm is financially penalised.<sup>1</sup> In some cases, the standard is only indicative and substandard performance does not lead to any penalty. These so-called indicative standards can, however, be considered as an indirect quality control rather than a minimum standard. Although the regulator would develop a view of desired (minimum) performance levels, enforcement of the standard would effectively be left to consumers.

Minimum standards define clearly the boundaries for quality levels; both firms and consumers know exactly what minimum level of quality to expect. The presence of a penalty can provide firms with strong incentives to deliver adequate quality levels. Still, minimum standards do have a number of limitations and problems. A minimum standard imposes a discrete relation between performance and price. Either the firm pays a fine or not; there is nothing in between. This may have the effect that firms, who have an interest to save costs, may choose to perform at a level close to the minimum standard. That is, they will not supply higher quality levels than strictly required by the standard (possibly taking into account some safety margin). Effectively then, the minimum standard would also implicitly prescribe at which level consumers would be served.

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<sup>1</sup> For some so-called Force Majeure events, breaching the standard does not lead to a financial penalty. Examples of Force Majeure events are faults resulting from exceptional weather, natural disasters, sabotage, war, or terrorist attacks. Force Majeure events are excluded from the scope of the minimum standard (as well as from other types of quality controls). See for example (CEER 2003 and 2005) for a listing of possible events that could be classified as Force Majeure.

## **Incentive Schemes**

A quality incentive scheme can be considered as an extended minimum standard. Here, a more continuous relation is imposed between price and quality. Each performance level results in a financial incentive, which varies with the gap between actual performance level and some predefined target level. In case the firm performs below the target, the incentive is a financial penalty while if the firm exceeds the target, the incentive comes in the form of a financial reward.

The main difference between the two classes of quality controls relates to the role of the regulator. Under direct controls, the regulator plays an active role; he develops a view of what quality levels to aim at and provides the firm with incentives to reach these. In contrast, under indirect controls, the role of the regulator is primarily one of an information provider and facilitator of disagreements on quality between firms and consumers.

## **4. Fully Integrated Price-Caps**

Next to a partially integrated approach, the regulator could opt for a fully integrated price-quality approach. Here, the regulator sets the X-factor directly as a function of quality so that an integrated price-cap formula is applied containing both efficiency and quality targets. If the regulator is better informed about the firm's price and quality performance, he can establish more effective incentives i.e. assure that the firm operates in a socially optimal way as well as assure that consumers share in the benefits resulting from the increase in social welfare.

### **Integrated Price-Cap Formula**

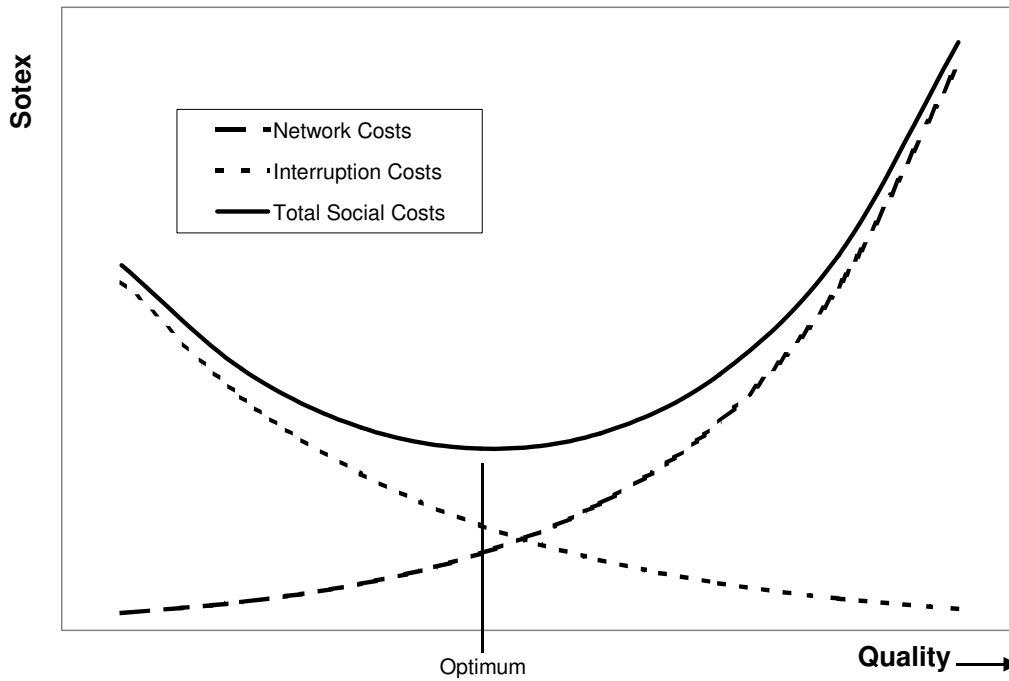
An integrated price-cap formula would need to consider two basic facts. Firstly, given that the X-factor sets a target for price (productivity) and quality, both these variables should be incorporated into the price-cap formula. That is, the costs that customers experience as a result of quality being less than perfect would somehow need to be internalised into the firm's decision-making process. These costs can be represented by interruption costs, resulting from interruptions in the electricity supply. The second fact is that full internalisation of interruption costs will most likely cause financial sustainability problems as there will be no revenues to cover the additionally imposed costs. In summary, the price formula would need to be designed in such a way that the firm is provided with an incentive to operate in a socially optimal mode i.e. provides an optimal quality level at least possible cost. In this sense, 'socially optimal' implies that the sum of network costs and interruption costs are minimised.

At the same time, the regulator would also need to take into consideration the financial sustainability requirement i.e. the firm should earn a reasonable rate-of-return if it operates in accordance with the regulatory targets. To achieve the former objective, the price-cap formula would need to be incentive compatible i.e. generate highest profits in case that the firm reaches an optimal quality level and operates in a productive way. Financial sustainability can be assured by internalising not all interruption costs, but only the

difference between interruption costs and some predefined target.<sup>2</sup> Assuming no demand variations, the price-cap formula will then take the following form:<sup>3</sup>

$$Rev(t) = (1 - X)^t \cdot (C_0 + IC_0) - IC(t) \quad (1)$$

Here,  $Rev(t)$  stands for the allowed revenue in year  $t$ ,  $C_0$  and  $IC_0$  stand for the firm's own costs (including a profit element) and the interruption costs, respectively, in the initial year  $t=0$ . The actual level of interruption costs in a given year is given by  $IC(t)$ .



**Figure 1.** The concept of 'sotex' being the sum of the total network costs and the interruption costs.

These two variables  $C_0$  and  $IC_0$  together make up total initial sotex, i.e. the total costs to society being defined as the sum of the total network costs and the interruption costs (see figure 1). These are also used as input in the benchmarking analysis. The efficiency score then reflects the extent by which the firm could reduce its initial sotex. This is reflected in the X-factor, which is the annual reduction in sotex levels. Allowed revenues are then obtained by subtracting actually incurred sotex from the annual sotex target. The firm profits will be higher in case that it manages to reduce its sotex levels in excess of the X-factor. The firm's profits  $\pi(t)$  in year  $t$  can be given by:

$$\pi(t) = Rev(t) - C(t) \quad (2)$$

<sup>2</sup> The financial sustainability requirement implies that the firm earns a predefined rate-of-return only if it manages to operate in line with the regulator's improvement potential estimations as reflected in the X-factor.

<sup>3</sup> In reality, demand will change over time and consequently impact costs. This can be taken into account by including additional demand drivers in the price-cap formula (Green and Rodriguez-Pardina 1999).

Where  $Rev(t)$  represents again the allowed revenue and  $C(t)$  stands for the firm's own costs in year  $t$ . The firm's profits can then be reformulated as follows:

$$\pi(t) = (1 - X)^t \cdot [C_0 + IC_0] - [C(t) + IC(t)] \quad (3)$$

The first part of formula 3 represents the regulatory target for sotex. Starting from the initial sotex levels at  $t=0$ , an annual reduction is imposed equivalent to the X-factor. The second part is the firm's actual level of sotex. If the difference between projected and realised levels of sotex is positive, then the firm earns additional profits. The firm has therefore an incentive to reduce sotex levels faster than anticipated by the X-factor. For example, if most of the savings are made in the first year of the regulatory period, then the firm will earn relatively more profits compared to when savings were achieved in the last year. Also, the firm can increase profits by exceeding the X-factor itself. If the true improvement potential is larger than the regulatory estimate, then the firm may achieve higher profits by beating this estimate.

Nevertheless, a sotex model (as any benchmarking method) tends to underestimate the true improvement potential.<sup>4</sup> Consequently, when the X-factor is based on the efficiency score, the probability of the firm exceeding the X-factor is high as are the firm benefits due to the fact that the regulator will be unable to conduct a perfect benchmarking analysis.

### **Integrated Benchmarking**

Benchmarking is an important regulatory asset in acquiring information about the firm's performance. Traditionally, benchmarking under price-caps has been mostly restricted to analyses in the area of costs. Under a fully integrated price-cap, quality should however also be included in the benchmarking model.

The quality-integrated benchmarking model will need to be compatible with the choice of the price-cap approach. Price-caps unlink prices from actual costs by imposing a predefined change in prices over the course of a fixed regulatory period. The annual change in prices is determined by the X-factor. The incentives would only need to apply to controllable cost items; non-controllable costs would be allowed to be passed through to consumers on the basis of actual costs. Generally, regulators distinguish between two types of controllable costs namely costs that are controllable in the short-term (*operational expenditures* – 'opex'), and costs that are controllable only in the longer term (*investments or capital expenditures* – 'capex').

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<sup>4</sup> A sotex model tends to underestimate the true improvement potential both in the productivity and in the quality sense. The underlying source of this problem is the fact that the firm with an efficiency score of one is not necessarily the most productive or the optimal quality-providing firm. In theory, this problem would be absent if the benchmarking sample would include the truly optimal. In practice however, each real-life data sample is constrained and is not likely to include this truly optimal firm (if it exists at all). This problem is not specific to the sotex model but generally applies to all benchmarking models. Under a cost-only model, the fact that there may be other more productive firms outside the sample also works in favour of the firms evaluated under the benchmarking. In case of sotex benchmarking, however, the absence of a complete benchmarking sample tends to underestimate not only the cost improvement potential, but also the scope for performance improvement in the quality sense.

Given that there are two cost categories to be regulated (opex and capex), two basic approaches can be identified. Firstly, the regulator could separately assess opex and capex. Essentially, the price-cap can then be thought to consist of two components or building blocks namely an allowance for opex and an allowance for capex (the latter of which would consist of depreciation plus a rate-of-return on the regulatory asset base). This approach is generally known as the building blocks method. A second approach is however one where the regulator considers opex and capex in an integrated fashion, i.e. one does not distinguish between them. Here, the sum of opex and capex would be regulated on the basis of a single price-cap strategy. This approach is known as the total costs or totex method.

The distinction between the totex method and the building blocks method has important implications for the configuration of the benchmarking model. Under the building blocks method, integration comes in the form of conducting an integrated price-quality assessment of the firm's proposed investments. Here, the regulator would need to simultaneously assess whether the implied investment leads to a desirable level of quality, and whether the investment is undertaken at least costs.

For the totex approach, quality integration implies the application of an integrated price-quality benchmarking analysis of the firm's actually incurred total costs and supplied quality levels. The benchmarking analysis would then somehow need to model quality into the determination of the productivity frontier and consequently in the derivation of the efficiency score. For building blocks, integration comes in the form of conducting an integrated price-quality assessment of the firm's proposed investments. Here, the regulator would need to simultaneously assess whether the implied investment leads to a desirable level of quality, and whether the investment is undertaken at least costs. The heterogeneous nature of investments limits the scope to perform benchmarking analysis across firms as investments are typically very different and difficult to compare against each other. Therefore, the regulator will rather need to assess the cost and quality performance of the firm's investment proposals on an individual basis.

It seems that the quality problem is more severe under totex than under building blocks. Under the former approach, the regulator leaves the discretion of deciding on investments with the firm and subsequently cannot influence the quality level that the firm is providing. If no additional quality provisions exist, the firm's quality choice is likely to be driven by cost reduction considerations rather than by a concern with providing high quality to consumers. Under building blocks on the other hand, the regulator can indirectly steer quality levels by prescribing the desired investment level. However, as determining the desired investment target is inherently difficult, this may well lead to some degree of over-investment.

The latter observation provides insight in the trade-off between price and quality. Under building blocks on the one side, quality degradation can be avoided by allowing a high investment level. This leads to higher prices and is essentially the premium for assuring high quality. Thus, the trade-off is biased towards quality rather than price. Under totex on the other side, the regulator cannot directly control the firm's investment level and therefore not influence quality. At the same time, efficiency incentives are higher as the firm has an incentive to reduce costs to a level that it considers suitable. Thus, under totex, the price-quality trade-off is somewhat biased towards price.

In both cases, the ability to integrate quality into the price-cap will contribute in developing a more effective regulatory approach. Under totex, incorporating quality into the analysis of productivity allows the regulator to derive an efficiency score that reflects an optimal trade-off between price and quality. Similarly, under building blocks, considering both the price and quality performance of an investment may help to determine an optimal level of the regulatory asset base. In the process of integrating price and quality, benchmarking can play an important role. Developing integrated benchmarking tools can assist the regulator in simultaneously evaluating price and quality and in this way, obtain better information to establish a more balanced regulatory approach. Such integrated benchmarking models have for example been developed by Ajodhia (2005).

## 5. Conclusions

Under both the totex approach and the building blocks approach, the regulatory ability to successfully evaluate price-quality performance is crucial to the effectiveness of the approach. The better information the regulator has available, the better the appropriate X-factor can be estimated and the more effective will be the regulatory approach. On the one hand, consumers will then directly share in the anticipated efficiency and quality improvements while, on the other hand, the regulator can make sure that the improvement targets imposed on the firm are realistic and do not lead to financial sustainability problems.

An integrated X-factor reflects the regulatory anticipation of both price and quality improvements. The ability to measure productivity and quality performance in terms of a single indicator is therefore an important regulatory asset. Integrated benchmarking deals with the problem of measuring the cost-quality relationship. In practical terms, combined price and quality performance takes the form of measuring total social costs ('sotex'), being the sum of network costs and consumer interruption costs.

If the regulator is better informed, he can establish more effective incentives i.e. assure that the firm operates in a socially optimal way as well as assure that consumers share in the benefits resulting from the increase in social welfare. Benchmarking is an important regulatory asset in acquiring information about the firm's performance. Traditionally, benchmarking under price-caps has been mostly restricted to cost efficiency assessment. At present, there is a development towards truly integrated benchmarking models.

At the same time, however, the limitations of benchmarking should also be recognised. These limitations stem from the informational problems. If the regulator cannot properly measure costs, quality, or consumer demand for quality, the results of the benchmarking analysis can be adversely affected. Furthermore, the benchmarking outcome is driven by modelling assumptions regarding the cost-quality relationship – these assumptions are bound to be imperfect. For benchmarking to be effective, these limitations should be recognised and properly dealt with in the determination of the integrated X-factor. The role of benchmarking tools therefore is primarily one of assisting the regulator in extracting (albeit imperfect) information from the firm in order to allow him to estimate the range within which the X-factor should fall. The better the regulator is able to conduct the benchmarking analysis, the narrower this range will be and the more accurately the X-factor can be set. Benchmarking thus is not the ultimate solution to the regulator's informational disadvantage,

but rather a tool to support the regulator in dealing intelligently with the informational problem.

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