Can we measure Welfare? Dynamic Comparisons of Allocative Efficiency before and after the Introduction of Quality Regulation for Norwegian Electricity Distributors

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We investigate empirically the usefulness of price-cap and quality regulation in terms of allocative efficiency and welfare. An analytical framework allows us to determine sufficient conditions for an increase in welfare. We propose Malmquist productivity indices and their decomposition to check the conditions and to see whether it was a better-solved trade off between quality and costs that caused the welfare increase. The application of this method to a representative sample of Norwegian distribution system operators yields strong evidence for a positive effect of quality regulation on welfare.

Contents

1 Introduction

In the wake of major blackouts and plummeting customer satisfaction with the quality of service in the liberalized electricity markets in Europe, some pressing questions have arisen:

- Whether and in how far is the prevalent price-cap regulation detrimental to quality?
- Even if quality increased - did welfare increase as well?
- Can we find evidence that it was quality regulation which increased welfare?

Concerning the first question, concerns are backed by theoretical analysis (see Sappington (2005) for example) but empirical evidence is scarce. Kridel et al. (1996) and Sappington (2003) found mixed impacts of different regulatory regimes on the quality of telecommunication service providers[1]. In a recent survey, Sappington (2003) did not draw an unequivocal conclusion about the effects of incentive regulation on the quality delivered by firms and suggests further research. Ter-Martiroysan (2003) is the only paper that investigates electricity distribution network providers. In a sample of 78 utilities from 23 U.S. federal states, Ter-Martiroysan finds that price-cap regulation is associated with an increase in the average duration of outages but explicit quality benchmarks reduce this figure again.

Our second question asks if quality regulation can solve the problem. In theory, direct incentive schemes sound useful. Sappington (2005) puts it as follows: "By specifying service quality targets and associated penalties and bonuses, a regulator can induce the regulated firm to employ its superior cost information to achieve desirable levels of service quality". Our paper will investigate empirically, whether a more desirable level of quality was achieved.

Since we will check these properties by means of so called cost Malmquist indices that incorporate quality, this directly leads to

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[1] Other studies are: Roycroft and Garcia-Murrilo (2000), Banerjee (2003), Clements (2004) and Ai et al. (2004).

a strand of literature that investigates the incorporation of quality into the efficiency measurement of electricity network providers: Giannakis et al. (2005) have shown that quality is an important aspect of the performance of electricity network operators and should be incorporated into a benchmark-study. However, Korhonen and Syrjäen (2003) were, to our knowledge, the first ones to use quality in a benchmark-study of electricity network operators. They find improvements in efficiency scores when quality of service was added. A study that uses Malmquist-indices to compare the efficiency of electricity distribution companies in Nordic countries has been performed by Edvardsen and Forsund (2003). Growitsch et al. (2005) used stochastic frontier analysis (SFA) for a sample of 500 European electricity distribution companies to find that quality and quantity could form a cost function that features increasing returns to scale in the two output case.

To the authors best knowledge, however, the two above stated important questions concerning welfare have not yet been addressed in the literature.

The contribution of this work is therefore to provide a methodology on how to investigate the effects of the introduction of quality regulation. We determine theoretically sufficient conditions for an increase in welfare and propose Malmquist indices to investigate changes in social costs and changes in the behavior of firms. A decomposite of Malmquist indices can be used to see whether social costs of electricity distribution really decreased because firms solved the trade-off between costs and quality in a better way than before. Then we apply our approach to a representative sample of Norwegian electricity distributors.

The rest of this chapter is organized as follows: Section 2 will present the Norwegian system of quality regulation in more detail. Section 3 contains our methodology where we first derive the sufficient conditions for a welfare increase in Norway due to regulation, formulate corresponding hypotheses and show how they can be checked with cost Malmquist indices and their decomposition. In section 4 our variables and our empirical model setup will be explained. This will be followed in section 5 by an account of the main results concerning the confirmation or rejection of our hypotheses. Finally we will make some concluding remarks in section 6.

2 Quality Regulation - the Case of Norway

For such a study, the focus of attention naturally shifts to Norway as it was one of the very first countries where quality of service was explicitly combined with a price-cap regulation regime. The liberalization of the Norwegian energy sector, monitored by the Norwegian Water Resources and Energy Directorate (NVE) began with the introduction of a new energy law in 1990. After a period of Rate-of-Return regulation (RoR) price-cap regulation was introduced in 1997, which was based on a benchmark-study conducted in the same year (cf. Bundesnetzagentur, 2006).

In the regulatory period 2001 - 2006 the incentive regime was supplemented by a system of quality regulation in which network providers have to pay penalties for energy-not-delivered (Kinnunen, 2003). That led to a development of *energy-not-supplied (ENS)* in Norway as illustrated in figure 1. The basic idea of such penalties is to internalize the external effect of a failure of the electricity distribution system. The incentive rates in table 1 should act like a Pigouian tax which induces firms to take the costs of the external effect into account. If the incentive rates are set appropriately, firms choose the trade off between costs and outages, such that the marginal costs of an additional hour of electricity interruption and the marginal cost of avoiding the interruption are equal[2].

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[2] Of course, different firms which face different marginal costs of providing quality would offer different quality levels. This is why a lot of regulators (not Norway), additionally,

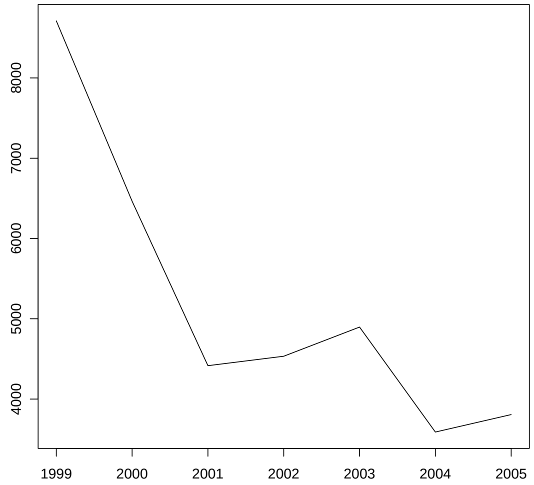

Figure 1: Development of ENS (MWh) in Norway
Source: Norwegian Water Resources and Energy Directorate (NVE) - `http://www.nve.no`

Setting an incentive rate does not determine whether firms will loose or gain money. The actual transfer from or to the regulator depends on where the allowance, or default value is set. In the Norwegian case, the maximum allowed revenue from price cap regulation is increased or decreased by the difference between the actual outage costs a firm caused, and the allowed outage costs of the firm. Allowed outage costs are also called expected outage costs, (which, of course, vary from firm to firm) and are estimated by the regulator by considering outage costs of the last five years and a panel regression (Haber and Rodgarkia-Dara, 2005). Additionally, improvements in the expected outage costs are prescribed by the regulator.
To sum up, the level of quality supplied is set by firms by equating marginal costs of quality provision and the incentive rate and thus depends only on the incentive rate, whereby the distribution of payments, depends on the target level set by the regulator. The penalties paid by firms are transferred to the regulator which is a government

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introduced minimum standards to avoid having some customers of minor importance suffering from too many outages even if this would be economically efficient. Thus it can be argued that the incentive rates (which are called cost of energy not supplied in Norway), indeed serve the purpose of efficiency, whereas minimum standards have their justification in fairness and public good considerations.

authority. Only in the new regulatory period which begins in 2007, payments which have to be made by firms will be used to reduce prices for customers.

3 Methodology

3.1 Quality Regulation and Welfare

To be able to discuss the effects at work when a quality regulation scheme is implemented, we set up an economic framework. Welfare in the area of each of the $i = 1 \dots N$ local monopolists consists of gross surplus (GS_i) minus the social costs of electricity production (C_i)[3].

$$W_i = \underbrace{\int_0^{\overline{y}_i} P_i(y_i, q_i)\, dy_i}_{GS_i(y_i, q_i)} - C_i(y_i, q_i) \qquad (1)$$

The inverse aggregate demand function $P_i(y_i, q_i)$ in each market depends on the quantity (y_i) of the good and the long run level of quality (q_i) and is allowed to differ in the submarkets to account for varying characteristics such as the potential market size. Demand is downward sloping ($\frac{\partial P_i(\cdot)}{\partial y_i} < 0$) and quantity can be interpreted as the number of accesses to electricity[4]. The level of quality q_i can be interpreted as the level of expected quality which means that it is the quality to which potential consumers of electricity adapt to and on which they base their decisions. Firms might set up operations or reduce own back up production and, more generally, quality increases private and commercial consumers willingness to pay so we have $\frac{\partial P_i(\cdot)}{\partial q_i} > 0$.

The social costs of electricity production $C_i(y_i, q_i)$ consist of the monetary costs of electricity companies like spendings on equipment

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[3] Possible transfer payments arising from the incentive scheme cancel out so we do not weight consumer and producer rent differently. Preferences are assumed to be quasi-linear such that there are no income effects.

[4] See for example Dröttboom (1996, p. 10 f.) for a similar approach.

and personnel and outages which are the main determinant for quality q_i.

From the questions asked in section 1, we can derive three hypotheses.

Hypothesis 1 After the introduction of quality regulation in Norway, the social cost of electricity distribution decreased. By referring to our welfare framework (see section 3.2) this means, that welfare increased.

Hypothesis 2 The decrease of the social costs and the increase in quality are due to the new regulation regime in that, by charging a price for outages, it induced electricity companies to substitute cost for outages in a more socially favorable manner.

Hypothesis 3 Quality was too low from a welfare point of view before the introduction of quality regulation as the improvement in quality had a positive welfare effect.

To check hypothesis 1, we first have to make sure that gross surplus did at least not decrease. A method to verify this precondition is presented in section 3.2. How firms and the costs they occur react to quality regulation and how changes in social costs will be investigated, is discussed in section 3.4. Cost Malmquist productivity indices are then used to check whether social costs of electricity production really decreased. Decompositions of such Malmquist indices are then used to see whether hypothesis 2 is justified which is explained in section 3.3.

A corollary is that if welfare really increased due to a better mix of outages and costs, it cannot have been optimal in the pure price cap regime before.

3.2 Gross Welfare

A precondition for a welfare increase due to quality regulation is that gross welfare did at least not decrease. Analytically, the change in gross surplus can be depicted by the total differential

$$dGS_i = \frac{\partial GS_i(y_i, q_i)}{\partial y_i} dy_i + \frac{\partial GS_i(y_i, q_i)}{\partial q_i} dq_i \tag{2}$$

Assuming that the change in $dGS_i(y, q)$ must be nonnegative and rearranging yields the following condition.

$$\frac{dy_i}{dq_i} \geq -\frac{\frac{\partial GS_i(y_i, q_i)}{\partial q_i}}{\frac{\partial GS_i(y_i, q_i)}{\partial y_i}} \tag{3}$$

The right part of (3) is the slope of the isowelfare curve at a certain point in a (y_i, q_i) diagram, whereby the left part gives the slope or direction in which the new quality - quantity combination on the market has moved. Following from the above-mentioned assumptions, gross surplus $GS_i(y_i, q_i)$ increases in y_i and q_i which means that the right hand side of (3) is always negative. Figure 2 can be used to interpret this condition graphically. If y_i and q_i both increase, one moves into the north east direction and welfare increases unambigously. If y_i increases and q_i decreases, one moves to the south east and the slope of the change ($\frac{dy_i}{dq_i}$) must be less negative than the slope of the isowelfare curve for welfare to increase. If y_i decreases and q_i increases, the graphical interpretation can be understood more easily if (3) is multiplied by -1.

We now try come to a crude judement whether condition (3) holds for our sample of Norwegian submarkets. To do so, we first compute the derivatives.

$$\frac{dy_i}{dq_i} \geq \frac{\int_0^{\overline{y}_i} \frac{\partial P_i(y_i, q_i)}{\partial q_i} dy_i}{P_i(y_i, q_i)} \tag{4}$$

The left hand side of (4) is still the same as before. The denominator on the right hand side of (4) is $P_i(y_i, q_i)$ so we use the price of accesses to the electricity network in 2001 to approximate that. For the numerator we use the average outage costs, weighted by market quantities in 2001. This gives us a crude measure of the slope of the isowelfare curve which can then be compared the slope of $\frac{dy_i}{dq_i}$. The results are shown in table 4, in the appendix. It can be seen that our precondition for a welfare increase seems to hold for our representative

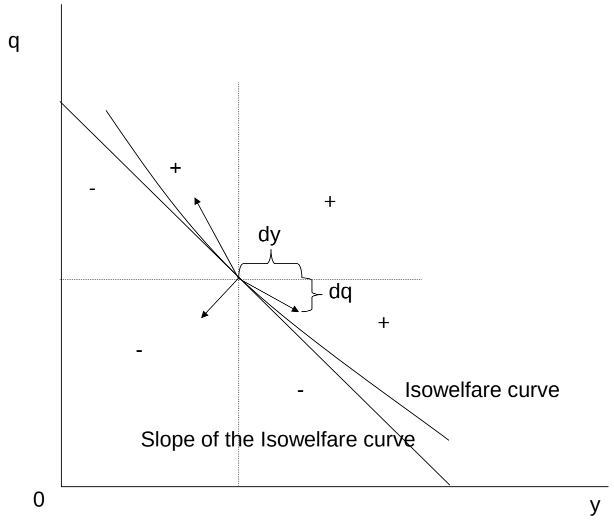

Figure 2: Graphical interpretation of (3)
Source: own calculations

sample of norwegian firms.

3.3 Malmquist Indices and their Decomposition[5]

3.3.1 The Cost Malmquist (CM) Productivity Index

The general aim of Malmquist indices is to measure productivity changes and to determine its reasons by decomposing it into its main sources. Malmquist indices have been used in a wide range of applications and been extended in many ways (for an overview see e. g. Faere et al., 1998). In order to answer our above questions we have to find out how the productivity of the firms changed in terms of costs. We will therefore adopt the approach of Maniadakis and Thanassoulis (2004) who define a cost Malmquist (CM) productivity index and decompose it in such a way as to be able to identify changes in allocative and technical efficiency, in the technology of production and in input prices. The CM index is the geometric mean of the CM index of

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[5] This section is largely based on Maniadakis and Thanassoulis (2004).

periods t and $t+1$ and looks as follows:

$$CM = \left[\frac{w^t x^{t+1}/C^t(y^{t+1}, w^t)}{w^t x^t / C^t(y^t, w^t)} * \frac{w^{t+1} x^{t+1} / C^{t+1}(y^{t+1}, x^{t+1})}{w^{t+1} x^t / C^{t+1}(y^t, x^{t+1})} \right]^{1/2} \tag{5}$$

where $w^t x^t \equiv \sum_{n=1}^{N} w_n^t x_n^t$ and n denotes the n-th input and $C^t(y^t, w^t)$ is a standard cost function, defined as the minimum cost required to produce output y^t with prices w^t and with a constant returns to scale technology in period t. The cost ratio $w^t x^t / C^t(y^t, w^t)$ measures the extent to which aggregate production costs in period t could be reduced, while still producing output y^t with the price vector w^t, so it measures overall efficiency in period t. The rest of the cost ratios are defined analogously.

CM index values smaller than 1 identify productivity progress (less costs for a given output), values greater than 1 indicate regress and a value of 1 means constant productivity. As will be explained in more detail in section 3.4, we will use this index to check our hypothesis 1.

3.3.2 The decomposition of the CM index

To be able to disentangle the various possible sources of the change in efficiency, the CM Index can be decomposed into two subcomponents, which can themselves be split into two components each as illustrated in figure 3.

Equation (5) can be rewritten as in (6), such that we get an expression for the so called overall efficiency change (OEC) and the so called cost technical change (CTC):

$$\begin{aligned} CM = & \frac{w^{t+1} x^{t+1} / C^{t+1}(y^{t+1}, w^{t+1})}{w^t x^t / C^t(y^t, w^t)} \\ & * \left[\frac{w^t x^{t+1} / C^t(y^{t+1}, w^t)}{w^{t+1} x^{t+1} / C^{t+1}(y^{t+1}, w^{t+1})} \times \frac{w^t x^t / C^t(y^t, w^t)}{w^{t+1} x^t / C^{t+1}(y^t, w^{t+1})} \right]^{1/2} \end{aligned} \tag{6}$$

The term outside the brackets is the overall efficiency change (OEC), it tells us by how much the firm managed to move closer to the minimum cost line at the respective prevailing relative prices ("catch up").

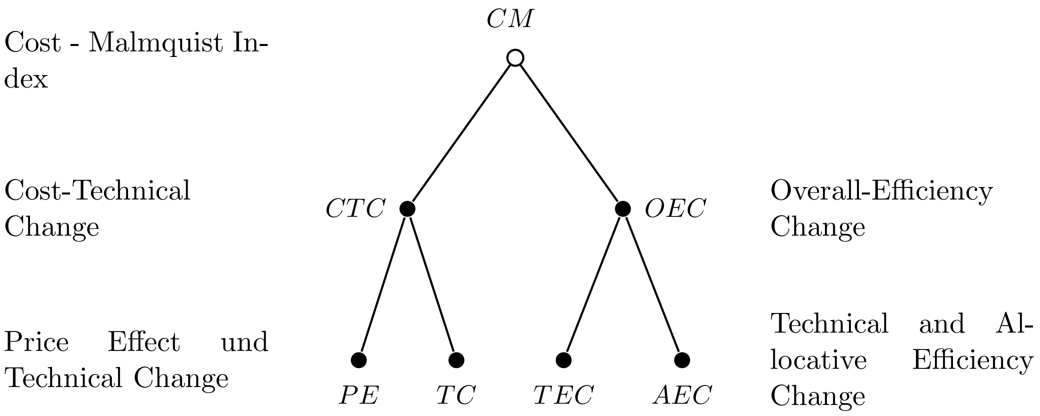

Figure 3: The decomposition of efficiency changes

The term inside the brackets, CTC, measures the cost boundary shift due to the combined effects of technical progress and price effects. The two parts can be decomposed further: First, we can divide the catch up factor (OEC) into the technical efficiency change (TEC) and allocative efficiency change (AEC):

$$\begin{aligned} OEC =& \frac{D_i^{t+1}(y^{t+1}, x^{t+1})}{D_i^t(y^t, x^t)} \\ &* \frac{w^{t+1}x^{t+1}/(C^{t+1}(y^{t+1}, w^{t+1})D_i^{t+1}(y^{t+1}, x^{t+1}))}{w^t x^t/(C^t(y^t, w^t)D_i^t(y^t, x^t))} \end{aligned} \tag{7}$$

Where $D_i^t(y^t, x^t)$ is the input distance function that gives the largest factor by which the input levels in x^t can be divided while x^t remains in the input requirement set $L^t(y^t) = \{x^t : x^t \text{ can produce } y^t\}$. $D_i^t(y^t, x^t)$ is therefore defined as

$$D_i^t(y^t, x^t) = \sup_{\theta}\{\theta : (x^t/\theta) \in L^t(y^t),\ \theta > 0\}$$

and D_i^{t+1} analogously (The i stands for "input orientation").

The first component of (7), (TEC), can also be called the technical catch up factor and measures by how much a firm came closer to the isoquant. The second term in (7) is allocative efficiency change (AEC) and indicates the extend to which the firm "catches up" with the optimal input mix regarding the input prices in each period.

Analogously, (CTC) can be decomposed into a part that accounts for shifts in the isoquant (TC) and a part that measures the effect of relative input prices (PE)[6]. :

$$CTC = TC \cdot PE \tag{8}$$

The technical change component (TC) is the same as the technical change component of a standard Malmquist-index as used for example in Giannakis et al. (2005) and measures by how much the change in productivity of firms can be attributed to technical progress (a shift of the isoquant). The residual part (PE) measures the impact of relative input price changes on changes of minimum costs.

As with the CM index, with all the discussed indices an index value of less than 1 identifies an improvement of the firm, a value greater than 1 indicates deterioration and a value of 1 means stagnation. It will be explained in section 3.4 how the CTC, OEC, TEC, AEC, PE and TC indices can be used to check hypothesis 2.

3.3.3 Computation of the Indices and their Components

As could be seen in the previous section, the decisive components of the various indices are the input distance functions $D_i^t(y^t, x^t)$ and the cost functions $C^t(y^t, w^t)$. These measures are crucially dependent on a definition of the production possibility set (PPS) and the corresponding isoquants. A widely used and practical approach to get a workable estimation of the PPS is the mathematical programming based method Data Envelopment Analysis (DEA). Other so called

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[6] The exact formulation of the decomposition follows similar lines as above and is therefore not given in detail here.

parametric approaches which are based on estimating econometrically or by means of mathematical programming a hypothesized parametric form of the production function or cost boundary are also possible but not elaborated here. The basic idea behind DEA is to estimate the PPS by laying a convex hull around the empirically available input-output combinations of the different players in the sample. The DEA-methodology can be used to compute the CM index as follows:

Suppose that in each time period t, there are $j = 1, ..., J$ production units which produce $m = 1...M$ outputs y^t_{km} by using $n = 1...N$ inputs x^t_{kn} at prices w^t_{kn}. For unit k the cost denoted by $w^t x^t$ is $w^t x^t \equiv \sum_{n=1}^{N} w^t_n x^t_n$. The costs denoted by $w^{t+1}_n x^{t+1}_n$, $w^{t+1}_n x^t_n$ and $w^t_n x^{t+1}_n$ are defined analogously. For unit k, the term $C^t(y^t, w^t)$ can be computed by solving the following linear program:

$$\begin{aligned} C^t(y^t, w^t) = &\min_{x,z} w^t_{kn} x_n \\ s.t. &\sum_{j=1}^{J} z_j y^t_{jm} \geq y^t_{km} \\ &\sum_{j=1}^{J} z_j x^t_{jn} \leq x^t_n \\ &z_j \geq 0, x_n \geq 0 \end{aligned} \tag{9}$$

where z_j is an intensity variable used to form convex combinations of observed inputs and outputs.

The terms $C^t(y^{t+1}, w^t)$, $C^{t+1}(y^{y+1}, w^{t+1})$ and $C^{t+1}(y^t, w^{t+1})$ can thus be computed by using the different combinations of prices, technologies and quantities of periods t and t^{t+1}. In order to get the values for the distance function $D^t_i(y^t, x^t)$ the following program, as conceptualized by Faere et al. (1989), has to be solved:

$$
\begin{aligned}
\left[D_i^t(y^t, w^t)\right]^{-1} &= \min_{\theta,z} \theta \qquad (10)\\
s.t. \sum_{j=1}^{J} z_j y_{jm}^t &\geq y_{km}^t \\
\sum_{j=1}^{J} z_j x_{jn}^t &\leq \theta x_{kn}^t \\
z_j &\geq 0
\end{aligned}
$$

$D_i^t(y^{t+1}, x^{t+1})$, $D_i^{t+1}(y^{t+1}, x^{t+1})$ and $D_i^{t+1}(y^t, x^t)$ can be derived with the same model after having adjusted the time periods t and $t+1$ accordingly.

With the CM index, its decomposition and the models to calculate all these indices from empirical data we have the necessary tools to check the hypotheses from section 3.1 as will be shown below.

3.4 Quality Regulation and the Firm

The main idea of quality regulation is to let the network operators bear the social (or external) cost of outages by charging a price for them. In what follows, we will first show how this measure affects the behavior of a cost minimizing firm, before we turn to explaining how this behavioral change can be measured by the above indices and thus how we can check our hypotheses.

The cost minimization problem of the firm looks as follows:

$$
\begin{aligned}
&\min_{\mathbf{x}\geq 0} \mathbf{wx} \qquad (11)\\
&s.t.: f(\mathbf{x}) \geq \widehat{y}
\end{aligned}
$$

Where $\mathbf{w}$ is the vector of input prices, $\mathbf{x}$ is the vector of inputs, $\widehat{y}$ is a given level of output and $f(\mathbf{x})$ is the chosen level of output. The input vector $\mathbf{x}' = (x_1, o) \in \mathbb{R}^+$ consists of the monetary input total expenditures x_1 and the physical input outages o. Outages are an undesired output of the firm and will thus be our first input variable like in Yaisawarng and Klein (1994)[7]. As the other input we consider is the monetary input total expenditures (TOTEX), we are not able to measure any misallocation between capital expenditures (CAPEX) and operating expenditures (OPEX) (Averch and Johnson, 1962, cf.) [8]. With our choice of inputs, we thus model the trade-off of the firm: Either produce with low costs and high outages, or with high costs and low outages. Figure 4 shall illustrate this situation of the industry.

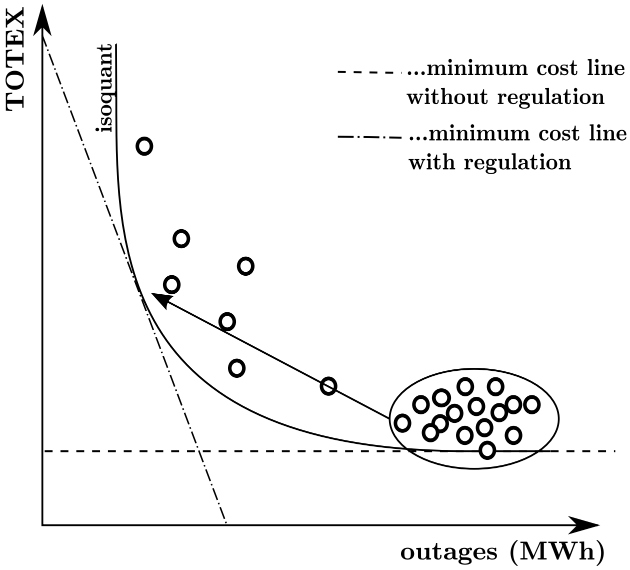

Figure 4: The situation of the industry before and after the introduction of quality regulation

The black rings mark the input combinations of the different firms in the sample at given output and the dashed line shows the minimum cost line that results without regulation, that is, when a price of zero

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[7] There is an extensive literature on how to treat undesired outputs in DEA, for a an overview, see for example Dyckhoff and Allen (2001).

[8] This approach is justified in our Norwegian case as price-cap regulation, which should lead to a right allocation between capital and other inputs had already been in place for some time before quality regulation was implemented so we can safely assume that firms have allocated all the other inputs in a cost minimizing manner.

is charged for outages[9]. Due to the location of the minimum cost line we conjecture, in accordance with our hypotheses, that the bulk of firms will have an input mix with relatively high outages and relatively low $TOTEX$. When a price for outages is introduced, the price line pivots and the cost minimizing point moves to the north west. As a consequence, according to our hypotheses again, most firms will have higher costs of production and will strive to reduce them by moving north west as well by adapting their input mix accordingly[10]. In other words, they want to achieve that their the expenditures for their new input mix at the new prices (the social costs of outages were actually always there) are lower than the expenditures for their old input mix valued at the new prices, i. e. $\mathbf{w_1 x_{2001}} < \mathbf{w_1 x_{2005}}$ (whether the firms were successful in this can be measured by the CM index).

It is clear then that by introducing a price for quality, the cost minimization problem of the firm becomes equal to social cost minimization. If we detect a movement as shown in figure 4 in our sample, this confirms our hypotheses that it was the new regulation, that induced firms to behave in a more welfare optimal way.

We now show how our indices can be used to detect and analyse such a movement. To that end, consider figure 5, which illustrates the situation of a firm (black rings) that moves from point B^t in period t in direction north west to point C^{t+1} in period $t+1$. Here, the isoquant results from the DEA-methodology as the piecewise linear convex hull around the firms in the sample that show the least inputs at given output. The minimum cost line is the result of the program in (9) when the new price for quality is already in place. For illustrative purposes, it is assumed here that there was no technological change between t and $t+1$ (so that the isoquant didn't move) and no price change (so that the minimum cost line didn't move).

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[9] Please note that due to our empirical approach and the corresponding DEA-methodology, firms can be situated off the isoquant which is not standard in microeconomic theory. We shall refer to Faere et al. (1998) for an overview of the literature that deals with this feature of DEA.

[10] In the graph it is assumed that firms have no cost of outages at all, before the introduction of the regulatory regime. In reality firms would, of course, consider lost turnover and lost willingness to pay as quality deteriorates. Additionally, incentives to provide quality change due to vertical structures as investigated by Buehler et al. (2004).

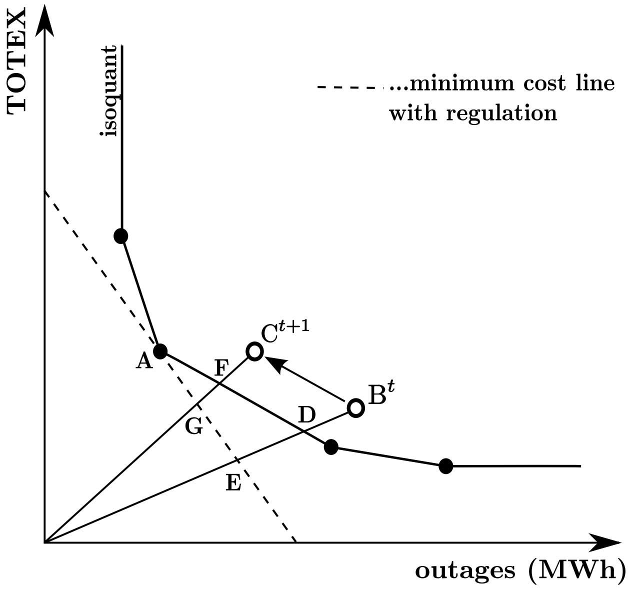

Figure 5: Malmquist indices and welfare changes

The CM index, expressed in Euclidean distances, is the ratio $(\overline{OC}/\overline{OG})/(\overline{OB}/\overline{OE})$ and thus smaller than one. In other words, the firm has decreased its producer cost so that hypothesis 1 can be confirmed here.

Moreover, by moving from B^t to C^{t+1}, the firm improves its allocative efficiency which is given by the ratios $\overline{OE}/\overline{OD}$ and $\overline{OG}/\overline{OF}$ in period t and $t+1$ respectively. In the case illustrated, the firm moves parallel to the isoquant, which itself did not change, so there was neither a change in technical efficiency, nor technical progress (TC and TEC would be close to one). As input prices did not change either, PE would be equal to one as well. As a consequence, the AEC index which measures cost decreases due to changes in the input mix is smaller than 1. In other words, if the substitution of $TOTEX$ for outages leads to an increase in allocative efficiency and thus a decrease in social costs, we see it in the AEC index[11].

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[11] Apart from seeing the effect in the AEC measure, technological progress could also indicate the effect of a quality scheme. This is due to the fact that our frontier is estimated empirically which means it is defined by what firms actually do. By trying to improve quality, the best firms would probably push the isoquant inward as well.

Putting it together, the decisive indices for testing our hypothesis are the CM and the AEC index: If their calculated values are smaller than 1 we can confirm our 2 hypotheses for the individual firm. In the aggregate, we can confirm them if the following conditions hold:

$$\sum_{i=1}^{N} \text{Social Cost}_{i,2001} * CM_i \Big/ \text{Social Cost}_{2001} < 1 \tag{12}$$

and

$$\sum_{i=1}^{N} (\text{Social Cost}_{i,2001} * AEC_i)/\text{Social Cost}_{2001} < 1 \tag{13}$$

Where $\text{Social Cost}_{i,t} = TOTEX_{i,t} + p_{o\,t} * o_{i,t}$. Equation 12 therefore gives the total relative change of social costs and 13 gives the relative change of social costs because of better allocative efficiency.

4 Data and Choice of Variables

4.1 Choice of Variables and Model Setup

To account for different aspects of the performance of a network provider, we use three different outputs, namely the amount of energy delivered over the network (MWh), the number of customers and network length. Using the network length is not undisputed as a firm could theoretically add network length and thereby increase its output. In our case however, it is crucial to measure geographical dispersion of customers. Moreover, our choice of output variables largely follows Forsund and Kittelsen (1998) and Edvardsen and Forsund (2003), who assessed the development of productivity of Scandinavian electricity distribution firms. Our choice is also consistent with the results of Korhonen and Syrjäen (2003) who investigated the appropriateness of different inputs and outputs in great detail. As mentioned above, two inputs, namely total expenditures (TOTEX) and ENS (i.e. outages), were used, the first one in monetary terms as in Giannakis et al. (2005). In order to be able to measure allocative efficiency concerning these 2 inputs we treat TOTEX as a nummeraire such that its price equals 1 and use the actual price for energy-not-supplied as estimated by the regulator. This way we get a price-ratio between these two inputs which is necessary for further calculations as described above.

4.2 Dataset

We used cost and output data of the fifty largest Norwegian distribution system operators, published by the Norwegian Water Resources and Energy Directorate (NVE). After having eliminated units with insufficient data quality, 31 DMUs (decision making units) were used for the calculation of our indices which we did for the periods 1999-2001, 1999-2005 and most importantly 2001-2005.

TOTEX consist of operating expenditures (OPEX) and capital expenditures (CAPEX). Our operating expenditures (OPEX) comprise costs for network losses, wages and other costs. Following Korhonen and Syrjäen (2003) costs for transmission services were not included, as they are beyond the control of a single unit. Our capital expenditures (CAPEX) consist of depreciation plus the value of the assets multiplied with the so called fair rate of return. The fair rate of return is set by the regulator and serves as a reasonable approximation of the actual financing costs of a firm. According to Grasto (1997) and Kinnunen (2003), the fair rate of return which is used in Norway is the return of a medium term government bond (risk free rate) plus a two percent risk premium, whereby debt and equity are treated equally. The rate of return a regulator grants can be assumed to be a reasonable approximation of the actual financing costs a firm faces.

As already mentioned in the previous section, the second input is energy-not-supplied (ENS) which measures the amount of energy (in MWh) which could not be delivered due to failures of the distribution system. To be more precise, ENS measures how much energy customers would have used, if there had been no failure by considering the typical load curve of customers and the time of the outage. The development of the sum of ENS is shown in figure 1.

We did not account for regional differences in factor costs, as our

Customer Group	**Non - notified**	**Notified**
Industrial	8.25	5.75
Trade and Service	12.38	8.5
Agricultural	1.88	1.25
Residential	1	0.88
Public Service	1.63	1.25
Wood processing/energy intensive industries	1.63	1.38
Weighted average (by electricity consumption)	6.74	

Table 1: Outage Costs

source: Norwegian Water Resources and Energy Directorate, in EUROs

sample of firms is very homogeneous. Moreover, the NVE already harmonized the data extensively for their own benchmark studies.

In order to be able to consider allocative questions, we need an estimate of outage costs, that is, the p_o in the above formulas. The cost of energy not supplied (CENS) per MWh as investigated by the Norwegian regulatory authority are given in Table 1. To get a price for ENS, we calculated the average of the outage costs of different groups, weighted by their electricity consumption. This value now represents the expected cost of an outage which occurs at any customer. This p_o was then discounted or inflated with the Norwegian rate of inflation to get measures for the different years.

5 Results[12]

The most important results of our investigation can be inferred from table 2 as it shows the aggregation of the individual results from the comparison 2001-2005 in order to check whether equations (12) and (13) hold (the other results can be found in the sections B.1, B.2 and B.3). It can be seen, that for most of the the single firms AEC and CM are smaller than one. In line "relative change" it can be seen that total social cost of electricity production decreased, mainly due to increases in allocative efficiency. So our hypotheses from section

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[12] For calculating the LP-problems and the indices we used the free software package R.

Firm	Social Cost$_{01}$	$CM_{01.05}$	$AEC_{01.05}$	SC_{01} $*CM_{01.05}$	SC_{01} $*AEC_{01.05}$
Alta Kraftlag AL	44220.84	0.83	1.05	36787.17	46299.28
Askoy Energi AS	27551.58	0.93	0.91	25641.46	25006.04
Bodo Energi AS	67827.65	1.13	0.98	76682.51	66223.13
Dalane energi IKS	53692.56	0.87	1.03	46665.46	55362.33
Eidefoss AS	49425.57	0.94	0.90	46398.87	44539.30
Elverum Energiverk Nett AS	53276.37	0.79	1.03	41856.29	54910.06
Fredrikstad Energi Nett AS	102831.98	0.72	0.98	73811.76	100439.45
Gudbrandsdal Energi AS	34689.11	1.21	1.02	41998.98	35290.91
Hadeland Energinett AS	65040.86	0.95	0.96	61518.20	62127.48
Hallingdal Kraftnett AS	53536.23	0.86	0.94	45933.75	50474.03
Halogaland Kraft AS	81103.98	0.89	1.01	71897.48	81897.30
Hammerfest Elverk Nett AS	34100.64	1.14	0.99	38855.53	33850.44
Haugaland Kraft AS	117702.97	1.48	1.00	174280.35	118032.46
HelgelandsKraft AS	237660.94	0.89	0.96	211886.07	227212.27
Klepp Energi AS	20754.11	1.00	1.16	20730.28	24105.33
Lier everk AS	33650.95	0.86	1.00	28790.03	33650.95
Lofotkraft AS	66079.09	0.84	1.03	55611.33	67871.22
Narvik Energinett AS	47740.15	1.13	0.98	54094.95	46613.29
Nordmore Energiverk AS	78536.33	1.06	0.84	82864.44	65582.71
Nord-Osterdal Kraftlag AL	34652.66	1.10	1.06	38279.52	36561.66
Notodden Energi AS	29043.99	0.92	0.92	26788.70	26705.01
Ringeriks-Kraft Nett AS	63172.29	1.22	0.94	77133.41	59207.35
Stange Energi Nett AS	41932.45	0.88	0.87	36722.62	36334.35
Sunnfjord Energi AS	54999.81	0.82	1.09	45188.20	60144.48
Tafjord Kraftnett AS	111933.04	0.98	0.99	109150.43	110612.91
Trondheim Energiverk Nett AS	210732.13	0.66	0.94	138236.61	198230.62
Tussa Nett AS	122701.19	1.04	1.09	128210.26	134109.28
Valdres Energiverk AS	62752.93	0.81	0.97	51055.27	60692.06
Varanger Kraftnett AS	53137.19	1.45	1.00	77262.72	53254.12
Vesteralskraft Nett AS	50440.64	1.13	0.96	57162.44	48565.21
Sum	2104920.25			2021495.09	2063905.03
relative change				**0.96**	**0.98**

Table 2: The aggregation of Malmquist indices (2001-2005)

3.1 can be confirmed: Quality regulation indeed induced companies to choose a more socially favorable input mix, thereby decrease their costs of production and thus to increase welfare.

When looking at the geometric average of the results in table 3 (the detailed results can be found in appendices B.1 and B.3), we can, moreover, diagnose a few other things: The CM is smaller than one in all three comparisons: Between 1999 and 2005 social cost efficiency increased by almost 8 percent which cannot be attributed to technical progress as this figure even shows a slight regress ($TC = 1.02$). Also, the technical catch up factor TEC shows only a three percent increase in efficiency.

Comparing the development of AEC before and after 2001 we observe

			CM			
			OEC		CTC	
	CM	IM^{*}	TEC^{*}	AEC	TC^{*}	PE
1999 - 2001						
Geometric average	0.9595	1.0343	0.9538	0.9527	1.0844	0.9738
Standard deviation	0.2076	0.1523	0.1147	0.1568	0.0588	0.0632
Min	0.5292	0.6628	0.7228	0.6148	0.8625	0.8738
Max	1.5619	1.3030	1.2002	1.3625	1.1561	1.1991
2001 - 2005						
Geometric average	0.9669	0.9673	1.0180	0.9805	0.9502	1.0163
Standard deviation	0.1940	0.2186	0.2295	0.0681	0.1218	0.0664
Min	0.6560	0.6637	0.7032	0.8351	0.6637	0.8657
Max	1.4807	1.4797	1.5613	1.1615	1.1246	1.2413
1999 - 2005						
Geometric average	0.9266	0.9989	0.9710	0.9370	1.0287	0.9900
Standard deviation	0.2739	0.2789	0.2480	0.1506	0.1367	0.0945
Min	0.4841	0.4930	0.5718	0.5580	0.7447	0.7519
Max	1.6352	1.6263	1.5613	1.4049	1.2247	1.3439

* $IM = TEC * TC$

Table 3: Summary of the main developments

that the bigger part of the advancement was made before 2001. The larger increase in AEC-efficiency in the first period can be partly explained by the methodology we have used. To see why, consider figure 5 again and note that an input-mix change has a much stronger effect on the change in allocative efficiency if the firm is originally located further in the south eastern part of the graph. After 2001, AEC was the second largest source of productivity progress and there occurred a frontier shift (TC). Therefore firms moved the estimated frontier outward by either reducing quality slacks or by investing in technology to produce less outages at lower costs.

An alternative way to interpret the results is by remembering that OEC measures the amount by which firms came closer to the price line. In the period 1999-2001 decreases in OEC can be attributed equally to technical catch up (TEC) and changes in the input mix (AEC). After the introduction of quality regulation, however, changes in the input mix, were the only driving force with the increase of OEC-efficiency (i.e. only (AEC) was below 1, whereas TEC was above 1). Apart from the effect of quality regulation there are other interesting observations to be made as well. Between 1999 and 2001, efficiency mainly increased because firms converged to the efficiency frontier. This could be due to the recently (1997) introduced price cap regulation which is supposed to promote convergence in efficiency. After 2001 technical progress was again the driving force in efficiency.

6 Conclusions

The aim of this paper is to investigate empirically the usefulness of price-cap and quality regulation, not only in terms of changes in quality, but in terms of allocative efficiency and welfare.

We develop a methodology on how to address the issue. An analytical framework allows us to determine sufficient conditions for a weak increase in gross welfare and a decrease in the social cost of electricity distribution. If both conditions are satisfied, welfare indeed increased. In order to investigate changes in social costs and reasons for such changes we propose Malmquist productivity indices. The next question is to what extend can a potential such welfare increase actually be attributed to quality regulation? This is the case if a substantial part of the increase in welfare (the decrease in social costs) can be attributed to a better-solved trade off between production costs and quality that is, higher allocative efficiency. In other words: If, by charging a price for outages, electricity companies were induced to substitute costs for outages in a more socially favorable manner. Whether this was the case or not, can be measured by a decomposite of the Malmquist Index.

Malmquist indices were then calculated for a representative sample of Norwegian distribution system operators. We found strong evidence that it was indeed quality regulation that induced firms to behave in a socially more optimal way. As the social costs of electricity distribution decreased and our condition for a weak welfare increase seems to hold it can be argued that welfare increased. A corollary result is that with the prior pure price cap regulation regime quality cannot have been optimal, since otherwise welfare would not have increased with increasing absolute quality levels.

Our results have implications for regulatory policy. If quality can be observed and contractually specified, it might well be worthwhile to directly regulate it even if regulation is costly as suggested by Buehler et al. (2006) and Burger (2008)

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A Gross Welfare

Firm	dy_i	dq_i	$\frac{dy_i}{dq_i}$	$\frac{\int_0^{\overline{y}_i} \frac{\partial P_i(y_i,q_i)}{\partial q_i} dy_i}{P_i(y_i,q_i)}$	condition satisfied?
Alta Kraftlag AL	-222.00	24.67	-9.00	-240.93	j
Askøy Energi AS	863.00	-1.81	-477.17	-229.39	n
Bodø Energi AS	701.00	-56.41	-12.43	-532.51	j
Dalane Elverk	622.00	11.75	52.93	-258.01	j
Eidefoss AS	4.00	-10.15	-0.39	-283.87	j
Elverum Energiverk Nett AS	35.00	212.03	0.17	-226.55	j
Fredrikstad Energi Nett AS	-549.00	-239.88			n
Gudbrandsdal Energi AS	1076.00	-26.26	-40.97	-306.03	j
Hadeland Energinett AS	212.00	71.98	2.95	-337.00	j
Hallingdal Kraftnett AS	1180.00	59.80	19.73	-401.45	j
Hålogaland Kraft AS	1484.00	4.06	365.25	-495.58	j
Hammerfest Elverk Nett AS	274.00	-45.01	-6.09	-158.40	j
Haugaland Kraft AS	2076.00	-58.97	-35.20	-1164.13	j
HelgelandsKraft AS	1847.00	238.99	7.73	-978.07	j
Klepp Energi AS	470.00	0.56	838.07	-129.16	j
Lier everk AS	1571.00	0.94	1678.33	-233.62	j
Lofotkraft AS	1015.00	28.83	35.20	-323.14	j
Narvik Energi AS	292.00	26.32	11.09	-259.52	j
Nordmøre Energiverk	929.00	-48.01	-19.35	-535.41	j
Nord-Østerdal Kraftlag Andelsverk AS	227.00	63.05	3.60	-225.28	j
Notodden Energi AS	158.00	-23.19	-6.81	-160.48	j
Ringeriks-Kraft AS	-576.00	55.45	-10.39	-432.08	j
Stange Energi AS	491.00	102.93	4.77	-212.82	j
Sunnfjord Energi AS	-123.00	43.19	-2.85	-318.58	j
Tafjord Kraftnett AS	935.00	19.08	49.01	-621.93	j
Trondheim Energiverk Nett AS	5853.00	62.73	93.30	-1937.78	j
Tussa Nett AS	175.00	60.17	2.91	-587.17	j
Valdres Energiverk AS	1080.00	52.64	20.52	-239.10	j
Varanger Kraft AS	-303.00	-69.77	4.34	-356.30	j
Vesterålskraft Nett AS	997.00	48.69	20.47	-262.91	j

Table 4: testing the condition for an increase in gross welfare

B Malmquist-Indices

B.1 1999 to 2001

1999 - 2001	CM	OEC	CTC	TEC	AEC	TC	PE	IM
Alta.Kraftlag.AL	0.91	0.87	1.04	0.99	0.88	1.06	0.99	1.04
Askoy.Energi.AS	0.53	0.51	1.04	0.83	0.61	1.12	0.93	0.93
Bodo.Energi.AS	0.87	0.82	1.05	0.89	0.93	1.08	0.98	0.96
Dalane.Elverk	1.02	0.98	1.03	0.72	1.36	0.97	1.07	0.7
Eidefoss.AS	1.1	1	1.1	1.04	0.96	1.09	1.01	1.14
Elverum.Energiverk.Nett.AS	0.99	0.95	1.05	0.97	0.97	1.15	0.91	1.11
Fredrikstad.Energi.Nett.AS	0.86	0.8	1.07	0.75	1.07	1.07	1	0.81
Gudbrandsdal.Energi.AS	1.08	1	1.08	1	1	1.05	1.03	1.05
Hadeland.Energinett.AS	1.05	1	1.06	1.05	0.95	1.16	0.91	1.21
Hallingdal.Kraftnett.AS	1.3	1.2	1.08	1.13	1.06	1.13	0.96	1.28
Halogaland.Kraft.AS	0.93	0.87	1.06	0.92	0.95	1.09	0.97	1
Hammerfest.E.verk.DA	0.61	0.6	1.03	0.87	0.69	1.13	0.91	0.99
Haugaland.Kraft.AS	1.05	1	1.05	1	1	1.11	0.94	1.11
Helgeland.Kraftlag.AL	1.1	1.01	1.08	1	1.02	1.14	0.95	1.14
Klepp.Energi.AS	0.96	1	0.96	1	1	1.1	0.87	1.1
Lier.everk.AS	0.94	0.98	0.95	1	0.98	1.05	0.91	1.05
Lofotkraft.AS	0.76	0.7	1.09	1.01	0.69	1.12	0.98	1.13
Narvik.Energi.AS	0.85	0.81	1.05	1	0.81	1.12	0.94	1.12
Nordmore.Energiverk	1.01	0.95	1.07	0.78	1.21	1.09	0.98	0.85
Nord.Osterdal.Kraftlag.AL	1.02	0.94	1.09	1	0.94	1.01	1.08	1.01
Notodden.Energi.AS	0.77	0.74	1.03	0.77	0.96	0.86	1.2	0.66
Ringeriks.Kraft.AS	1.35	1.26	1.07	1.18	1.07	1.11	0.97	1.3
Stange.Energi.AS	1.56	1.47	1.06	1.2	1.22	1.08	0.99	1.29
Sunnfjord.Energi.AS	0.85	0.78	1.1	1	0.77	1.09	1	1.1
Tafjord.Kraftnett.AS	0.95	0.9	1.05	0.94	0.96	1.08	0.97	1.02
Trondheim.Energiverk.Nett.AS	1.15	1.06	1.09	1	1.06	1.06	1.02	1.06
Tussa.Nett.AS	0.79	0.75	1.06	0.84	0.89	1.07	0.99	0.91
Valdres.Energiverk.AS	1.18	1.08	1.09	0.99	1.1	1.13	0.97	1.12
Varanger.Kraft.AS	0.88	0.86	1.03	1	0.86	1.12	0.92	1.12
Vesteralskraft.Nett.AS	1.01	0.93	1.08	0.95	0.98	1.15	0.94	1.08
Mgeom	0.96	0.91	1.06	0.95	0.95	1.08	0.97	1.03
Mavrg	0.98	0.93	1.06	0.96	0.97	1.09	0.98	1.04
SD	0.21	0.19	0.04	0.11	0.16	0.06	0.06	20.96
Min	0.53	0.51	0.95	0.72	0.61	0.86	0.87	0.99
Max	1.56	1.47	1.1	1.2	1.36	1.16	1.2	0.96

Table 5: Malmquist-indices for the period 1999 to 2001

B.2 2001 to 2005

2001 - 2005	CM	OEC	CTC	TEC	AEC	TC	PE	IM
Alta.Kraftlag.AL	0.83	0.74	1.13	0.7	1.05	1.02	1.11	0.72
Askoy.Energi.AS	0.93	1.1	0.84	1.21	0.91	0.78	1.08	0.95
Bodo.Energi.AS	1.13	1.52	0.75	1.55	0.98	0.75	0.99	1.17
Dalane.Elverk	0.87	0.82	1.07	0.79	1.03	0.86	1.24	0.68
Eidefoss.AS	0.94	0.9	1.04	1	0.9	1.01	1.03	1.01
Elverum.Energiverk.Nett.AS	0.79	0.78	1.01	0.76	1.03	0.94	1.08	0.71
Fredrikstad.Energi.Nett.AS	0.72	0.9	0.79	0.92	0.98	0.72	1.1	0.67
Gudbrandsdal.Energi.AS	1.21	1.1	1.1	1.08	1.02	1.11	0.99	1.2
Hadeland.Energinett.AS	0.95	0.93	1.01	0.98	0.96	1.02	0.99	1
Hallingdal.Kraftnett.AS	0.86	0.83	1.03	0.88	0.94	1.03	1	0.91
Halogaland.Kraft.AS	0.89	0.82	1.08	0.81	1.01	1.09	1	0.88
Hammerfest.Elektrisitetsverk.DA	1.14	1.12	1.02	1.13	0.99	1.01	1	1.14
Haugaland.Kraft.AS	1.48	1.57	0.95	1.56	1	0.93	1.01	1.46
Helgeland.Kraftlag.AL	0.89	0.86	1.04	0.9	0.96	1.05	0.99	0.94
Klepp.Energi.AS	1	1.16	0.86	1	1.16	0.99	0.87	0.99
Lier.everk.AS	0.86	1	0.86	1	1	0.88	0.97	0.88
Lofotkraft.AS	0.84	0.79	1.06	0.77	1.03	1.08	0.98	0.83
Narvik.Energi.AS	1.13	1.36	0.83	1.4	0.98	0.84	0.99	1.17
Nordmore.Energiverk	1.06	1.06	0.99	1.27	0.84	0.93	1.06	1.19
Nord.Osterdal.Kraftlag.AL	1.1	1.07	1.04	1.01	1.06	1.09	0.95	1.1
Notodden.Energi.AS	0.92	0.99	0.93	1.08	0.92	1	0.94	1.07
Ringeriks.Kraft.AS	1.22	1.17	1.04	1.25	0.94	1.03	1.01	1.29
Stange.Energi.AS	0.88	0.9	0.97	1.04	0.87	0.99	0.98	1.03
Sunnfjord.Energi.AS	0.82	0.78	1.05	0.72	1.09	1.05	1	0.75
Tafjord.Kraftnett.AS	0.98	1.17	0.84	1.18	0.99	0.78	1.07	0.92
Trondheim.Energiverk.Nett.AS	0.66	0.94	0.7	1	0.94	0.66	1.05	0.66
Tussa.Nett.AS	1.04	1.02	1.03	0.93	1.09	0.96	1.07	0.9
Valdres.Energiverk.AS	0.81	0.8	1.02	0.82	0.97	1.03	0.99	0.85
Varanger.Kraft.AS	1.45	1.32	1.1	1.32	1	1.12	0.98	1.48
Vesteralskraft.Nett.AS	1.13	1.13	1	1.17	0.96	0.99	1.02	1.16
Mgeom	0.97	1	0.97	1.02	0.98	0.95	1.02	0.97
Mavrg	0.98	1.02	0.97	1.04	0.99	0.96	1.02	0.98
SD	0.19	0.22	0.11	0.23	0.07	0.12	0.07	42.89
Min	0.66	0.74	0.7	0.7	0.84	0.66	0.87	0.91
Max	1.48	1.57	1.13	1.56	1.16	1.12	1.24	1.03

Table 6: Individual Malmquist-indices for the period 2001 to 2005

B.3 1999 to 2005

1999 - 2005	CM	OEC	CTC	TEC	AEC	TC	PE	IM
Alta.Kraftlag.AL	0.73	0.64	1.14	0.69	0.93	1.09	1.04	0.76
Askoy.Energi.AS	0.48	0.56	0.86	1.01	0.56	0.92	0.93	0.93
Bodo.Energi.AS	0.97	1.25	0.78	1.38	0.91	0.82	0.94	1.13
Dalane.Elverk	0.93	0.8	1.16	0.57	1.4	0.86	1.34	0.49
Eidefoss.AS	1.03	0.9	1.14	1.04	0.86	1.09	1.05	1.13
Elverum.Energiverk.Nett.AS	0.79	0.74	1.07	0.73	1	0.97	1.1	0.71
Fredrikstad.Energi.Nett.AS	0.58	0.72	0.8	0.7	1.04	0.85	0.95	0.59
Gudbrandsdal.Energi.AS	1.32	1.1	1.21	1.08	1.02	1.21	1	1.3
Hadeland.Energinett.AS	0.98	0.93	1.05	1.03	0.91	1.12	0.93	1.15
Hallingdal.Kraftnett.AS	1.13	1	1.13	1	1	1.09	1.04	1.09
Halogaland.Kraft.AS	0.84	0.72	1.17	0.75	0.96	1.21	0.96	0.9
Hammerfest.Elektrisitetsverk.DA	0.69	0.67	1.03	0.98	0.68	1.15	0.89	1.13
Haugaland.Kraft.AS	1.54	1.57	0.99	1.56	1	1.04	0.95	1.63
Helgeland.Kraftlag.AL	0.98	0.87	1.13	0.89	0.97	1.21	0.94	1.08
Klepp.Energi.AS	0.96	1.17	0.82	1	1.17	1.1	0.75	1.1
Lier.everk.AS	0.82	0.98	0.83	1	0.98	0.83	0.99	0.83
Lofotkraft.AS	0.62	0.55	1.13	0.78	0.71	1.21	0.94	0.94
Narvik.Energi.AS	0.89	1.1	0.81	1.39	0.79	0.85	0.94	1.19
Nordmore.Energiverk	1.06	1.01	1.05	1	1.01	1.07	0.98	1.07
Nord.Osterdal.Kraftlag.AL	1.13	1	1.14	1.01	0.99	1.12	1.02	1.12
Notodden.Energi.AS	0.75	0.73	1.02	0.83	0.89	0.96	1.06	0.8
Ringeriks.Kraft.AS	1.64	1.48	1.11	1.47	1	1.06	1.04	1.56
Stange.Energi.AS	1.4	1.32	1.06	1.25	1.06	1.1	0.97	1.37
Sunnfjord.Energi.AS	0.7	0.61	1.14	0.72	0.85	1.12	1.03	0.8
Tafjord.Kraftnett.AS	0.93	1.05	0.89	1.11	0.95	0.87	1.02	0.96
Trondheim.Energiverk.Nett.AS	0.78	1	0.78	1	1	0.74	1.05	0.74
Tussa.Nett.AS	0.82	0.76	1.08	0.79	0.97	1.03	1.05	0.81
Valdres.Energiverk.AS	0.96	0.86	1.11	0.81	1.06	1.15	0.96	0.94
Varanger.Kraft.AS	1.27	1.13	1.13	1.32	0.86	1.22	0.92	1.61
Vesteralskraft.Nett.AS	1.15	1.05	1.1	1.11	0.95	1.06	1.03	1.18
Mgeom	0.93	0.91	1.02	0.97	0.94	1.03	0.99	1
Mavrg	0.96	0.94	1.03	1	0.95	1.04	0.99	1.02
SD	0.27	0.26	0.14	0.25	0.15	0.14	0.09	19.24
Min	0.48	0.55	0.78	0.57	0.56	0.74	0.75	1.15
Max	1.64	1.57	1.21	1.56	1.4	1.22	1.34	0.87

Table 7: Malmquist-indices for the period 1999 to 2005