ANALYSING THE DIRECTING SIGNALS OF THE ECONOMIC REGULATION

Samuli HONKAPURO  
Lappeenranta University of Technology – Finland  
Samuli.Honkapuro@lut.fi

Jarmo PARTANEN  
Lappeenranta University of Technology – Finland  
Jarmo.Partanen@lut.fi

ABSTRACT
In this paper, the methodology for holistic analysis of the directing signals of the economic regulation in the electricity distribution business is presented. Major focus is on the effects of the regulatory benchmarking. The basic idea of such analysing methodology is to calculate how certain changes in the input parameters affect the regulatory allowed incomes, by taking into account the effects of the efficiency benchmarking, quality adjustment, and regulatory asset base. This methodology is used successfully during the analysis and development of the regulatory benchmarking model, used in Finnish electricity distribution sector. This development process is illustrated in the paper as the practical application of the methodology.

INTRODUCTION
The major objective of the economic regulation is to direct monopoly companies to provide their services so that the total socio-economic welfare is maximised. In the field of the power distribution, this means that companies have to be provided with incentives to minimise the total life-cycle costs of the electricity distribution, including building, operation, and maintenance costs of the distribution network, as well as the costs incurred by the customers due to the imperfect quality of supply. Since the capital intensity in the electric distribution business is high and asset lifetimes are long, network investments usually lead to significant and long lasting economic impacts. Hence, considerable indirect costs may occur, if regulation model encourages companies to unnecessary investments. Therefore, it is essential to ensure that the economic regulation provides companies with appropriate directing signals, and unwanted incentives are not included in the regulation model. Consequently, the holistic analysis of the regulation model is needed, to find out the practical directing signals of the model.

In this paper, methodology for analysing the directing signals of the economic regulation is presented. Furthermore, the analysis and development of the Finnish regulatory benchmarking are presented as the practical example of the utilisation of the methodology. More detailed illustration of the analysis and development of the Finnish regulatory model, as well as analysing methodology, are presented in [1].

The structure of the paper is as following: The directing signals of the economic regulation in general are discussed in the Chapter 2. Analysing methodology is presented in the Chapter 3. Development process and the evaluation of the directing signals of the Finnish regulatory benchmarking are illustrated in the Chapter 4, and the conclusions are drawn in the Chapter 5.

DIRECTING SIGNALS OF THE ECONOMIC REGULATION
The fundamental problem in the regulation of the monopoly companies is the asymmetry of the information between the regulator and the companies. In the economic literature, see for instance [2], this is described as principal-agent problem. In such situation, the objectives of the principal and agent are different, and principal tries to find an optimal incentive scheme for agent, with incomplete information about the behaviour and circumstances of the agent. Similar situation occurs in the regulation of the monopoly business, where regulator is the principal, company is the agent, and regulation model is a contract between the principal and agent. Regulator tries to direct company to fulfil the interests of the public, but the company is mainly interested in its own profits. In addition, regulator does not have full information about the company, for instance cost reduction possibilities. Hence, the major objective in the analysis of the directing signals of the regulation is to find out how an opportunistic regulated company generally operates to maximise its profits under regulatory constraints.

The most relevant questions during the analysis of the directing signals are: (1) which subjects are under regulation, (2) which subjects are excluded from the regulatory calculations, and (3) how can a regulated company affect these issues. In the electricity distribution, major subjects are operational costs, capital costs, and quality measurements. These can have different roles in the regulatory framework, and they can be affected by the network investments, as well as by the operational activities of the distribution company.

Although the objective of the regulation is to direct companies to maximise the total socio-economical welfare, there may be unintended incentives, which encourage companies to maximise their own profits with the non-optimal design of the networks. The classical example of such signal is overcapitalisation incentive in the Rate-of-Return (ROR) regulation (so-called Averch-Johnsson effect). In addition, regulation may encourage companies to
pursue virtual efficiency improvements by so-called regulatory gaming, as illustrated in [3].

Since regulation model may be complex and piecemeal developed, there may be some directing signals, which cannot be found without the holistic analysis of the regulatory model. For instance, efficiency benchmarking may have been developed separately from the other parts of the regulation model and during the development process, analyses may have focused only on the benchmarking model. In such situation, the incentives of the complete regulatory framework may not be found. Hence, it is essential that the comprehensive analyses of the regulatory incentives are made during the development of the model.

**METHODOLOGY FOR REGULATORY ANALYSIS**

The major regulatory effects of a network investment are illustrated in Fig. 1. This figure is in general terms based on the Finnish regulatory model. Although the effects vary between the models, they, however, are usually similar to this figure in the other models also, to some extent at least.

![Figure 1. Relationships between network investment and allowed incomes.](image)

In this analysing methodology, the practical calculations of the directing signals are made by running sensitivity analyses for quality adjustment, efficiency benchmarking, and regulatory asset base. The results of the sensitivity analyses are combined on the properties of the regulation model, so that the actual economic effects of the input parameter are found. For instance, the effect of an input parameter variation to the efficiency score is calculated by sensitivity analysis, and the economical effect of the input parameter is evaluated by taking into account the effect of the efficiency score to the allowed incomes. This process is illustrated in the Fig. 2.

![Figure 2. Basic principle of the analysing methodology.](image)

Based on the dependencies between the input data and regulatory allowed incomes, the marginal price of each parameter can be calculated. By this way, the effect of a single parameter to regulatory outcomes can be analysed, or the profitability of a network investment, for instance, can be evaluated by changing multiple parameters simultaneously. The directing signals of the regulation can be determined by evaluating the profitability of the different network investments, as well as operational activities of the companies. By that way, it is possible to find out the actions, which are encouraged by the regulation model.

Analysing the effects of the regulatory asset base is quite straightforward; replacement investment increases only the present value of the network, while extension investment affects also the repurchase value of the network. The effect of the quality adjustment is also relatively simple to analyse, since it is based on the difference between the actual and reference value of the interruption costs. However, in the case of the efficiency benchmarking, the re-calculation of the efficiency scores of every company is needed every time when the input data is changed. That is because efficiency scores are calculated by comparing companies against each other, and therefore the input data of one company may affect efficiency scores of the other companies. Further illustrations of the regulatory analyses are provided in the next section, where the directing signals of the Finnish regulation model are evaluated.

**DEVELOPMENT OF THE FINNISH REGULATORY BENCHMARKING**

Above described analysing methodology has been applied in practice during the analysis and development of the efficiency benchmarking, used in the Finnish regulatory model. The key subjects in this development process have been the role of the power quality and capital costs in the efficiency benchmarking. The starting point of the development process was the former Finnish benchmarking model, which was used before year 2005. In that model, operational costs were used as only controlled input parameter, and quality was measured as interruption time and included in the benchmarking as non-controllable input parameter. Capital costs were excluded from the benchmarking model.

**Power quality**

Since the power quality was included in the former benchmarking model as interruption time, it was possible to calculate the regulatory interruption costs, that is the marginal price of the interruption time. The sensitivity analyses showed that such interruption costs varied significantly between the companies and observation years, as reported for instance in [4]. Furthermore, interruption time did not provide comprehensive information about the power quality.

The principle problem in such model rises from the nature of the technical efficiency measurement. The weights of the benchmarking parameters are chosen so that they reflect the technological feasible production sets, and the weights of the two inputs reflect the mutual valuation of these parameters. Thus, the weight of the interruption time related
to the weight of the costs reflects the cost that is needed to decrease the interruption time. However, this cost does not necessary reflect the cost incurred by customers due to the interruption time. Hence, in order to provide companies with incentives for maximising the total socio-economical welfare, the cost of the interruption for the company should be equal to the welfare losses of the customers.

Consequently, solution that corrected the above-mentioned drawbacks was to measure power quality as interruption costs and combine these to operational and capital costs as single input parameter of the benchmarking. In such approach, interruption indices, such as number and duration of the interruptions, are weighted by the interruption cost parameters that reflect the welfare losses of the customers. Such model provides companies with incentives to minimise the total socio-economic costs, including the operational and capital costs of the company, as well as interruption costs of the customers. Furthermore, the predictability of the efficiency benchmarking increases, if there is only one input parameter, since the weight of the single parameter is better foreseeable. However, there was still problem concerning the measurement of the capital costs.

**Capital costs**

Since the capital costs were not included in the former Finnish efficiency benchmarking, the directing signals were distorted so that companies received efficiency gains by trade-offs between the OPEX and CAPEX. Such situation may encourage companies for instance to choose replacement investment instead of the maintenance action.

In practice, there are number of different possibilities to include capital costs in the regulation and benchmarking. Capital can be measured as physical quantities of the network components, or monetary values can be used. Furthermore, capital costs can be determined from the accounting records, annual investment costs, or the repurchase value of the network. During the development of the Finnish benchmarking model, analyses have been concentrated in two options: annual investment costs and straight-line depreciations, calculated from the repurchase value of the network.

If capital costs are based on annual network investments, there is risk that even profitable investments are penalised by efficiency benchmarking model. For instance, if five years’ average of the investment costs is combined to annual operational and interruption costs in the efficiency benchmarking, investments are beneficial from the viewpoint of the efficiency evaluation only, if their payback time is less than five years. This is rarely the situation in the electricity distribution business.

Straight-line depreciations, on the other hand, represent the long-term investment need of the company. However, companies have quite limited opportunities to affect these depreciations, especially in the short run, since they can be decreased only by dismantling the network or rebuilding it by using less expensive components.

However, major objective in the network planning is to minimise the sum of the operational, capital, and interruption costs during the lifetime of the network, within technical boundaries. As the annual costs, this corresponds to the sum of the annual depreciations, operational costs, and interruption costs. Hence, the directing signals of the efficiency evaluation would be inline with the above-mentioned objectives, if the sum of those costs components were used as the input parameter of the benchmarking. Consequently, benchmarking model was developed so that in the new model, there is one input parameter, which is the sum of the operational costs, interruption costs, and straight-line depreciations.

**Directing signals of the new model**

The basic principles of the Finnish regulation model are illustrated in the Fig. 3.

As it has been presented in [5] and [1], the sum of the operational costs, capital costs, and interruption costs is the input parameter of the efficiency benchmarking, which is used to derive the efficiency requirement that focuses on the operational costs. Benchmarking models are DEA (Data Envelopment Analysis) with the assumption of the Non-Decreasing Returns to Scale (NDRS) and SFA (Stochastic Frontier Analysis). The average of these two is used to determine the company specific efficiency requirement. Further, the value of the network assets affects the allowed incomes as the present value of the network is used as regulatory asset base, and reasonable depreciation costs are determined based on straight-line depreciations, calculated from the repurchase value of the network. In addition, interruption costs are used in quality adjustment, so that allowed incomes are adjusted by the half of the difference between the actual interruption costs and their reference value.

The directing signals of the Finnish regulatory model are illustrated by the analysis of the regulatory effects of a network investment. In this example, a network company, of which relevant information is presented in the Table 1,
increases its reliability of supply by replacing 12 km of the overhead lines with underground cables. Relevant data of this network investment is presented in the Table 2.

Table 1. Information of the example network company.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repurchase value of the network</td>
<td>80 000 k€</td>
</tr>
<tr>
<td>Depreciation time of the network</td>
<td>40 a</td>
</tr>
<tr>
<td>Average age of the network</td>
<td>20 a</td>
</tr>
<tr>
<td>Annual straight-line depreciations (SD)</td>
<td>2 000 k€</td>
</tr>
<tr>
<td>Present value of the network</td>
<td>40 000 k€</td>
</tr>
<tr>
<td>Annual operational expenses (OPEX)</td>
<td>2 000 k€</td>
</tr>
<tr>
<td>Average annual interruption costs (IC)</td>
<td>1 000 k€</td>
</tr>
<tr>
<td>Efficiency score (ES)</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Table 2. Input data of the example investment.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repurchase value of the replaced line</td>
<td>250 k€</td>
</tr>
<tr>
<td>Remaining lifetime of the replaced line</td>
<td>0 a</td>
</tr>
<tr>
<td>Investment cost</td>
<td>500 k€</td>
</tr>
<tr>
<td>Depreciation time of the investment</td>
<td>40 a</td>
</tr>
<tr>
<td>Estimated impact on annual interruption costs</td>
<td>- 40 k€</td>
</tr>
<tr>
<td>Estimated impact on annual OPEX</td>
<td>- 2 k€</td>
</tr>
</tbody>
</table>

Due to the investment, the present value of the network will increase by 500 k€. Reasonable return on capital is assumed to be 5 %, thus investment will increase allowed profit by 25 k€. However, increase in the repurchase value of the network will be only 250 k€, which is the difference between the repurchase values of the new and replaced lines. Hence, straight-line depreciations, which are used as reasonable depreciation costs, will increase by 6.3 k€. The influence of the quality adjustment is half of the reduction in the interruption costs, which in this case means 20 k€ increase in the allowed annual incomes.

The input parameter of the efficiency benchmarking is the sum of the operational expenses, interruption costs, and straight-line depreciations. Example network investment will decrease this sum by 35.7 k€, which will lead to 0.006 increase in the efficiency score. Company specific efficiency requirement (ER), focusing on OPEX, is calculated in the Finnish regulation model as presented in the Equation (1).

\[
ER = \frac{1 - (1 - ES) \times 0.84 \times \frac{OPEX}{OPEX + SD + IC}}{1 - (1 - ES) \times 0.84 \times \frac{OPEX}{OPEX + SD + IC}}
\]  

(1)

Hence, investment will decrease the annual efficiency requirement by 0.03 percentage unit, which will increase the allowed annual incomes by 0.6 k€. Total effects of the example investment are presented in the Table 3.

Table 3. Regulatory effects of the example investment.

<table>
<thead>
<tr>
<th>Effect of the example investment</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in the allowed profit (k€)</td>
<td>+ 25 k€</td>
</tr>
<tr>
<td>Change in the reasonable annual depreciations (k€)</td>
<td>+ 6.3 k€</td>
</tr>
<tr>
<td>Effect of the individual annual efficiency requirement (k€)</td>
<td>+ 0.6 k€</td>
</tr>
<tr>
<td>Change in the quality adjustment (k€)</td>
<td>+ 20 k€</td>
</tr>
<tr>
<td>Total effect on the allowed annual incomes (k€)</td>
<td>+ 51.9 k€</td>
</tr>
</tbody>
</table>

As it can be seen, the return on investment is significantly higher than regulatory return on capital, mainly due to the quality adjustment. Hence, this regulation model provides strong incentives for increasing the quality of supply. However, this calculation is valid only for the regulation model, used during the years 2008–2011. Hence, the long-term effects of the investment are unclear, since there is no information about the details (e.g. the effects of the quality adjustment) of the upcoming regulation model.

Furthermore, this example analysis showed out that it is necessary to analyse all the elements of the regulatory framework, in order to find the actual regulatory return on investment.

**CONCLUSIONS**

Economic regulation has to provide companies with incentives to design their networks and business models so that the total socio-economic welfare is maximised. To ensure that the directing signals of the economic regulation are inline with above-mentioned requirement, the holistic analyses of the regulation model’s incentives are needed. Hence, the methodology for such analyses is developed, and it is used in practice during the development of the Finnish regulatory benchmarking, as illustrated in this paper.

In the case of the Finnish benchmarking model, directing signals have been improved by using single input parameter, which is the sum of the operational expenses, annual straight-line depreciations, and interruption costs. By this way, the impacts of the changes in the input parameter are better predictable for the companies, and benchmarking provides companies with incentives to minimise the total costs of the electricity distribution, including also cost incurred by the customers because of the interruptions.

**REFERENCES**


