

# Comparing welfare effects of different regulation schemes: an application to the electricity distribution industry

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## Abstract

We compare the welfare effects of different regulation schemes of electricity distribution utilities. The compared regulation schemes are fixed price regulation, cost of service regulation, menu of cost-contingent contracts and simple menus of contracts. In our calculations we utilize the information of firm specific potential to improve cost efficiency. The firm specific cost information of Finnish electricity distribution utilities is obtained by using various Stochastic Frontier models. Our basic result is that welfare can be improved by changing the cost of service regulation scheme to the menu of contracts regulation. Welfare also increases in the case of fixed price regulation and simple menus of contract regulation. There is however, a significant difference among regulation regimes on how this improved welfare is distributed to consumers and producers.

Keywords: welfare, regulation, benchmarking, stochastic frontier analysis, cost efficiency, electricity distribution.

JEL Classifications: C13, C23, D60, D24, L51, L94

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## 1. Introduction

It is generally known that fully informed regulators do not exist in reality. In most of the cases the regulated firm has more information about its costs and other factors and accordingly, the regulated firm may use its information advantage strategically in the regulatory process to increase its profits or to pursue other managerial goals, to the disadvantage of consumers. Many regulatory agencies have put lot of effort to reduce this information asymmetry. Theoretical research on regulation (especially incentive regulation) has also evolved and it has provided new information to regulators (see e.g. Laffont, 1994; Laffont and Tirole 1986, 1993; Armstrong et al., 1994; Armstrong and Sappington, 2004). Because the regulator has less information than the firms the regulated firms have strategic advantage. Generally any firm would like to convince the regulator that it is a “higher cost” firm than it actually is. By behaving like this the firm believes that the regulator sets higher prices (which increases firms’ profits and removes welfare from consumers to the regulated firms).

When a social welfare maximizing regulator tries to distinguish between firms with high cost endowments and firms with low cost endowments it faces an *adverse selection* problem. One possible solution to this problem is to use firm’s ex post realized costs to set regulated prices. This means that the regulator uses some form of “cost of service” (or rate of return) regulation. However, when the regulator in this way solves the adverse selection problem it leads to another problem, namely to the *moral hazard* problem. This is because the loss of the opportunity for the firm to earn extra profits reduces managerial effort and consequently less managerial effort increases the firm’s realized costs. This leads to the situation where regulation actually increases the costs above their efficient levels.

The moral hazard problem may be solved by some form of incentive regulation (e.g. price cap regulation, revenue cap regulation or yardstick competition), but then full costs of adverse selection problem are incurred. The regulator is thus in a complicated situation. One problem connected to the price cap regulation is also the fact that price cap regulation is very weak at rent extraction for the benefit of consumers and society and it potentially leaves a lot of rent to the firm. This raises the question whether we could find a regulatory mechanism which will lie somewhere between these two extremes. The task of the regulator is hence to find such a mechanism that takes the social costs of adverse selection and moral hazard into account. One of

these kinds of methods is menu of contracts regulation, where for each firm a menu of cost-contingent contracts is offered and the firm can choose a contract which it prefers among the menu (see Laffont and Tirole, 1986).

In this paper we compare the welfare effects of different regulation schemes in electricity distribution utilities.<sup>2</sup> We use Finnish data in our study. The four regulation schemes which we compare are fixed price regulation, cost of service regulation, menu of cost-contingent contracts and simple menus of contracts. In our calculations we utilize the benchmarking information of firm specific costs. The firm specific cost information is obtained by using various models of Stochastic Frontier Analysis. Our basic result is that total welfare can be improved if we move from the cost of service regulation scheme to the menu of contracts regulation, simple menu on contracts or to the fixed price regulation. There is however, a significant difference among regulation regimes on how this improved welfare is distributed to consumers and producers.

The rest of the paper is organized as follows: Section 2 gives an introduction of different regulation schemes and in section 3 the stochastic frontier models and their estimation is presented. In section 4 the calculated welfare effects are presented. Section 5 summarizes the findings.

## **2. Different regulation regimes**

### *2.1. Rate of Return / Cost of Service regulation*

The Rate of return (ROR) or cost of service regulation is the traditional approach to regulate monopolies. In the purest form of this regulation the rate of return is fixed to the costs. This means that the utility does not face the risk connected to input prices or other risks related to the costs. There are naturally both advantages and disadvantages connected to each regulatory method. The advantages of rate of return regulation are its relatively simple practical application in limiting monopoly pricing, the possibility to use second-best (e.g. Ramsey-Boiteux) or non-linear prices, the use of deliberate cross-subsidization<sup>3</sup> and finally the rate hearings provide an

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<sup>2</sup> See Pint (1992) for comparing the welfare effects of price-cap and rate-of-return regulation in a stochastic-cost model.

<sup>3</sup> E.g. local telephone service at low rates (subsidized by long-distance service).

opportunity for customers to express their views (see e.g. Liston, 1993). It has been also argued that an additional positive feature of this regulation method is better certainty of long-term investments. Disadvantages connected to this regulation scheme (just to remark the most obvious ones) are that it does not give incentive to produce efficiently and if the allowed rate of return on capital is higher than the cost of capital an input bias (called the Averch-Johnson effect) follows. Rate of return regulation also typically entails high administrative costs (due to time-consuming hearings and requirement of considerable knowledge about the firm's costs). One further difficulty is in determining the "right" level of allowed rate of return which has been seen problematic. On the other hand it is not possible for the firms to gather excessive profits or to incur big losses. Formally the rate of return regulation<sup>4</sup> for firm  $i$  can be written as:

$$P_{i,t} = (1 + r)C_{i,t-1}, \quad (1)$$

where  $P$  is the allowed price at period  $t$ ,  $r$  is the allowed rate of return, and  $C$  is realized costs at period  $t-1$ .

To summarize, the main reservation against this approach is clearly that it does not provide incentives for cost savings and efficiency improvements. It may also easily lead to overinvestments.

## 2.2. *Price Cap regulation*

The price cap regulation has perhaps been the most significant alternative to the ROR regulation method in utility regulation. The price cap method was first proposed by Littlechild (1983) and it has since been adopted in the regulation of many industries (including telecommunication, gas distribution, water distribution, airline industry, railway industry and electricity) in the UK and other countries as well.<sup>5</sup>

In its purest form either the price or price path is fixed. This means that the utility faces the full risk connected to the input prices and demand. On the other hand utility has full incentive to

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<sup>4</sup> When the rate of return regulation is determined this way it is identical to the pure cost of service regulation where firm is allowed to add some fixed percent above its costs.

<sup>5</sup> For the description and discussion of price cap and rate-of-return regulation see also Armstrong et al. (2007), Joskow (2006) and Liston (1993).

reduce costs because it can keep all the benefits from cost reduction. This has been seen as the main advantage of this regulation scheme. The other advantages are relatively small administrative costs, non existence of input bias (A-J effect) and the fact that price ceilings on monopoly services prevent predatory pricings. Because of the differentiation of the price from costs and the fact that in pure price regulation the price does not react to any exogenous factor it is possible for the firm to gather excess profits or also to incur big financial losses. As in any regulatory scheme there exist also some disadvantages in this method. The disadvantages include the uncertainty about the service quality, the fact that potential benefits of e.g. Ramsey-Boiteux prices are ruled out, implementation of price cap can be difficult and there may be greater possibility for capturing the regulatory process by the firm (see e.g. Liston, 1993).

The price cap regulation essentially decouples the profits of the regulated utility from its costs by setting a price ceiling. This method is also referred to as the “RPI – X” model. In this model the price cap for each year is set based on the Retail Price Index and an efficiency factor X. Hence prices remain fixed for the rate period and the utility is allowed to keep the achieved cost savings. Formally the price ceiling for firm  $i$  is set according to the following equation:

$$P_{i,t} = P_{i,t-1} * (RPI - X_i) + /- Z_i \quad (2)$$

According to the equation above the price ceiling  $P_t$  for each year is calculated based on the previous year’s price ceiling  $P_{t-1}$  adjusted by RPI minus the efficiency factor X. The efficiency factor X is set by the regulator. In practice the price ceiling may be adjusted using a correction factor Z. This correction factor accounts for the effect of exogenous extraordinary events affecting the utility’s costs.

The potential problems associated with the practical implementation of price cap regulation are connected to the price review procedure, to the commitment of regulating authority, to the quality and to the rules how to determine the X parameter (see e.g. Joskow, 2006; Jamasb and Pollitt, 2001).

### 2.3. *The Optimal Incentive Scheme*

It has been argued (see e.g. Laffont and Tirole, 1986, 1993; Joskow, 2006) that perhaps the optimal regulatory mechanism will lie somewhere between these two extremes i.e. between the pure cost of service (or rate of return) and pure price regulation. The regulation model will then have the form of either a profit sharing contract or a sliding scale mechanism (price that the regulated firm can charge is partially responsive to changes in realized costs and partially fixed ex ante). It has also been argued that more generally, by offering a menu of cost-contingent regulatory contracts with different cost sharing provisions, the regulator can do even better than if it offers only a single profit sharing contract (Laffont and Tirole, 1993). The basic idea of the optimal incentive scheme is to make it profitable for a firm with low cost opportunities to choose relatively high powered incentive scheme (e.g. price or revenue cap regulation) and a firm with high cost opportunities a relatively low-powered scheme (e.g. rate of return or cost of service regulation).

In the Laffont-Tirole model (1986) the firm chooses output and effort and after the costs are realized and observed, the planner rewards the firm according to the two observables, output and costs. Equivalently, the planner can ask the firm to reveal its true productivity parameter. Laffont and Tirole show that it is possible to construct such an incentive scheme that it induces the firm to tell the truth such that the level of effort is voluntarily optimally chosen by the firm. The incentive scheme is linear in costs and can be written as  $T(\beta, C) = s^*(\beta) + K(\beta)[C^*(\beta) - C]$ , where  $T$  is net transfer to the firm,  $s^*$  is ex ante reward,  $C^*$  is ex ante cost,  $C$  is realized costs,  $\beta$  is the productivity parameter and  $K^*(\beta) = \frac{\psi'[e^*(\beta)]}{q^*(\beta)}$ , where  $q^*$  is optimal output,  $e^*$  is optimal effort level and  $\psi'$  is marginal disutility of effort. Hence the reward depends on the announcement of the  $\beta$  and the ex post costs.

In practice the optimal allocation can be implemented by asking the firm to announce expected average costs and by making the transfer depend on the expected and realized average costs. The ex ante reward and the slope of the ex post bonus scheme decreases with the announced cost. Chu and Sappington (2009) consider a straightforward extension of Laffont and Tirole's model which allows the supplier to be able to reduce production more easily when cost

are initially high than when they are initially low. Chu and Sappington also show how this extended model admits many of the forms of optimal contracts that prevail in practice.

The theory of a menu of cost-contingent regulatory contracts with different cost sharing provisions has two related problems when the practical implementation comes to question. These problems are firstly the fact that the economic logic and the underlying mathematics involved in calculating the optimal menu are quite complex, and secondly the issue that principal must be able to specify the agent's entire disutility of effort function in order to calculate the optimal menu. Consequently the model has not been widely used in practice or even in empirical applications of the theory. Because of these reasons we use a simplified version of this model in our calculations presented below in Section 4.

#### *2.4. Simple Menu of Contracts*

Rogerson (2003) shows that dramatically simpler menus which are easy to understand and calculate and which have lower informational requirements, can capture a substantial share of the gains achievable by the fully optimal complex menu.<sup>6</sup> The problem for the principal (or regulator) is to find such a menu of contracts that minimizes his expected payment to the agent, subject to the constraint that all types of the agents accept a contract and produce the good. Rogerson uses the name "Fixed Price Cost Reimbursement" (FPCR) for a simple contract menu. Pure cost-reimbursement contracting corresponds to rate of return regulation and fixed-price contracting corresponds to price cap regulation. In his paper Rogerson shows that there is a unique optimal FPCR menu which solves the principal's cost minimization problem. In order to use this simple menu in real contracting situations, a principal would need to be able to have information on the cumulative distribution and density of costs if a cost-reimbursement contracts is used and the size of the efficiency gain that he believes would be induced by fixed-price contracting.

Rogerson also shows that considerably simpler menus with lower informational requirements can capture a substantial share of the gains achievable through using the fully optimal menu of contract.

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<sup>6</sup> See also Reichelstein (1992), Bower (1993), Sappington and Weisman (1996) and Gasmi et al. (1999) for studying the performance of simple mechanism in Laffont-Tirole type framework.

The procedure to determine FPCR menu is the following: first, the principal offers the agent a menu of contracts specifying price as a function of costs, and then the agent decides which contract to accept. A theoretical lower bound on the principal's expected price is the price equal to procurement cost in the case he had full information of the type of the agent. The principal would minimize his price by offering to pay an agent of type  $x$  a fixed price equal to  $x - k$ , where  $k$  denotes the resulting surplus. If the agent accepts this contract, he reduces costs to the efficient level (or first-best level) and earns zero profits. The upper bound on the principal's expected price is the price which guarantees that agent will always produce the good i.e. principal will offer the agent a cost-reimbursement contract in which the principal promises to pay the agent a price equal to the measured cost of production. Under such a contract, agent has no incentive to cost reduction and earns again zero profits. The problem of the principal is to find the "cut-off type"  $\theta$  so that his expected payment to the agent is minimized. The "cut-off type" is the highest type willing to accept the fixed price contract. Rogerson (2003) shows that if there exists an  $x^* \in [x_{\min}, x_{\max}]$ , which solves  $F(x^*) = kf(x^*)$  then  $\theta = x^*$ . However, if  $F(x) < kf(x)$  for every  $x \in [x_{\min}, x_{\max}]$  then  $\theta = x_{\max}$ .  $F(x)$  is the distribution function of  $x$  and  $f(x)$  is the density function of  $x$ .

### 3. Estimation for the efficiency costs

#### 3.1. Stochastic Frontier Analysis and Estimated Model Specifications

We use Stochastic Frontier Analysis for the estimation of efficient costs which we need in order to calculate the welfare effects of the different regulation regimes presented in section 2. The literature concerning Stochastic frontier analysis and its applications is quite large and we refer the reader to see e.g. Kumbhakar and Lovell (2000), Pitt and Lee (1981), Schmidt and Sickles (1984), Greene (2005a, 2005b), Farsi, Filippini and Greene (2006) (2005) and Kopsakangas-Savolainen and Svento (2008)).

We estimate four modifications of the basic random and fixed stochastic frontier models by using Cobb-Douglas specifications. In the following models (3-6) we assume that the deterministic cost frontier takes the log-linear Cobb-Douglas form and linear homogeneity of cost frontier is attained through dividing all prices by input price. In each model total annual costs per

kwh (C) is explained by distributed kilowatts (y), load factor (LF) number of customers (CU) and labour and capital prices ( $p_L, p_K$ ).

Our benchmark model is the basic random effects (RE) model. We assume the random terms  $v$  and  $u$  to be normally and half normally distributed. The inefficiency term ( $u$ ) is time invariant in this model specification. The first of the estimated models which accounts heterogeneity (observed) is the RE model extended by the inclusion of a heterogeneity component into the mean of the distribution of  $u_i$ . We call this model as the REH model. Model TRE is the random parameter version of the RE model. Now, however, the inefficiency term ( $u$ ) is time variant. In the TRE model a firm specific random constant term is used. This model specification is what Greene (2005a) calls the true random effects model. Last model estimated is the True fixed effect model (TFE) proposed by Greene (2005a).

The estimated model specifications are

RE model

$$\ln C_{it} = \alpha + \beta_y \ln y_{it} + \beta_{LF} \ln LF_{it} + \beta_{CU} \ln CU_{it} + \beta_L \ln p_{Lit} + \beta_K \ln p_{Kit} + \beta_t t + v_{it} + u_i \quad (3)$$

REH model

$$\begin{aligned} \ln C_{it} &= \alpha + \beta_y \ln y_{it} + \beta_{CU} \ln CU_{it} + \beta_L \ln p_{Lit} + \beta_K \ln p_{Kit} + \beta_t t + v_{it} + u_i \\ v_{it} &= N(0, \sigma_v^2), \quad u_i = N^+(\mu_i, \sigma_u^2) \\ \mu_i &= \delta_0 + \delta_1 \ln LF_{it}, \end{aligned} \quad (4)$$

TRE model

$$\begin{aligned} \ln C_{it} &= (\alpha + w_i) + \beta_y \ln y_{it} + \beta_{LF} \ln LF_{it} + \beta_{CU} \ln CU_{it} + \beta_L \ln p_{Lit} + \beta_K \ln p_{Kit} + \beta_t t + v_{it} + u_{it} \\ w_i &\sim N(0, \delta_w^2) \end{aligned} \quad (5)$$

TFE model

$$C_{it} = \alpha_i + \beta_y \ln y_{it} + \beta_{LF} \ln LF_{it} + \beta_{CU} \ln CU_{it} + \beta_L \ln p_{Lit} + \beta_K \ln p_{Kit} + \beta_t t + v_{it} + u_{it} \quad (6)$$

All models are estimated by maximum likelihood. Since there exists no closed form solution for the TRE model it is estimated using a grid for  $w$ . After a choice for  $w$  is made the model is

estimated using maximum likelihood. The global optimum is the one with the highest likelihood over the w grid.

### 3.2. *The data*

The data used in this study consists of a panel of 76 electricity distribution utilities in Finland. It covers the 6-year period from 1997 to 2002. The data, which is unbalanced panel data, is collected from the statistics of the Finnish Electricity Market Authority.<sup>7</sup> Distribution utilities which are owned by industrial enterprises are excluded from this study. The relative size of the distribution utilities varies significantly which may explain part of the quite large variations in costs.

Table 1 gives the summary of descriptive statistics of the variables used in this paper. We have used constant Euro prices by converting all money values to the year 1997 by using the retail price index. Costs (C) are expressed as average costs calculated as total annual costs per kWh delivered. This includes the delivery to the final customers and the delivery to the networks. The costs of losses are excluded because of the lack of reliable data. Annual output (y) is measured in Gwh and as can be seen from Table 1 it varies quite significantly since the range runs from very small local utilities to the relative large utilities operating on urban areas. Annual labour price  $p_l$  is calculated by dividing total annual labour cost by the average number of employees. The capital price  $p_k$  is calculated by dividing the annual capital expenditures by the value of capital stock. Total capital expenditure is calculated as residual costs. We have approximated the capital stock by the present value of the network. The present value of the network is calculated using the information of annual inventories and replacement value of the network. The price of the input power  $p_p$  is in most cases computational.<sup>8</sup> This is particularly the case when the distribution utility receives part of its delivered energy directly from the local generator and purchases only part of its total delivered energy. Load Factor (LF) is the ratio of the average load supplied during a designated period to the peak load occurring in that period, in kilowatts. Simply, the load factor is the actual amount of kilowatt-hours delivered on a system in

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<sup>7</sup> The data is available in the address [www.energiamarkkinavirasto.fi](http://www.energiamarkkinavirasto.fi)

<sup>8</sup> The input price is computed when distribution utility purchases only part of its delivered energy. The calculations are based on the market place payment, payment to the other companies' network and on the relative share of the received power and delivered power. It is important to correct the input price when only part of the delivered electricity is purchased. Otherwise it distorts the cost structure of these companies.

a designated period of time as opposed to the total possible kilowatt-hours that could be delivered on a system in a designated period of time.<sup>9</sup>

**Table 1**

Descriptive statistics (456 observations)

	Mean	Standard Deviation	Minimum	Maximum
Total annual costs (C)per kWh output (cents)	1.74	.40	.77	2.97
Annual output (y) in GWh	433.47	727.87	11.83	5825.90
Number of customers (CU)	27494	42784	1109	324197
Load Factor (LF)	0.499	.773E-01	.191	.866
Annual labour price ( $p_l$ ) per employee (1000€)	28.39	7.75	8.14	53.00
Capital price ( $p_k$ ) (1000€)	.103	.058	.020	.353
Price of input power ( $p_p$ ) per kWh	.36	.14	.09	1.06

<sup>9</sup> Utilities are generally interested in increasing load factors on their systems. A high load factor indicates high usage of the system's equipment and is a measure of efficiency. High load factor customers are normally very desirable from a utility's point of view. Using a year as the designated period, the load factor is calculated by dividing the kilowatt-hours delivered during the year by the peak load for the year times the total number of hours during the year.

### 3.3. SFA results

In Table 2 results for the estimations are presented.<sup>10</sup> The endogenous explained variable is total annual costs per kWh in 1997 cents. The linear homogeneity normalising price divider is the input power price  $p_p$ .

The first observation on the estimation results is that all coefficients of the frontier are highly significant<sup>11</sup> and have expected signs. Both price effects have positive signs in the all model specifications and the capital price effect is larger in absolute terms in all other models than in the TFE model. The high capital price estimates are understandable due to capital intensity of distribution networks. The sign of output ( $y$ ) estimator is negative in all specifications which is expected since the explained variable is total costs per kWh. As the distributed quantity increases the unit costs decrease up to the point of minimum efficient scale. Also the sign of the time estimate is negative. This indicates that there has been technological development which has decreased the total unit costs.

It is also notable that in the basic random effects model (RE) the constant term is considerably smaller than the corresponding averages from the REH specification. This being the case the basic RE model estimates the frontier to be down to the left compared to the extended RE model. The estimate of LF is significantly smaller in REH model than in other specifications. The other parameter estimates are relatively close to each other.

The variance parameter of the underlying distribution of  $u_i$ ,  $\sigma_{u_i}$  is estimated as .353 (see Table 3) in basic random effects model (RE). In the extended version of RE (REH) as well as in the randomized version TRE and TFE the counterparts are .150, .096, and .101. These points out that some of the variation in the inefficiency in the original RE model can be explained as heterogeneity. Based on this notification we can expect the estimated inefficiencies to diminish. According to BIC-criteria it seems that Greene's (2005a) true random effects model (model TRE in our case) fits the data best.

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<sup>10</sup> We have used LIMDEP 8.0 and 9.0 in estimations (see Greene, 2002, 2007).

<sup>11</sup> Except LF in the RE model.

**Table 2.**

Cost frontier parameters of models 3 – 6

	RE		REH		TRE		TFE	
	Coeff.	Std.er	Coeff	Std.er	Coeff.	Std.er	Coeff.	Std.er
Constant	-1.614	.272	-2.326	.126+07	-1.484	.049		
lny	-.647	.053	-.657	.050	-.703	.010	-.595	.018
LnCU	.584	.054	.603	.052	.644	.010	.569	.016
LnLF <sup>12</sup>	-.057	.050	-2.550	.675	-.032	.014	-.352	.033
lnp <sub>l</sub>	.297	.008	.288	.007	.300	.004	.445	.014
lnp <sub>k</sub>	.386	.009	.394	.009	.402	.003	.277	.012
T	-.014	.002	-.014	.002	.015	.001	-.017	.005
Scale par. for distr. <sup>13</sup>					.193	.003		
Log likelihood	389.40		413.52		416.79		302.60	
N	419		419		419		419	
BIC-criteria <sup>14</sup>	-736		-779		-791		-569	

<sup>12</sup> In the model REH this is refers to the third equation in model (4).<sup>13</sup> Scale parameter for distributions of random parameters.<sup>14</sup> BIC=-2\*logL+Q\*logN, where Q is the number of parameters.

In Table 3 we present statistics of inefficiency scores. The scores represent the percentage deviation from a minimum level that would have been incurred if the company had operated as best-practice (or cost efficient) based on our data.

These basic statistics clearly show that the models REH, TRE and TFE capture the firm specific heterogeneity into the cost frontier allowing the inefficiency distribution move to the left and become more concise. Also the distribution of the frontier in randomized specifications is more concise. Another clear observation is that TFE produces clearly different inefficiency scores than either the basic RE model or the random parameterized versions of the RE model. The difference among basic RE model inefficiency scores and those which TFE model produces can be explained by the clearly different model assumptions. First difference is the assumption of time varying inefficiency. Both RE and REH models assume constant inefficiency over time. The second difference is that in TFE correlation between firm specific effects and explanatory variables is allowed. This is not the case for the basic RE model. Third clear difference is that in the basic RE model any unobserved firm-specific differences are interpreted as inefficiency. Given that in electricity distribution a considerable part of the unobserved heterogeneity is related to network characteristics and is very likely beyond the firm's own control, the inefficiency estimates can be overestimated in RE models. All these three distinguishing assumptions among TFE and RE models can be observed from our inefficiency estimates. It is notable that the variance of the frontier in TFE model is rather big (.165) which shows that the model does not produce robust estimates for the frontier. This can be due to the rather short panel of the data or insufficient number of observations.

When we compare the basic random effect model to the random parameterized versions of RE model one observation to note is that mean inefficiency estimates clearly diminish. This can be explained by the fact that in the random parameterized models unobserved heterogeneity is not appearing as inefficiency. Also the inefficiency scores among TFE and random parameterized versions of the RE model differs somewhat. Even though the maximum inefficiency score is clearly smaller in TFE model the mean of inefficiency is higher in TFE model than in model TRE. However, the mean of inefficiency is clearly closer each other among the TFE model and the random

parameterized version of the RE model than among the basic RE model and its parameterized versions.

**Table 3.**  
Statistics of inefficiency scores<sup>15</sup>

	RE	REH	TRE	TFE
Minimum	.972-01	.419-01	.117-01	.575-01
Maximum	.782	.481	.450	.142
Mean	.327	.141	.737-01	.775-01
Std.Dev. of $E[u_i   \varepsilon_i]$	.130	.738-01	.470-01	.948-02
$\sigma(v)$	.068	.067	.032	.165
$\sigma(u)$	.353	.150	.096	.101

<sup>15</sup> On the estimation of inefficiency in the stochastic frontier models see Jondrow et. al (1982)

#### 4. SFA Based Welfare Effects of Different Regulation Schemes

Next we combine our empirical SFA cost inefficiency information to different regulation schemes and calculate changes in total social welfares related to each model specification and regulation scheme. In these calculations we use cost of service regulation as the benchmark.

We of course face a fundamental question here in the sense that the inefficiencies are naturally endogenous to the regulation scheme in use. In this sense our results are short term efficiency gains resulting from immediate change of the scheme in use. The endogenous long term effects escape our results because there is no data to be used for this test. However, the endogenous long term effects can safely be expected to strengthen the short term welfare gains calculated here.

The overall social welfare change is calculated as the sum of the change in producer and consumer surpluses. These changes in consumer and producer surpluses can be specified as follows. The change in consumer surplus can be written as the line integral.

$$\Delta CS_i = \int_{P_{Ci}}^{P_{Ni}} D^{-1}(Q_i) dQ_i, \quad (7)$$

where  $\Delta CS_i$  is the change in consumer surplus for customers of firm  $i$ ,  $P_{Ci}$  is the price of firm  $i$  under cost of service regulation,  $P_{Ni}$  is the new price of firm  $i$  under either the fixed price, menu of contracts<sup>16</sup> or simple menu of contracts regulation,  $D^{-1}$  is the constant elasticity inverse demand function with the elasticity value<sup>17</sup> of -0,35 and  $Q_i$  is distributed total energy of firm  $i$ .

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<sup>16</sup> We use the names “menu of contracts” and “fixed price” regulation for our applications of the incentive contract scheme and price cap regulation respectively.

<sup>17</sup> According to Törmä (1985) the price elasticity of electricity demand in Finland was approximately -0,35. Also the results by Andersson and Damsgaard (1999) and Willner (1996) support the assumption of inelastic demand.

The corresponding change in producer  $i$ 's surplus is:

$$\Delta PS_i = (P_{Ni}Q_{Ni} - C(Q_{Ni})) - (P_{Ci}Q_{Ci} - C(Q_{Ci})), \quad (8)$$

where the new volume  $Q_N$  is the supply and demand equilibrating quantity at the new price  $P_N$ <sup>18</sup> and  $C(Q_{Ci})$  are the costs resulting from cost of service regulation and  $C(Q_{Ni})$  are the new costs resulting from the alternative regulation scheme and based on our efficiency estimation results.

Therefore, the change of total surplus is

$$\sum_{i=1}^{76} (\Delta CS_i + \Delta PS_i) = \sum_{i=1}^{76} \left[ \int_{P_C}^{P_N} D^{-1}(Q_i) dQ_i + [(P_{Ni}Q_{Ni} - C(Q_{Ni})) - (P_{Ci}Q_{Ci} - C(Q_{Ci}))] \right], \quad (9)$$

The range of regulatory options in our welfare calculations can be illustrated as follows. Consider a regulatory process in which the firm's allowed price  $P$  is determined based on a component of the costs of the firm with the highest efficient costs,  $C^*$ , and on a component that is based on the firm's own realized costs  $C_i$ . The efficient cost of the highest type  $C^*$  is obtained from our SFA estimations. Then the allowed price is determined according to the following equation<sup>19</sup>:

$$P_{Ni} = aC^* + (1-a)C_i, \quad (10)$$

where  $a$  is the sharing parameter that defines the responsiveness of the firm's allowed price to the realized costs,  $t$  refers to time and  $i$  to the firm in question. In the case of fixed price contract (price or price cap regulation)  $a = 1$  whereas in the case of pure cost-

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<sup>18</sup> This assumption can be made because real time demand and supply must always equal each other in electricity distribution.

<sup>19</sup> In the equation (10) the efficient cost of the highest type  $C^*$  is calculated as a six year average based on the yearly estimation results and  $C_i$  is the average value of the firms realized cost.

of –service (or ROR) regulation, assuming that the regulator can observe the firm’s expenditures but not evaluate their efficiency,  $a = 0$ . The profit sharing contract (or contracts of menu on our case) emerges with  $0 < a < 1$ .

Laffont-Tirole (1986) and (1993) show that it is socially optimal for the regulator to offer a menu of contracts with different combinations of responsiveness parameters. This should drive the firms with low true cost opportunities to choose a high powered scheme ( $a$  close to 1) and consequently firms whose true (efficient) cost are high to choose a lower powered incentive scheme ( $a$  close to zero). In calculating the welfare effects we assume that each firm chooses the efficiency level which maximizes its profits.

### **Fixed price regulation**

In fixed price regulation the value of parameter  $a$  is equal to 1 for each firm and the  $C^*$  is efficient cost of the highest type firm obtained by utilizing the SFA results:  $P_{Ni} = C^*$ . Now the profit maximizing strategy for each firm is to produce at efficient costs. In the cost of service regulations (which acts as benchmark model in our welfare calculations) the value of parameter  $a$  is equal to zero for each firm and consequently firms produce at zero profits.

### **Menu of contracts regulation**

The game behind the contracts of menu regulation scheme in our application is as follows: first the regulator announces the regulation rule i.e. the rules according to which the value of parameter  $a$  is determined and then the firm decides what efficiency level to choose (and we assume that it chooses the efficiency level which maximizes its profits). The value of parameter  $a$  is defined as follows. The regulator orders the firms in descending order according to their firm specific efficiency scores obtained as a result of SFA estimations. The most efficient firm, i.e. the firm which has relatively small inefficiency score, is referred as  $eff^{\max}$ . The most inefficient firm based on its inefficiency score is referred as  $eff^{\min}$ . Now the value of parameter  $a$  for each firm  $i$  is resulting from the following equation

$$a_i = 1 - \frac{eff^i - eff^{\max}}{eff^{\min} - eff^{\max}}. \quad (11)$$

Using equation (11) we in fact rescale our efficiency results so that they vary from zero to one:  $0 \leq \text{eff} \leq 1$ . According to this announced rule for parameter  $a$ , for the most efficient firm the value of  $a$  is equal to 1 and thus this firm is allowed to set price such that it equals the efficient cost of the highest cost type. For the most inefficient firm the value of parameter  $a$  is equal to zero and consequently the price is equal to its realized costs and the firm earns zero profits. For firms between the most efficient and most inefficient firms the value of parameter  $a$  is bigger for the more efficient firms than to those which are more inefficient compared to the other firms. As a result of this rule the profit maximizing strategy for each firm is to produce at efficient costs.

### **Simple menu of contracts regulation**

The price determined by the simple menu of contracts is calculated directly according to the rule described in section 2.4. According to that rule the objective of the regulator is to choose the so called "cut-off type" such that the costs of the regulator are minimized if it should cover the procurement costs. The "cut-off type" is the highest type willing to accept the price cap contract. The cut-off type ( $\theta$ ) is found by solving the equation  $F(x^*) = kf(x^*)$  (then  $\theta = x^*$ ), where  $x$  is the agent's type,  $F(x)$  is the distribution function of  $x$  and  $f(x)$  is the density function of  $x$ . In the simple menu of contracts the firm can choose between either price cap or cost of service regulation. Now each firm more or as efficient as the cut-off type firm maximizes its profits by choosing price cap contract (parameter  $a$  equal to 1) and the best strategy for rest of the firms is to choose cost of service regulation (parameter  $a$  equal to zero).

Based on these regulation schemes we are able to calculate the total welfare changes using our firm specific results on efficiency improvement potentials. The results for all four SFA model types (see equations 3-6) are presented in Table 4.

**Table4.**

Change in average yearly welfare (TS =PS + CS), Cost of Service regulation<sup>20</sup> as benchmark, million€

SFA model	Fixed Price			Menu of Contracts			Simple Menu of Contracts		
	ΔTS	ΔPS	ΔCS	ΔTS	ΔPS	ΔCS	ΔTS	ΔPS	ΔCS
RE	177,8	240,9	-63,1	194,4	150,0	44,4	144,43	70,6	73,9
REH	49,6	234,2	-184,5	61,5	184,1	-122,6	25,9	10,4	15,6
TRE	5,6	239,7	-234,1	25,8	163,6	-137,8	6,4	4,5	1,9
TFE	8,3	235,5	-227,2	14,7	207,4	-192,7	3,6	1,4	2,2

Changing the regulation scheme from cost of service to whatever other regulation regime presented above results in welfare improvement. The change in welfare is quite significant at least in the case of RE and REH based SFA models. If the potential for efficiency improvements are evaluated according to RE model the resulting welfare change is 33,1% from the total value of distribution in fixed price regulation, 36,2% in the menu of contracts and 26,9% if the new regulation is based on the simple menu of contracts. The corresponding percentage changes in welfare based on REH model are 9,2% for the fixed price, 11,5% for the menu of contracts and 4,8% for the simple contracts of menu. Notable is, however, that if the potential to improve efficiency is based on either TRE or TFE models the resulting changes in welfare are much more smaller. The TFE model fails to estimate the frontier distribution robustly (see Table3 for the variance of the frontier error term) and is thus not very interesting here. Interesting is that randomized modeling of heterogeneity (TRE) reduces the potential welfare gains substantially. Part of this can be explained by the fact that the firms in question are local monopolies and it is possible that they do not put maximum effort to the efficiency and consequently part of the time invariant inefficiency (now assumed to be due to firm specific unobserved heterogeneity) may be due to inefficient management and hence the model TRE may underestimate the inefficiency scores. This results stresses the need to model heterogeneity correctly in SFA models. From our welfare results point of view this

<sup>20</sup> We have used 4% for the r in cost of service regulation (see equation (1)).

indicates that the welfare changes resulting from TRE models can be kept as a lower bound on the longer term welfare improvements potentiality.

Another observation from the welfare results is that there is clear difference how different regulation schemes divide welfare to producers and consumers. In the case of menu of contracts both the producer surplus and consumer surplus increase if the efficient levels of the firms' costs are determined by using the values of random effects (RE) model. If the possibilities of the efficiency improvements are determined according to the REH, TRE or TFE models producer surplus clearly increases but the consumer surplus decreases. This is due to fact that the efficiency improvement possibilities according to the REH, TRE, and TFE models are smaller than according to the model RE and consequently the efficient cost of the highest type  $C^*$  (see equation 10) is quite high. This raises the average level of the allowed price and hence removes the welfare from the consumers to the producers. This result is even more clear in the case of fixed price regulation where all firms are allowed to set the price equal to the efficient cost of the highest type (parameter  $a$  is equal to 1 for every firm). The only regulation scheme which improves both producer and consumer welfare regardless of the model used in efficiency estimations is the simple menu of contracts. However, the overall welfare improvement is smaller than resulting from the fixed price regulation or menu of contracts regulation. If the regulator is interested only in maximising total welfare it should choose menu of contracts regulation. In the case where the regulator is interested more on consumer welfare and wishes to see lower overall prices it should set the regulation according to the simple menu of contracts. In many countries during the restructuring process of electricity industry the main role of the electricity distribution network is determined to behave as a neutral market place for competitive parties of the industry. Based on this view it might be that the regulator is more interested on the consumer welfare than to provide possibilities to gather higher profit by the local electricity distribution monopolies. Regardless of the target of the regulator it is clear that our results support the theory and changing the regulation method of network prices from traditional cost of service regulation it is possible to considerably improve social welfare.

## **5. Conclusions**

The purpose of this study was to analyze whether it is possible to improve social welfare by changing the regulation scheme of electricity distribution and how the regulator can utilize information on firm specific cost efficiency obtained by SFA models in regulatory process. A great deal of theoretical research has been conducted concerning different regulation methods but the connections of the regulation theory to the real regulatory processes have been seen problematic. In this paper we combine the theory of different regulation schemes to the firm specific cost information of electricity distribution utilities obtained by using various Stochastic Frontier models. According to our results – consistently with the theory – fixed price regulation solves the problem of moral hazard and welfare improves if we move from cost of service regulation to the fixed price regulation. However, in fixed price regulation the problem of adverse selection remains unsolved. According to theory the menu of contracts regulation should solve both the moral hazard and adverse selection problems. Our empirical results support this. Welfare can be improved by removing from the pure cost based regulation to the menu of contracts regulation. Notable is that welfare increases in all model specifications. However there are significant differences among regulation schemes on how improved welfare is distributed to consumers and producers. The only regulation scheme which improves both producer and consumer welfare regardless of the model used in efficiency estimations is the simple menu of contracts.

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