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The welfare effects of different pricing schemes for electricity distribution in Finland

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Abstract

The main components of electricity prices can be divided into the wholesale price, the price of network operations and taxes. Even if the wholesale price is determined efficiently, total welfare can be significantly disturbed if network operations are priced inefficiently. In this study, we calculate network prices based on four alternative methods. These are marginal cost pricing, Ramsey pricing, FDC-pricing and optimal two-part tariffs. The welfare effects on the prevailing pricing system are compared. We show that potentially significant improvements in welfare can be achieved by using marginal cost prices or optimal two-part tariffs. Also Ramsey pricing indicates that prevailing prices are inefficient.

JEL: Q43; D42; I39; L94

Keywords: Distribution price of electricity; Optimal two-part tariffs; Welfare improvements

1. Introduction

The distribution pricing currently used in Finland aims to collect the Local Distribution Company's (LDC's) procurement cost resulting from wholesale transactions and embedded costs that include the return on investment. While the wholesale markets in Nordic countries are reasonably competitive with prices reflecting of marginal generation costs (Amundsen et al., 1998; Hjalmarsson, 1996), the LDC's distribution rates deviate from marginal distribution costs. To test whether such deviations are optimal with the least distortions, this paper answers the substantive policy question: "Can the Finnish distribution pricing be improved by applying well-known schemes in the efficient pricing literature?"

Three basic assumptions underlie the idea of efficient prices. Efficient prices are those that lead to the highest possible level of welfare.[1] If we move from an inefficient price to a more efficient price, potential welfare rises for all individuals.[2] If there are two regulated firms from which one must break even out of its own sales revenues but the other is not required to break even, the potential welfare of society cannot be higher in the first case.

In this paper the term distribution refers to the distribution network,[3] which is a natural monopoly with conjectural variation close to unity. The role of a regulator is hence crucial in order to prevent distribution companies from exploiting market power. The main objective of the regulator is to maximise social welfare by choosing efficient pricing schemes. In reality this should be done, at least in most of the countries, subject to the breakeven constraint. Furthermore, the indefinite regulatory rule used in Finland has led to a situation where distribution prices differ largely between companies,[4] which raises the question of whether they can be justified by differences in costs.

The four alternative pricing schemes that we numerically solve are the first best optimum prices based on marginal costs, prices based on Ramsey pricing, optimal

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[1] Welfare is defined as the sum of consumer surplus and producer surplus.

[2] This is possible if the "winners" of the price change compensate to the "losers" of the price change.

[3] For further explanation of terms, see e.g. Román et al. (1999).

[4] In 1998 distribution prices varied from 1.38 to the 3.26 c/kWh in 0.4 kV networks.

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Coasian two-part tariffs and prices based on the fully distributed cost pricing (FDC).

Section 2 introduces different pricing methods and theories behind them. Section 3 discusses the empirical basis and data of this study. Calculations are presented in Section 4, and the last section concludes the paper.

2. Four alternative pricing schemes

2.1. Marginal cost pricing

We use marginal cost pricing as one possible alternative to price distribution. Marginal cost pricing maximizes social welfare but may violate the LDC's revenue requirement. Even though the revenue requirement may be violated, many papers argue that it is still the most efficient pricing scheme (see e.g. Laffont and Tirole, 1994). By setting prices efficiently, a social planner can thus maximise ''welfare'', which then can be distributed as the society pleases.

In practice, however, many countries expect also regulated companies to at least cover their costs. Clearly this means that in the case of a natural monopoly, marginal cost pricing is not a feasible pricing method. The society is willing to deviate from the first best prices, even though this results in the decline of overall welfare. Next, we review three pricing methods that fulfil the requirement of breaking even.

2.2. Ramsey pricing

Ramsey pricing is a second best solution for linear rates since it covers costs such that the overall welfare decreases as little as possible. Given the breakeven constraint for the firm, the efficient public utility pricing can be formulated as follows:

> Given a regulated firm that must break even and which is serving M markets, the efficient set of prices $P_1, P_2, \ldots, P_M$ is the one that maximises total surplus subject to the constraint that the firm earns zero profit (Baumol and Bradford, 1970; Baumol, Panzar and Willig, 1982).

Here we concentrate on uniform prices[5] and maximise total surplus subject to the breakeven constraint. This means that we derive prices where producer surplus is set to zero. If we want the firms to break even with as little disturbance in the markets as possible, what types of price changes are necessary? We should impose high mark-ups in the markets that are least influenced by them, and low mark-ups in the markets that are more easily disturbed. That is, we should aim to increase prices in markets where price elasticity of demand is relatively low and decrease prices in the markets where demand is more elastic. The mark-up in each market is given by

$$\text{Mark-up} = (P_i - C_i)/P_i = \lambda/\varepsilon_i, \tag{1}$$

where P_i is the price, C_i the marginal costs, and ε_i the price elasticity of demand.

In the equation above λ adjusts the mark-ups in all markets uniformly to the point where the firm breaks even. This is a well-known inverse elasticity rule (IER)(Ramsey, 1927).[6] Generally speaking this means that for any pair of markets served by a regulated firm, the percentage deviations from the marginal cost, weighted by the price elasticity of demand, should be equal in both markets. The numerical solutions to the Ramsey prices can be very difficult to compute in many cases. To make calculations easier we assume that the price elasticity of demand in each market is constant.

The mark-up fraction λ is set such that total revenue equals total costs:

$$\sum_{i=1}^{M}(P_i - C_i) * Q_i - F = \sum_{i=1}^{M}\frac{\lambda k_i}{\varepsilon i}\left(\frac{C_i\varepsilon_i}{\varepsilon_i - \lambda}\right)^{1-\varepsilon_i} - F = 0. \tag{2}$$

This means that one simply sets prices with different values of λ until a value of λ is found which satisfies the equation $producersurplus = F$. In Eq (2) F refers to the fixed costs, Q_i to the quantity distributed, M to the number of markets and k_i is a scaling term.

2.3. Optimal two-part tariff

Another possible pricing scheme is to use nonlinear tariffs, which enables us to take taste differences into account. One form of such tariffs is a two-part tariff, which is actually marginal cost pricing with fixed fees. It maximises social welfare and satisfies the LDC's revenue requirement (Littlechild, 1975; Brander and Spencer, 1985; Panzar and Sibley, 1989; and Pang-Ryong, 1997).

The social planner has, however, two fundamental problems when choosing the welfare maximising two-part tariffs. First, he has to choose the tariff such that it enables the firm to break even and second, the tariff structure should be such that the consumer is willing to participate in the market. As early as Coase, 1946 suggested a special type of a two-part tariff as a solution to this problem:

> ''Set marginal price (usage charge) equal to the regulated firm's marginal cost and set the entry fee at

[5] Uniform prices are prices which do not vary with the level of consumption.

[6] Because the derivation as well as the formula for Ramsey pricing is well known we refer the reader to e.g. Brown and Sibley (1986) to see more detailed description of this pricing scheme. See also Berry (2000) and Horowitz and Seeto (1996) for using Ramsey pricing in electricity industry.

a level sufficient to cover the firm's total costs when it is paid by each consumer''.

Formally the optimal two-part tariff structure can be solved as

$$R(Q) = E + P * Q \tag{3}$$

subject to $R(Q) = C(Q)$.

This means that the consumer pays a fixed entry fee E and usage charge P such that revenue $R(Q)$ just covers the costs $C(Q)$. He can avoid paying the entry fee only if he does not buy a positive amount of the good.

This pricing mechanism leads consumers to buy exactly the same amount they would buy under straight marginal cost pricing. The only difference is that now an amount equal to the fixed costs is transferred from consumers to the firm, which can be seen just as a pure distributional effect (Brown and Sibley, 1986; Naughton, 1989; Wilson, 1993). The deadweight loss is thus eliminated. This kind of a pricing procedure is, however, useful only if we are assured that none of the consumers will drop out of the markets as a result of the price change. Because in the case of electricity distribution, demand is known to be very inelastic (see e.g. Borenstein, 2002) it is justified to assume that every consumer will participate in the market.

2.4. FDC pricing—allocation of common costs

In many regulated industries the requirement of cost-based pricing forces the pricing scheme to deviate from the first best solution. In this study, we use the method of fully distributed costs (FDC) as an alternative pricing method. FDC rates do not follow the marginal cost or Ramsey pricing principle. Even though it is the least efficient among the four alternatives, it is relatively widely used in practice.

The objective of FDC pricing is to allocate common costs ''somehow'' and then set prices in such a way that each service just barely covers its fully distributed costs (Braeutigam, 1980). It is typical of FDC pricing that the allocation of common costs is done without considering the economically relevant criteria. Here, we have allocated the common costs according to the relative output method, which means that the allocation is based on each service's share of the total output of the firm. Formally

$$\mathrm{FDC}_i = \text{Attributable cost of } i + (Q_i/Q_1 + Q_2 + \cdots + Q_m) * \text{ common costs.} \tag{4}$$

Next we briefly describe the data and in Section 4 we report the results obtained by using these four methods.

3. The data

We use data from 1998. It has been obtained from the Finnish Electricity Market Centre.[7] It consists of 111 electricity distributors. The original data does not give any specific information about how each cost category is divided between 0.4, 6–70 and 110 kV networks.[8] Information on the average distribution costs, company by company, is nevertheless included in the original data. The allocation to variable costs and fixed costs is done based on the opinion of the distribution companies. Variable costs are costs of losses, variable operation costs, payments to the other networks and some other costs.[9] Fixed costs consist of maintenance costs, capital costs and some other costs.[10] Companies are divided into three groups named A, B and C. Group A includes companies that operate only in the 0.4 kV network. Group B is composed of companies that have activities in the 0.4 and 6–70 kV networks, while group C includes companies that operate in the 0.4, 6–70 kV as well as 110 kV networks.

In calculations for the 0.4 kV network, we use price elasticity numbers estimated from Swedish data (Andersson and Damsgaard, 1999). Calculations for the 6–70 kV network are based on elasticity values estimated from Finnish data (Törmä, 1985).[11] Perhaps the most problematic category of costs was the transmission losses. For a more specific explanation of how costs of losses are allocated between 0.4, 6–70 and 110 kV networks the reader is referred to the appendix.

4. Empirical results

In this section, we present the prices and resulting welfare changes calculated by using: (1) marginal cost prices, (2) Ramsey prices, (3) fully distributed cost prices and (4) coase optimal two-part tariffs. Welfare calculations concern only the distribution level and thus 110 kV networks are excluded.

4.1. Prices

We report marginal cost prices, Ramsey prices and optimal two-part tariffs in Table 1. In order to make

[7] Finnish Electricity Market Centre is a agency that gives advise to consumers, compiles and compares price information of electricity companies and gives general information about Finnish electricity markets.

[8] This is the classification that electricity companies use.

[9] For example variable salary payments.

[10] For example fixed salary payments.

[11] Also the results from other countries support inelastic demand. According to Filippini (1999) the price elasticity of electricity demand in Switzerland was –0.3. According to e.g. Borenstein (2002) electricity demand can from time to time be even more inelastic.

Table 1
Prevailing prices in 1998 and resulting prices when marginal cost pricing, Ramsey pricing, optimal two-part tariffs and FDC pricing are used (c/kWh)

	Prices in 1998		Marginal costs prices		Ramsey prices		Two-part tariffs		FDC-prices	
	0.4 kV	6–70 kV	0.4 kV	6–70 kV	0.4 kV	6–70 kV	0.4 kV	6–70 kV	0.4 kV	6–70 kV
A	2.108		1.192				2.034		2.281	
B	2.167	1.059	0.973	0.958	1.843	2.498	2.354	0.973	2.034	2.020
C	2.286	1.004	0.762	0.736	1.530	2.145	1.845	0.769	1.697	1.671

Note: A refers to the companies which have distribution only in the 0.4 kV network, B to the companies which have distribution in 0.4 and 6–70 kV networks and C to the companies which operate in 0.4, 6–70 and 110 kV networks. FDC is abbreviation of Fully Distributed Costs. In order to make comparison between different pricing methods, optimal two-part tariffs are presented here as the average price per kWh. The real two-part tariff structure is presented in Table 2.

comparisons, we also report prices from 1998. All prices are average prices.[12] In Table 2 we describe optimal two-part tariffs in more detailed.

As reported in Table 1 real prices in 1998 have been quite near to the prices suggested by the average two-part tariffs. From Table 2 we see the real tariff structure of two-part tariffs. They are constituted from a fixed entry fee and from a usage charge, which is equal to the marginal costs. Thus even though the average prices of two-part tariffs are close to the prevalent prices it does not evidently mean that prevalent prices are optimally determined. A clear welfare improvement would result if the prevalent price structure were changed to the optimal two-part tariffs as can be seen from Table 3. The real prices in the 0.4 kV network have been quite near also to the prices suggested by FDC pricing method. This is not surprising since FDC pricing, even though it is not efficient from an allocation perspective, is widely used in reality. It is interesting that the prices in the 6–70 kV network have been perhaps unexpectedly near to the first best optimum prices. Both FDC prices and Ramsey prices suggest considerable price increase in the 6–70 kV network.

Optimal two-part prices are calculated such that each consumer pays a fixed entry fee independently on the quantity consumed and in addition a constant usage charge equal to the marginal cost of the distribution. The level of the fixed entry fee is chosen in such a way that it covers the fixed costs of the company. It is important to notice that this kind of price structure can be used only if we can be certain that the size of the fixed fee does not cause customer disconnection. In the case of the electricity market, we know that demand is very inelastic and thus we may assume that this kind of problem does not exists. According to the optimal two-part prices and as well marginal cost prices a substantial reduction in 0.4 kV unit prices should be implemented.

Table 2
Optimal two-part prices

Company type	Entry fee (EURO)	Usage charge in 0.4 kV (c/kWh)	Usage charge in 6–70 kV (c/kWh)
A	149.86	1.151	
B	144.81	0.984	0.969
C	131.49	0.793	0.765

Table 3
Welfare changes (million EURO)

Pricing method	Change in consumer surplus	Change in producer surplus	Change in total surplus
Marginal cost pricing	477.21	−416.39	60.82
Ramsey pricing	40.79	−19.58	21.21
Optimal two-part tariff	−19.54	80.36	60.82
FDC-pricing	25.88	−32.67	−6.79

4.2. Welfare effects

The effects of the price changes with respect to the welfare are calculated by using the prices from 1998 as a reference. The overall welfare change is calculated as the sum of the change in producer and consumer surplus.[13] The welfare changes are reported in Table 3:

Changing the prevalent pricing methods to the marginal cost pricing would result in a significant welfare improvement. The producer surplus decreases but the total effect is clearly positive since the increase in the consumer surplus is bigger than the producers' decrease.

The Ramsey pricing seems to be a better method than the prevalent one. However, as in the case of marginal cost pricing the producer surplus decreases and thus the implementation might be opposed by producers. The

[12] Average prices are calculated as arithmetical means. All companies in one group have equal weight.

[13] See e.g. Brown and Sibley (1986) for formal description of consumer and producer surplus.

welfare improvement is a little less than one-third of that obtained by marginal cost pricing.

According to the theory and also our results the welfare improvement of the optimal two-part tariff is exactly the same size as the one obtained by marginal cost pricing. Even though the overall effect is equal in size it comes from clearly different sources, since in the two-part tariff structure the consumer surplus decreases and producer surplus increases.

The fundamental feature that FDC pricing does not ensure an efficient allocation shows up in our results since welfare would decrease if we shifted from the prevalent price structure to FDC pricing. As in the cases of marginal costs prices and Ramsey prices, the producer surplus decreases and consumer surplus increases. Now the decrease in producer welfare is, however, bigger than the increase in consumer welfare and hence the overall effect is negative.

By changing the pricing of network operations it is possible to considerably improve social welfare. The first best optimum prices, Ramsey prices and optimal two-part prices improve welfare, whereas moving to the FDC prices decreases welfare as measured by the consumer and producer surpluses. The producer surplus decreases in all the alternatives except with the optimal two-part tariff. The increase in the consumer surplus compensates for this decrease in the case of marginal cost pricing and Ramsey pricing. Welfare improves most and equally in the case of marginal cost pricing and the optimal two-part tariff system. The improvement, on average, is 21,20 Euro per customer. Because marginal cost pricing may not be possible in practice[14] the best pricing method according to our results is the optimal two-part tariffs.

5. Concluding remarks

The purpose of this study was to analyse whether it is possible to improve social welfare by changing the pricing principles of distributed electricity. Network companies have remained regulated monopolies[15] also after the wholesale markets for electricity have been liberalised. A great deal of research has been aimed at facilitating efficient pricing and the operation of the wholesale markets for electricity. The share of distribution price in the total electricity price is, however, equal in size to the wholesale price and it can thus significantly disturb the total efficiency. Because network services are regulated, it has perhaps not been of primary interest for competing companies to ensure efficient operation in this area as well.

We showed that it is possible to improve welfare quite markedly if the existing pricing principles are changed to more efficient ones. The resulting welfare is highest if we use the first best prices based on marginal costs or optimal two-part tariffs. Because pure marginal cost prices may result in negative profits that would require some form of compensation, which in turn can be politically difficult, we suggest that the distribution prices should be based on optimal two-part tariffs. Ramsey pricing also indicates an improvement in welfare but at the same time it suggests a considerable price rise in the 6–70 kV networks. This pricing impact on the downstream industries may be large and thus the overall welfare changes in that case may be controversial.

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Appendix A. Calculation of losses

As a starting point we assume that the relative share of total cost of losses of different voltage levels of distribution is similar to that found in Denmark (Olesen and Mortensen, 1992; DEF, 1995; Danish Economic Council (DAE), 1999). We have used Danish values because the cost of losses in Finnish data is stated as an average number over all different voltage levels of distribution. First, we have divided distribution companies into three groups, A, B, and C. Group A consists of distributors that operate only in the 0.4 kV network.[16] From the original data we know the average costs of losses, p/kWh. This is referred as Xp. Thus, in the group A the costs of losses in the 0.4 kV network are the average value of losses.[17]

Companies that have distribution in 0.4 and 6–70 kV networks belong to group B.[18] We have used the cost of distribution of group A as a reference value for the distribution in the 0.4 kV network. We assume that this group operates equally efficiently in this low voltage network so that the average price (X_p) over companies is the same 0.183 c/kWh. Additionally, we know that the real average costs of losses in group B were 0.163 c/kWh.

[14] Because of a breakeven constraint.

[15] The present regulatory system in Finland, however, appeared to be inefficient which raises the question of more efficient pricing methods as a base of the regulation.

[16] There are 16 companies in group A.

[17] average value over companies was 0.183 c/kWh.

[18] There are 76 companies in group B.

Table 4
Reference values for the different groups of companies

	X_p	Y_p	K_p
Firm type A	0.183		
Firm type B	0.183	0.112	
Firm type C	0.162	0.100	0.056

Table 5
Relative values of companies

	X_p	Y_p	K_p
Firm type A	1	0	0
Firm type B	1	0.645	0
Firm type C	1	0.616	0.345

Next, we can calculate the average costs of losses, denoted by Y_p, in the 6–70 kV network over the companies by using the following formula:

$$(X * X_p) + (Y * Y_p)/\text{total quantity} = 0.163. \quad (A.1)$$

The resulting value of Y_p is 0.118 c/kWh.

The last group, C, includes companies that have distribution in all levels of networks, i.e. 0.4, 6–70 and 110 kV networks.[19] The calculation method for prices is similar to that for group B. However, now we assume that the companies in group C have operated 11.5% more efficiently in the 0.4 kV network than the firms in groups A and B, and 15.5% more efficiently in the 6–70 kV network than the firms in group B. We use these prices as reference values and calculate the average costs of losses in the 110 kV network. Additionally, we know that the real average costs of losses in group C were 0.128 c/kWh.

Now we can calculate the costs of losses, referred to as K_p, in the 110 kV network by using the formula:

$$(X * X_p) + (Y * Y_p) + (K * K_p)/\text{total quantity} = 0.128. \quad (A.2)$$

The resulting reference value of the costs of distribution in the 110 kV network is 0.056 c/kWh.

The reference values of the different company groups are summarised in Table 4.

Next we can calculate the relative value to the different types of companies by normalising the value of X_p equal to 1 (Table 5).

The next step in the calculation is to define the firm-specific costs of distribution losses in networks with different voltage levels. Group A is very clear since it has distribution only in the 0.4 kV network, and thus the cost of distribution losses of this network are exactly the same as they are in the original data. When we calculate the costs of distribution losses to the individual firms in groups B and C we just use the relative values and total costs of losses by using the following formulas in order to find out the firm-specific value of X_p and thus consequently the firm-specific values of Y_p and K_p:

For group B:

$$(X * X_p) + (Y * 0,0.645Xp) = \text{total costs of losses.} \quad (A.3)$$

For group C:

$$(X * X_p) + (Y * 0.616X_p) + (K * 0.345X_p) = \text{total costs of losses.} \quad (A.4)$$

By solving these equations we can define firm-specific costs of losses at networks with different levels of voltage.

[19] There are 19 companies in group C.

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