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The Norwegian aluminium industry, electricity prices and welfare

by

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Abstract

This paper presents a partial equilibrium analysis of the changes in the the Norwegian aluminium industry which would follow if the industry was faced with higher electricity prices. The industry is modelled as an imperfectly competitive industry, where the producers recognize their market power, and where the firms produce products which are imperfect substitutes in demand. The paper provides an empirical implementation of the model, using panel data for the Norwegian producers. The final part of the paper presents results from policy simulations on the model. These simulations show that an increase in electricity prices to long term production costs would essentially eliminate the Norwegian activity in this industry. Nevertheless, the value of the reduced electricity consumption in the aluminium industry, if this policy is introduced, is more than sufficient to compensate for the reduction in operating surplus and pay the workers if they are unable to find alternative jobs. The paper also provides an analysis of the scope for strategic trade policy in this industry.

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Contents

1 Introduction

This paper is a contribution to the analysis of the welfare consequences of the cheap electricity sold to the energy intensive industries in Norway. Bye and Strøm (1987) discussed this question, and concluded that as a conservative estimate, there will be generated a consumer surplus around 1500 millions Nkr. (1984) if the energy intensive industries in Norway were to pay the same price as the rest of the economy for their electricity consumption. However, the welfare analysis was based on a very rough model for the industries involved, both in terms of the industries' demand conditions and their cost structure. The primary purpose of this paper is to provide a more detailed analysis of one of the industries which currently receives cheap electricity, the Norwegian aluminium industry. The policy simulations presented in this paper confirm the conclusion that there would be considerable welfare gains if the aluminium industry was faced with the same electricity price as the rest of the Norwegian economy.

This paper is divided into three parts. Firstly, the paper presents a theoretical model for a market in intermediary inputs, where there are few suppliers, but many firms demanding this intermediate input. The model uses an address approach (see e.g. Lancaster (1979)) in order to model the demand side of this market. The second part of this paper presents an empirical implementation of this model for the aluminium industry, using panel data for the Norwegian part of this industry. These panel data makes it possible to estimate the degree of substitutability on the demand side for the different products sold in this industry. Thirdly, the implemented model is used to analyze the primary question addressed by this paper; the consequences of altering the electricity prices for the Norwegian firms in the aluminium industry.

The modeling approach chosen draws on the recent developments in the theory imperfect competition. The model is one of monopolistic competition in imperfectly substitutable goods, including oligopolistic elements. Empirical models for policy analysis in the context of imperfectly competitive industries constitute a small, but growing literature (see e.g. Dixit; 1986, Baldwin and Krugman; 1986, Venables and Smith, 1987. Daltung et al., 1987, have provided two Norwegian examples). So far, these kinds of models has not been estimated econometrically. Instead, parameter values have typically been picked from literature studies or chosen more or less arbitrary. The rest of the model has been numerically determined based on a data set from a single year. In this paper, the central parameter of the model has been estimated using panel data for 14 years (1972-85) and 8 Norwegian firms. The model used in the econometric part of this analysis is consistent, and in fact draws heavily on the theoretical model employed in this paper. The rest of the model was based on a panel data set for 4 years. Hopefully, this implies that the numerical values involved in this analysis can be given a bit more weight than some of the previous works in this field [1].

It is a widespread belief that the aluminium industry sells its production of primary aluminium as one homogeneous good. If that is the case, the theory of competition in differentiated products would not be appropriate for this industry. However, there are several pieces of evidence which reveal that this cannot be the case. Figure 1 displays the development of aluminium prices as they are quoted at the London Metal Exchange, the Norwegian trade statistics and U.S.producers prices quoted by "Metals Week". The figure reveals that there are considerable differences between the price quoted at the London Metal Exchange, and the prices obtained for Norwegian and U.S. producers of aluminium. Secondly, the micro data show that the prices per ton aluminium obtained for different Norwegian firms vary by more than 20 percent as a four year average. Hence, data seem to expose that aluminium is not an entirely homogeneous product, and hence Norway is not bound to take prices as given. Aluminium is sold at different levels of fabrication (bars, sheets, rods, tubes and so forth), in different degrees of purity and under different contractual agreements (spot market vs. long term contracts etc.). However, the empirical results presented below show that the different variants of aluminium are close substitutes, as one would expect. Hence, the Norwegian producers face a high price elasticity of demand.

The rest of this paper is organized as follows: Section 2 provides a brief description of the Norwegian aluminium industry and its export markets. Section 3 spells out the theoretical model which is applied in the analysis. The model gives a detailed description of both the demand side and the supply side in this industry, and takes into consideration that aluminium is demanded as an intermediary input into other industries. In section 4 the results from the empirical work are presented. Section 5 contains the results of the policy simulations on this model. We investigate different policy questions under alternative assumptions with respect to capacity and entry conditions for the foreign producers. The section contains an extensive discussion of the consequences of changes in electricity prices, including the corresponding welfare effects. Section 5 also investigate the scope for strategic trade policy in this industry. In the last section the results are summarized and some shortcomings are pointed out.

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[1] See e.g. Daltung et al., (1986), who concluded that the policy implications from their work remain almost entirely ambiguous due to the poor quality of the data set they employed.

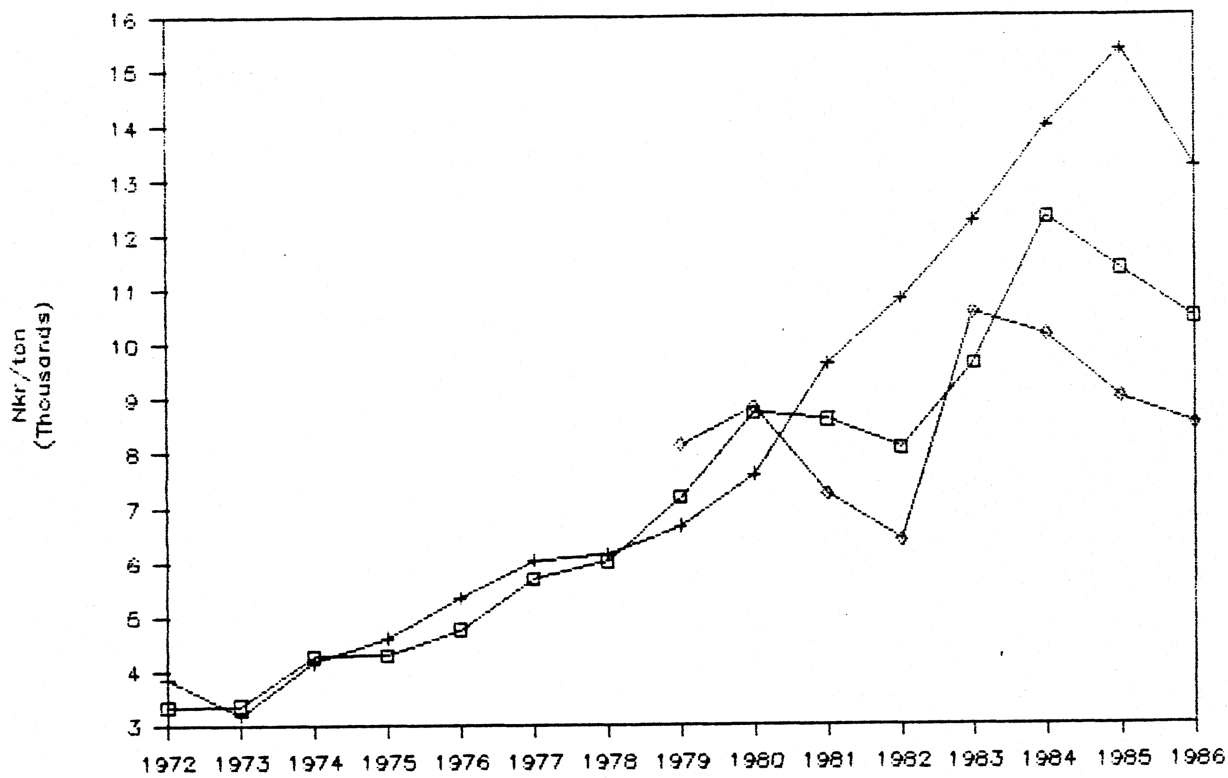

Figure 1: Prices of aluminium 1972-86. The squares refer to Norwegian export prices, the crosses correspond to U.S. producer prices and the diamonds refer to the prices quoted at the London Metal Exchange. Sources: Norwegian External Trade Statistics (NOS) and World Metal Statistics.

2 The aluminium industry

2.1 The Norwegian producers

There are currently seven Norwegian production units in the aluminium industry. Four of these units belong to Hydro Aluminium, two belongs to the company Mosal, and Husnes is an independent producer [2]. One production plant, Tyssedal, was closed down in 1983. There was a merger between Hydro Aluminium and Årdal og Sunndal verk (ÅSV) in 1986.

The average price paid for electricity was 0.08 Nkr/kWh (deflated to 1984) for the period 1983-86. However, there was more than 40 percent difference between the minimum and maximum price charged. The aluminium industry buys almost all its electricity according to long term contracts, in contrast to other parts of the energy intensive industry which buy a substantial part of the electricity on the "spot-market".

Almost 90 percent of the Norwegian aluminium production was exported (average 1983-86). 32 percent of the exports went to West-Germany, whereas 18 percent went to U.K. (World Metal Statistics, 1988). The rest of the

[2]Husnes is registered as an independent enterprise. However, Hydro and Alu-Suiss own 50 percent of the shares each. Hence, it seems ambiguous whether or not one should treat Husnes as an independent producer.

Norwegian exports was distributed more or less evenly to other European countries. Almost nothing was exported outside Europe. Import from Norwegian producers amount to about 18 percent of the consumption of (primary) aluminium in West Germany. The corresponding figure for U.K. was 31 percent. Assuming that the Norwegian exporters are selling in the same proportion to all countries implies that Hydro Aluminium, the largest Norwegian company, has a market share around 21 percent in U.K. and 12 percent in West Germany, after the merger in 1986.

2.2 The European aluminium industry

There are several studies of the aluminium industry (Svendsen (1980), Brown et al. (1983), OECD (1983) and Holloway (1988). According to OECD (1983, p. 35-39) the annual European production capacity of primary aluminium was 3 500 000 tons in 1981-82. OECD (1983, p.127-35) shows how the structure of ownership is distributed in this industry. It is clear that the European aluminium industry is dominated by relatively few large companies (Hydro, Pechiney-Ugine-Kuhlman, Alu-suisse, Alcan).

2.3 The demand for aluminium in Europe

OECD (1983, p.56-68) provides an overview of the main end-use markets for aluminium. The most important consumers of aluminium in Europe is the car industry, which absorbs 27.1 of the primary aluminium consumption in Europe. Building and construction is another large field of application for aluminium (18.9 percent). Other main buyers of aluminium are the electrical engineering industry and the packaging industry. In all these industries there are possible substitutes for aluminium; plastics, iron and steel in the car industry, plastics in building and construction, copper in electrical engineering to mention some.

3 The theoretical model

The model presented below assumes that the firms using aluminium as an intermediary input, take prices as given. The sellers on the other hand are relatively large, and behave imperfectly competitive, both due to their size (oligopolistic competition) and also because they sell imperfect substitutes (monopolistic competition).

3.1 The demand side

In the specification of the demand side, I will draw on the recent work by Anderson et al. (1987), in order to obtain a demand side with a relatively simple and tractable functional form on the one hand, but on the other hand, which is sufficiently rich in structure to be a reasonable description of the real market. That is to say, I will specify the demand side of the model as an "address" (location) type model of imperfect competition along the lines developed by Lancaster (1979) and others. There are many agents on the demand side which are located differently either in geographical space or in the space of product characteristics. However, drawing on the work of Anderson et al., I will restrict the model sufficiently to end up with an aggregate demand system which is consistent with demand obtained from a single representative consumer with a nested log-linear/CES-type utility function. In a forthcoming paper by Dagsvik and Klette, we will show that there is a representative consumer representation of location models under more general conditions than described below and in the paper by Anderson et al.

Since my empirical model represents the aluminium industry, it is preferable to derive demand from firms demanding intermediary inputs, rather than demand generated from one or many consumers as in the analysis by Anderson et al. Hence, the starting point of this analysis is a firm which faces the optimization problem:

$$\min_{x,m_I} wx + w_I m_I \quad s.t. \quad y = Am_I^{\alpha}x^{1-\alpha} \tag{1}$$

where w_I and w are the prices for the factors of production, y is output, m_I is input of the intermediary good *produced* by the industry in question (m_I corresponds to the amount of aluminium demanded per individual firm in the industry which uses aluminium as a factor of production, in the empirical model presented below), x is an index of the input of all other factors of production. A is a productivity factor. The story now goes as follows: We assume that there are many variants of the intermediary input, i.e.

$$I \in S_I, \tag{2}$$

where S_I is the set of alternative variants offered. Each variant is located differently in the n-dimensional characteristics space; variant i is located at z_i, which is an n-dimensional vector. Furthermore we will assume that the productivity of the firm will decrease with the distance between the location of the variant the firm chooses, and the firms' optimal choice of input of this intermediary input. Let us denote the location of the most preferred variant of the firm in question by $\hat{z}$. Hence, we can write this assumption as follows:

$$A = A(\| z_i - \hat{z} \|), \qquad A' < 0. \tag{3}$$

if the firm chooses variant i. The expression inside the parenthesis on the right hand side in equation (3) represents a distance measure between the location of variant z_i and the location of the firm's optimal choice of this intermediary input, located at $\hat{z}$. We assume that the firm follows a two stage decision procedure: (i) First the firm chooses what variant of the intermediary input it wants to buy. (ii) Then the firm determines how much it wants to buy of each factor of production.

It is straight forward to show that the cost function corresponding to the second stage of this decision process can be expressed:

$$c(w, w_I, y) = \frac{ky}{A} w_I^{\alpha} w^{1-\alpha} \tag{4}$$

where k is a constant. Equation (4) expresses the cost function for the firm, conditional on the choice of the variant. Hence, the conditional factor demand for the intermediary input can be expressed

$$m_I = \frac{dc}{dw_I} = \frac{k\alpha y w^{1-\alpha}}{A w_I^{1-\alpha}} \tag{5}$$

We can now turn to the first stage of the firm's decision process. Following Anderson et al. we assume that the location of variants are given, and located in a symmetric fashion. It turns out that, from a theoretical point of view, a convinient choice of location pattern is as follows. Variant i is located at the point

$$z_i^j = \begin{cases} a & \text{if } i = j \\ -a & \text{otherwise} \end{cases}$$

except for variant n which is located at $(-a, -a, \cdots, -a)$. Superscript j refers to the coordinate axis in the characteristics space. Furthermore, we will assume that $A(\cdot)$ has the specific functional form

$$A = A_0 \exp\left[-b \sum_{j=1}^{n} (z_i^j - \hat{z}_i^j)^2\right] \tag{6}$$

i.e. a bell shaped form similar to the normal distribution. The central idea in this approach is now to claim that the firms demanding this intermediary input is distributed in the characteristic space according to their most preferred variant. Given that the characteristics space is rich enough (see Anderson et al., 1987), given the characterization of the firms and the location of the variants offered, one can show that the firms which are indifferent between using variants n and j are located at a hyperplane orthogonal to the j-axis at

$$\tilde{z}^j = \frac{\alpha \log(w_j / w_n)}{4ab} \tag{7}$$

where w_j and w_n are the prices of variant j and n respectively. All firms located at $z^j > \tilde{z}^j$ will prefer variant j to variant n. Hence, if we denote the distribution of firms in characteristics space with $f(z)$, demand for variant n can be expressed

$$X_n = \frac{\alpha y w^{1-\alpha}}{w_n^{1-\alpha}} \int_{-\infty}^{\tilde{z}^1} \cdots \int_{-\infty}^{\tilde{z}^{n-1}} f(z) dz^1 \cdots dz^{n-1} \tag{8}$$

It is possible to show that if the distribution function $f(z)$ is of the multinomial logit form, the aggregate demand function will take the CES functional form. That is to say, f(z) has the functional form

$$f(z) = M\left(\frac{4ab}{\mu}\right)^{n-1}(n-1)!\frac{\prod_{i=1}^{n-1}\exp\left(-\frac{4ab}{\mu}z^i\right)}{\left[1+\sum_{j=1}^{n-1}\exp\left(-\frac{4ab}{\mu}z^j\right)\right]} \tag{9}$$

where M is the total mass of firms ("the number of firms"), and $\mu/4ab$ is a measure of degree of concentration of the firms around origo. A high value of $\mu/4ab$ indicates a low degree of concentration and vice versa. Using the approach developed by Anderson et al. (1987), given (9), the aggregate demand function (8) can be simply expressed [3]

$$X_n = Myw^{1-\alpha}\alpha\frac{w_n^{-(1+1/\mu-\alpha)}}{\sum_{j=1}^{n}w_j^{-1/\mu}} \tag{10}$$

Notice that the price elasticity of demand can be attributed to two different sources in this framework:

- Firstly, the individual firms using this input have the possibility of substituting the intermediary input on which we focus, and some other inputs (e.g. between aluminium and say, plastics).
- Secondly, the individual firms can substitute between the different variants of the intermediary input (different variants of aluminium).

Both these substitution possibilities are reflected in the demand equation (10), and will give a contribution to the price elasticity facing the individual firms selling the intermediary input.

Let us assume that the cost share of the intermediary input (α) is negligible relative to $(1+1/\mu)$ [4]. In that case the aggregate demand function has exactly the CES functional form. Good n is not essentially different from the other variants of this intermediary input. Hence, we can carry trough the same argument for all variants:

$$X_i = Myw^{1-\alpha}\alpha\frac{w_i^{-(1/\mu+1)}}{\sum_{j=1}^{n}w_j^{-1/\mu}} \quad i=1,\cdots,n \tag{11}$$

3.2 The supply side

Let us now turn to the firms *supplying* this intermediary inputs. These firms also faces a two-stage decision problem. Firstly, they have to choose which

[3]Dagsvik and Klette (forthcoming) shows that similar and more general aggregate demand systems can be derived under less restrictive assumptions about the density distribution of consumers, dimensionality of characteristics space, etc.

[4]The econometric work presented below shows that $1+1/\mu$ to give an estimate of a value around 6. The cost share of aluminium, say, in the car industry, is probably much below 0.1.

variant(s) to produce. Secondly, given this choice, they have to decide how much to produce and/or what price to charge for this variant. However, I will not provide an analysis of the first stage of this decision process, but follow earlier works in this field (see e.g. Dixit and Stiglitz, 1977), and assume that each production unit produces a different variant of this good.

I assume that the firms have quantities as their strategy variable. That is, I will investigate a Nash-Cournot equilibrium for the second stage of the firms decision problem. That firms have quantities as their strategy variable is reasonable if they have to commit themselves to the choice of inputs before sales are determined. This seems to be the case in the aluminium industry where intermediary inputs (bauxite) have to be ordered in advance [5].

The firms face the following decision problem

$$\max_{X_i} \left[w_i(X_i)X_i - C_i(X_i)\right], \quad i = 1, \cdots, n \tag{12}$$

where $w_i(X_i)$ is the inverse demand function corresponding to equation (11). $C_i(X_i)$ is total costs of producing X_i. Let us furthermore allow for the possibility that the firms might face capacity constraints:

$$X_i \leq K_i, \quad i = 1, \cdots, n \tag{13}$$

Solving the optimization problem given by (12), subject to (11) and (13), gives the following price setting rule in Cournot-Nash equilibrium (see Klette, 1987, for more details):

$$w_i = \frac{c_i + \lambda_i}{\rho(1 - s_i)}, \quad i = 1, \cdots, n \tag{14}$$

where

$$c_i \equiv \frac{dC_i(X_i)}{dX_i}, \quad i = 1, \cdots, n \tag{15}$$

are the marginal costs. λ_i is the Lagrange parameter associated with the capacity constraint for firm i, (13), which will be zero if the constraint is not binding, and, to put it briefly, take whatever value is necessary in order to clear the market if the constraint is binding. Furthermore; $\rho = 1/(1 + \mu)$, and s_i is the market share of firm i:

$$s_i \equiv \frac{w_i X_i}{\sum_{j=1}^{n} w_j X_j} \tag{16}$$

[5] On the other hand, stockholding is important in this industry. In periods with large stocks, one might argue that competition in prices is a better approximation to the nature of competition in this market. However, as shown e.g. in Klette (1987), price setting rules will not be substantially different in the Nash-Bertrand game if the number of competitors is not too small or the goods are not too close substitutes. The market equilibriums presented in this paper would as a consequence not have been substantially different if we assumed that firms compete in prices.

One might notice that the more spread out the firms on the demand side are in terms of distribution of optimal choice of input (that is the higher is μ), the higher will the margin between marginal costs and price charged be, according to (14). This is reasonable, since a more spread out population on the demand side will reduce the price elasticity of demand for the individual variants [6].

The two sets of equations (11) and (14) completely determine the market equilibrium.

3.3 The firms' technology

We assume that the individual firms on the supply side have Leontief technology [7]. That is to say, ***the individual firms*** have no substitution possibilities. Formally, we can express this as follows

$$X_i \leq \min(z_i^L L_i, z_i^M M_i, z_i^E E_i) \tag{17}$$

where i refers to the Norwegian firms (notice that we do not describe the production technology in similar detail for the foreign producers, since we assume that they will face fixed factor prices, and hence will have constant marginal costs). L_i, M_i and E_i are the individual firms input of labour, intermediary inputs (except electricity) and electricity respectively. z_i^L, z_i^M and z_i^E are the corresponding unit production coefficients for the individual firms.

4 Empirical implementation of the model

4.1 The econometric model

In the theoretical presentation of the model above, we assumed a lot of symmetry which is likely not to be consistent with any real markets. E.g. it was assumed that the distribution of firms on the demand side and the goods offered were symmetrically located in characteristics space. Also, we assumed that productivity losses for the firms on the demand side due to non-optimal inputs would be the same for deviations from the optimal choice of characteristics, in all directions in characteristics space. These assumptions are too strong when we want to implement this model empirically. I conjecture that it is consistent with some relaxations of the symmetry assumptions

[6]More precisely; what matters is the density on the demand side *relative* to the distance in charcteristics space between the variants offered and the costs (productivity losses) associated with deviations from the optimal choice of variant.

[7]See Førsund and Jansen (1983) for a brief description of the technology for production of aluminium.

mentioned, to end up with an aggregate demand system of the more general CES-functional form

$$X_i = N \frac{\delta_i w_i^{-(1+1/\mu)}}{\sum_{j=1}^{n} \delta_j w_j^{-1/\mu}} \qquad i = 1, \cdots, n \tag{18}$$

where N is a new constant term.

In order to get an estimate for the substitution parameter ρ, I have inverted equation (14):

$$\rho = \frac{c_i + \lambda_i}{w_i(1 - s_i)} \tag{19}$$

If the capacity constraints are not binding everything on the right hand side is observable in principle. The results presented below are derived under the assumption that the capacity constraints were not binding for the Norwegian producers in the period 1972-86. Cappelen and Jansen (1984) have provided a detailed study of capacity utilization in the Norwegian aluminium industry for the period 1960-81. Their results are vaguely consistent with my assumption, with a possible exception for 1977. Notice that in periods when the capacity constraints are binding the right hand side of (19) is not observable. Hence, observations for years when the capacity constraints are binding should be eliminated in the estimation. However, experiments by omitting observations for 1977 showed that the results presented below where not sensitive in this respect.

I have employed the assumption that marginal costs corresponds to the sum of labour costs, material costs and energy costs. On the one hand, this seems to underestimate the true marginal costs, since one would like to include maintenance costs among the marginal costs. On the other hand, some of the labour costs might be regarded as fixed costs from the firms' point of view. The overall bias therefore seems to be ambiguous.

There is another aspect of equation (19) which deserves some comments, and that is the market share indicator, s_i. First of all, the right hand side of equation (19) has been calculated for all the Norwegian producers for the period 1972 to 1986. Since, some of this production units are controlled by the same company, I have used the companies' market share rather than the production units' market share. Secondly, the size of the relevant market is not well defined. There is no clear or operational definition of what one is to understand as the market size, or in practice which firms are competing with the Norwegian firms. I have assumed that the market in my case is the market for what is called primary aluminium. Next, one has to take into consideration what part of this market is actually (or potentially) in competition with the Norwegian producers. E.g. what regions of the world, both on the demand side and the supply side, is relevant for the Norwegian producers. I ended up using the following approach: I assumed that the market shares for the individual Norwegian companies in the U.K. and West Germany are representative for all the markets these companies compete in.

The primary justification for this assumption is that they absorb about 50 percent of Norwegian exports. One might argue that for this precise reason, my approach overestimate the average market share for the Norwegian companies. However, in other countries (e.g. Sweden), the Norwegian companies have a considerably higher market share than in the U.K. and West Germany, whereas in countries like Italy, the market share is negligible.

Data is not avaiable for the individual companies' export to individual countries. However, it is possible to obtain data for Norwegian exports to individual countries, as well as total consumption of primary aluminium in the corresponding countries. I have assumed that export shares to the different countries by individual Norwegian companies are fixed proportions, according to companies' shares in total Norwegian production of aluminium.

Hence, I ended up with the following approximation formula for the market share indicator for *company* j:

$$s_j = \frac{X_j}{X}\left(\frac{E^{UK}}{E^{UK}+E^{G}}\frac{E^{UK}}{C^{UK}} + \frac{E^{G}}{E^{UK}+E^{G}}\frac{E^{G}}{C^{G}}\right) \tag{20}$$

where j refers to the Norwegian *companies*. X_j and X are production of company j and all Norwegian companies respectively. E^{UK} and E^{G} represents Norwegian exports to U.K. and West Germany C^{UK} and C^{G} correspond to total consumption of primary aluminium in the two countries. All these variables are in terms of tons of aluminium, rather than in value terms. This is due to the fact that data are available in physical units rather than in value terms, which would have been preferable from a theoretical point of view.

Since, there are several sources of measurement errors in the econometric implementation of equation (19), an enor term should be added as follows

$$\rho = \frac{c_{it}}{w_{it}(1-s_{it})} + \varepsilon_{it} \tag{21}$$

where ε_{it} captures measurement errors, and possible deviations between actual behavior and the relativly simple model I have employed. The subscript t refers to the time-coordinate. If

$$E\varepsilon_{it} = 0 \tag{22}$$

then

$$\hat{\rho} = \frac{1}{TN}\sum_{i\in N}\sum_{t=1}^{T}\frac{\hat{c}_{it}}{\hat{w}_{it}(1-\hat{s}_{it})} \tag{23}$$

will provide an unbiased estimate for ρ, where the hats above the variables on the right hand side of (23), refer to the observations and estimates for the corresponding variables. N is the set of all Norwegian producers (observations for the foreign producers were not available). T denotes the number of periods with observations.

In order to estimate the δ-parameters in equation (18), I used the following model, which can be derived from (18)

$$\frac{\delta_i}{\delta_j} = \frac{w_i}{w_j}\left(\frac{X_i}{X_j}\right)^{\rho} \tag{24}$$

Since I do not have quantities and prices for individual foreign firms, I assumed that the foreign firms are all identical.

The production coefficients (cf. equation (17) has been determined by dividing labour inputs, intermediary inputs and electricity inputs by production for the individual (Norwegian) firms. All these variables were calculated as four year averages (1983-86).

4.2 The data

In order to estimate the ρ-parameter by equation (25), I used data for the period 1972-86 for all the Norwegian production units.

The production data for the Norwegian production units are taken from the Norwegian manufactoring statistics. A detailed description of this extracted data base is given in Torvanger (1988). The data base contains plant specific price indexes for output, labour and energy as well as value figures for output and the three factors of production; energy material inputs and labour.

The data needed to calculate the market shares by equation (20) were obtained from *World Metal Statistics* (several volumes).

The δ-parameters were calibrated to the data set for the base-year, which was constructed by taking average price- and quantity-data for the period 1983-86 (deflated to 1984). This period was chosen for two reasons. Firstly, several years was needed in order two average out business cycle phenomena [8]. Secondly, the years 1981 and 1982 were quite extraordinary for the aluminium industry (see e.g. OECD, 1983) which during these years experienced a severe depression, with a low level of demand combined with the high energy prices following from the rise in oil prices in 1979. As a consequence, there were considerable structural changes in the industry at the end of this period, including scrapping of capacity (see OECD, 1983). Hence, my belief is that the years before 1983 are not representative for the present and future state of this industry. That is the reason why years before 1983 have been omitted in the construction of the base data for the model.

[8] An alternative treatment would have been to calibrate the model to alternative base years within a business cycle. See Dixit (1986) for an example of this approach.

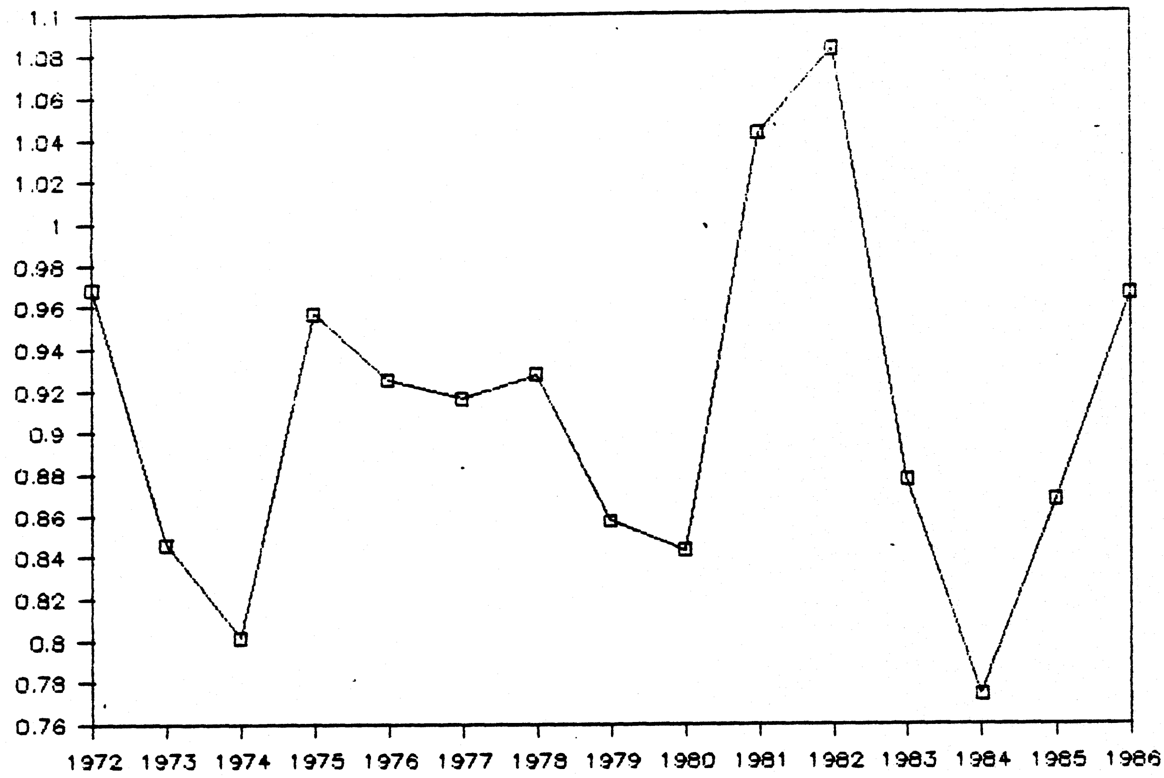

Figure 2: The right hand side of equation (13) (average for all Norwegians firms).

4.3 Estimation results

Figure 2 shows the average value for the Norwegian producers for the right hand side of equation (14), assuming that λ is zero for all producers, i.e. that the capacity constraints are not binding.

There is one outlier in the sample which seems to be running with negative operating surplus for the whole period 1975 to 1983. This production unit has been omitted from the calculations presented in figure 2. The other firms displayed a reasonably stable value for the RHS of (14), with one notable exception which shows up in figure 2. That is the peak in 1981 and 1982 where the margin between output price and marginal costs where close to zero for most of the firms. There is no apparent trend in the RHS of (14) for any of the firms.

The estimates obtained for the ρ parameter were 0.91 (standard deviation 0.134) when the outlier was included and 0.88 (standard deviation 0.099) when it was excluded.

In the simulation I used the estimate obtained by omitting the outlier. Estimating the ρ-value for the outlier independently gave a value significantly above unity, which is not a permissable value. There are several possible explanations for this result: It might be due to systematic measurement errors, e.g. that marginal costs for the outlier in fact are systematically lower than what I have defined as marginal costs above. Alternatively, the company might not be operating at a maximum profit level as defined by the model above, e.g. due to tactical considerations. For instance, governmental goodwill and cheap electricity might be reduced if the firm (the outlier) was closed down. The firm, as most of this industry, is located in rural areas, where the preservation of jobs are given priority by the Norwegian government. Alternatively, other tactical considerations might be omitted from the picture I have outlined above. Possibly, the outlier is operated for strategic reasons, in order to keep new entrants out of the market. This is an issue which could possibly be analyzed by our model, i.e. to investigate whether company profit is higher with the outlier producing compared to a situation where it is closed down and we allow for new entry into the industry. However, having given the issue some thoughts, I will leave it and carry on with the main task of this paper.

5 Policy analysis

5.1 The consequences of altering electricity prices

As mentioned in the introduction, the primary motivation for this study is to analyze the effects of increasing the electricity prices to the aluminium industry up to the price level paid by the rest of the economy, or some other relevant price level.

What price level one should compare to, is a matter of controversy. Hence, I will investigate two alternatives:

- Alternative 1: Market clearing price as calculated by Bye and Strøm (1987) by means of the MSG-model. They found an energy price at 0.126 Nkr/kWh (1984).
- Alternative 2: Current long term costs on the production of electricity for certain deliveries corrected for energy-intensive industries, as calculated by Johnsen (1986). This implies a price of 0.26 Nkr/kWh [9].

Also, it is not clear what situation exists in this market with respect to the response from foreign producers as the Norwegian aluminium export gets more expensive. That is to say, it is not clear to what extent one could expect expansion of production in existing plants outside Norway. This is a question to what extent there exists excess capacity abroad, or whether there are possibilities for entry by new firms. OECD (1983) argue that new entry by European producers is not likely. This is due to the fact that in order to enter this industry, producers are dependent on heavily subsidized electricity, which is not likely to be supplied to this industry from European

[9] Another price of interest could possibly be the export price for Norwegian electricity. However, the current export prices varies considerably from year to year and falls below and in the lower part of the interval spanned by alternative 1 and 2. This is due to the fact that Norwegian exports of electricity are currently traded in the (Scandinavian) "spot market". Probably, exports in terms of fixed contracts will give a price much above this level.

governments. On the other hand, Brazil and other Third World countries intend to expand their output of primary aluminium, which possibly could penetrate the European market.

Hence, I have carried out several simulation scenarios:

- Alternative a: There is no excess capacity among the foreign producers, neither any prospect of entry by new producers.
- Alternative b: There is excess capacity in the industry, but no possibility of entry by new producers.
- Alternative c: There is no constraints on capacity, nor on entry.

One might argue that alternative a) and b) correspond to the medium run, while alternative c) *might* correspond to the long run. However, as will be clear below, there is not much difference between alternative b) and c) in numerical terms. The number of firms operating in the industry under free entry has been calculated in the following way: The central assumption is that entry is only credible if the new production units produce at least 100 000 tons per [10]. The equilibrium number of foreign producers is calculated as the largest number of firms consistent with this restriction.

I do not have micro data on the price charged by foreign producers. The price charged by foreign producers is assumed to be equal to the average price charged by the Norwegian producers in the period 1983-86. This corresponds to 11000 Nkr/tons. The price on the spot market is below this value; 9550 Nkr/tons on average for the period 1983-86.

Below I will present the results for some different combinations of alternatives, e.g. alternative 1a) corresponds to an increase in current electricity prices to 0.126 Nkr/kWh, given that there is no excess capacity in the industry, nor any possibilities for entry. And so forth for alternative 1b), 1c), 2a) etc. Due to the confidential nature of the data I have used, I will only present summary measures of the results. I have excluded the outlier from these summary measures, since this production unit seems to run with negative operating surplus even at today's energy prices. Consequently, it will be closed down under all the policy scenarios presented below.

Alternative 1a:

This case involves an increase in electricity prices to 0.126 Nkr/kWh. We assume no free capacity on behalf of the foreign producers, neither any possibility for entry by new producers.

The main results are displayed in table 1. This table shows that on average there will be a 10.3 percent increase in production costs. This will not fully be passed over to the consumers, who will face on average a 6.5 percent increase in prices from the Norwegian producers. At the same time

[10]OECD (1983), assumes a "base" plant of 200 000 tons yearly capacity in their cost analysis. However, average size in the European industry is around 100 000 tons capacity per year.

Table 1. $\Delta\bar{C}$, $\Delta\bar{P}$ and $\Delta\bar{X}$ corresponds to relative changes (in percent) in respectively costs, prices and production for the average Norwegian producer. ΔL is the relative change in total employment among the domestic producers. ΔP^* and ΔX^* represents relative changes in prices and production for the representative foreign production unit. Δn^* is the number of foreign entrants. $\Delta(\Sigma\ \pi_i)$ is the difference between profits after the policy change and today's profits (i.e. average profit 1983-86) for the Norwegian producers. V^E is the value of the reduced electricity consumption in the Norwegian part of the industry. ΔW is the sum of column 8 and 9. $\Delta W'$ is ΔW minus the reduction in the industries labour costs.

Policy alternative	$\Delta\bar{C}$	$\Delta\bar{P}$	ΔP^*	$\Delta\bar{X}$	ΔX^*	ΔL	Δn^*	$\Delta\left(\sum_i \bar{\pi}_i\right)$[1]	V^E[1]	ΔW	$\Delta W'$
1^A	10.3	6.5	4.8	-6.6	-	-19.4	-	-370	329	-41	-265
1^B	10.3	5.1	0.7	-19.2	8.2	-29.3	-	-635	492	-143	-486
1^C	10.3	4.7	0.8	-22.7	-	-32.1	2	-706	538	-168	-544
2^A	37.8	28.4	16.1	-52.8	-	-57.5	-	-1052	1978	925	242
2^B	37.8	24.8	2.0	-74.5	22.6	-76.2	-	-1497	2607	1110	202
2^C	37.8	24.2	2.2	-78.2	-	-79.5	4	-1564	2718	1155	207

[1] Mill. Nkr (1984)

foreign producers will increase their prices with 4.8 percent, due to increasing demand. The result is a fall in production of 6.6 percent on average for the Norwegian producers. The value of the reduced electricity consumption is 329 mill Nkr. Overall employment will fall by 19.4 percent [11].

There are however considerable differences between the Norwegian plants. Minimum cost rise is 7.2 percent, whereas maximum is 13.8 percent. The corresponding figures for price changes is 0 percent, versus 13.1 percent. With respect to production some Norwegian firms actually expand production [12]. The firm which leaves its price fixed expands its output by 45 percent. Another Norwegian firm expands by 19 percent. However, the general picture is a decline production; maximum reduction is 46 percent. One firm enlarges its profit by 1 percent, maximum decline in profit is 36 percent.

Alternative 1b:

In this scenario the price increase on electricity is the same as above. However, in this case we assume that there is no binding capacity constraint in the industry. No entry of new foreign producers is assumed to take place.

The average cost increase is the same as above. However prices rise somewhat less in this case; 5.1 percent on average. The expansion in demand facing foreign producers in this case is matched by an escalation of production, while the foreigners' price remains almost unchanged. The reduction in prices in this case can be explained by the fact that Norwegian producers faces a more elastic demand in this case, since the foreign producers do not augment their prices as demand increases, in contrast to the previous case. However, despite the lower boost in prices, output falls considerably more in this case; by 19.2 percent on average. The decline in operating surplus is 635 mill. Nkr. Employment in this industry falls by 29.3 percent.

As above, one firm leaves its price unchanged. On the other extreme another firm escalates its price by 11 percent. The firm leaving its price unchanged expands its activity level by 20 percent. In this case all firms have a decline in their operating surplus, varying between 18 to 46 percent.

[11]This figure deviates from the average fall in production which was calculated as an arithmetic mean for the 6 plants, whereas the fall in employment is calculated incorporating all 7 units currently producing, including the outlier which will be closed down.

[12]One might argue that it would be more consistent with the other assumption in this simulation, to assume that also the Norwegian producers have access to no free capacity. On the other hand, there will be released a substantial amount of electricity in the Norwegian part of the industry if this policy was introduced. Hence, the supply of electricity would presumably not be a limiting factor for the Norwegian producers, possibly in contrasts to the foreign producers.

Alternative 1c:

In this alternative we assume that there is no constraints on capacity or entry, but the price increase is as above.

The boost in costs is as explained above, but in this case the rise in prices is smaller, on average 4.7 percent. That is to say, the swelling costs are reducing the profit margin to a larger extent in this case compared to the previous cases. The fall in average output is 22.7 percent, which is higher than in the previous case. This is due to competition from 2 new entrants in addition to the existing foreign firms in the industry. The result is a fall in operating surplus for the Norwegian producers of 706 mill. Nkr. Employment will decline by 32.1 percent in this case. The value of the electricity which is not used by the industry any longer is 538 mill. Nkr.

The differences between the firms are relatively similar to the picture in the previous case, and I will not go through it again.

Alternative 2a:

In this scenario, electricity prices are increased to 0.26 Nkr/kWh. There is no expansion of foreign output, since there is assumed to exist no free capacity, nor any possibility for entry.

Table 1 shows that on average, the augmentation of electricity prices will lead to a rise in marginal costs of 37.8 percent. This cost increase will only partly be passed over to the consumer, who will experience a price elevation of 28.4 percent. The price increase will lead to a substantial decline in activity; 52.8 percent on average. In terms of operating surplus there is a reduction of 1052 mill. Nkr. The value of the cutback in electricity consumption is 1978 mill. Nkr. Employment in this industry declines by 57.5 percent as a consequence of this boost in electricity prices.

Minimum cost increase is 33 percent, maximum 43 percent. The corresponding price figures are 23 percent and 35 percent. On the production side there are considerable differences; minimum reduction in output is 35 percent versus a maximum at 70 percent. Operating surplus fall between 44 percent to 68 percent.

Alternative 2b:

In this case there is excess capacity abroad, but no possibilities for entry. The electricity price is raised to 0.26 Nkr/kWh as above.

The increases in costs are of course the same as above. The rise in prices are smaller; on average they increase by 24.8 percent. Average fall in activity level is 74.5 percent, and operating surplus is reduced by 1497 mill. Nkr. for the Norwegian part of this industry. Employment will fall by 76.2 percent. The value of the reduction in electricity consumption is 2607 mill. Nkr.

Price augmentation varies between 20 and 31 percent. Three out of the six plants have their production reduced by 80 percent or more. Minimum contraction in output is 73 percent. Operating surplus falls between 67 percent and 83 percent.

Alternative 2c:

This scenario assumes no constraints on behalf of the foreign producers with respect to capacity or entry. The electricity price is the same as in the previous case; 0.26 Nkr/kWh.

The picture in this case is very similar to the previous case; prices increase by 24.2 percent, output falls by 78.2 percent on average, and operating surplus is reduced by 1564 mill. Nkr. for the Norwegian producers. The value of the electricity which the industry doesn't consume after the electricity price rise, is 2718 mill. Nkr. There is entry by 4 new foreign firms.

I will not elaborate on the detailed description of changes for the individual plants, since they are very similar to the changes described in the previous case.

5.2 Welfare considerations

It has been proposed that Norway should close down its energy intensive industry, and sell the electricity on long term contracts to Sweden, and at the same time stop the building of hydro electric power plants. It is not an unreasonable estimate that electricity sold to Sweden according to long-term contracts could obtain at least a price at 0.26 Nkr/kWh, which is the long term production costs of electricity in Norway, as mentioned above.

Policy simulation 2a) - 2c) presented above can be used to study the welfare effects of this proposal. It is reasonable to assume that it takes time to establish new production plants, and so in the short/medium run scenario 2c) is not appropriate. If there exists no free capacity among Norway's competitors, scenario 2a) shows that Norwegian output would be reduced to less than half of the current level. Employment would correspondingly decline by more than 50 percent. Operating surplus would decline by more than 1 billion Nkr. On the other hand the electricity which now becomes available, has a value of almost 2 billion Nkr. This implies that even if there is no alternative use for labour (which is not an unrealistic possibility in the short run) this value exceeds the reduction in operating surplus and the decline in wage payments by 242 mill. Nkr (see last column in table 1). That is to say, the workers and the firm owners could be fully compensated for they reduced incomes, and there would still be an annual surplus of 242 mill. Nkr. If there are alternative employment opportunities for the workers, the surplus is 925 mill. Nkr. on an annual basis.

If there exists free capacity in the rest of this industry, the reduction in the activity level among the Norwegian producers would be larger. However, the larger loss in operating surplus among the Norwegian producers in this case, is in value terms more than balanced by the value of the increased amount of released electricity. If the workers have no alternative employment opportunities, but is fully compensated, there would be surplus of 202 mill. Nkr. per year. If the workers can get alternative employment, net surplus exceeds 1 billion Nkr. per year.

In the long run, entry into the industry might be feasible, but this will give rise to welfare consequences which is fairly similar to the free capacity case discussed above.

It is worth stressing that one should not place to much emphasis on the exact figures in this exercise, since the parameters in the model has been determined from data which do not involve changes of the order of magnitude involved in this policy exercise. Nevertheless, the rough picture is probably robust: The reduction in employment and profits will be dramatic if electricity prices where to be changed to 0.26 Nkr/kWh. However, the value of the reduced electricity consumption in the aluminium industry is sufficient to more than compensate for the cutback in operating surplus and possible need for compensation to the workers which will have to leave their jobs.

Similar arguments can be carried through in the other policy alternative presented above, where the electricity price is set to 0.126 Nkr/kWh. The numbers presented in table 1 show that the value of the reduced electricity consumption in the aluminium industry is much lower in this case, which is obviuos. The table demonstrate that the value of this electricity will not be sufficent to counterbalance the losses in operating surplus, not to mention compensation to dismissed workers. However, in this case there will be an additional welfare gain in comparison to the policy alternative where electricity prices is changed to 0.26 Nkr/kWh. That is to say, if electricity is sold to Norwegian companies and consumers for 0.126 Nkr/kWh, there will be generated larger consumer surpluses and possibly increases in operating surplus in several industries. To quantify this effects a general equilibrium model is required, and hence I will not be able to provide a complete welfare analysis of this case.

5.3 Sensitivity analysis

There are at least two parameters which contains uncertainty in the model presented above and which might be of some importance for the results. That is the *number of foreign competitors/size of the market* and *the substitution parameter* on the demand side. In table 2 I have presented results for some sensitivity analysis for these parameters. I used the policy simulation 2^b, (see section 5.1) as the test case.

Table 2. Results from sensitivity analysis for the case of free capacity but no entry. "Expanded market" refers to simulation based on the assumption that the number of competitors is twice as many as for the results presented in table 1. The market size is expanded correspondingly. "Increased ϱ" reports results obtained when ϱ is increased with 5%. $\Delta\bar{C}$, $\Delta\bar{P}$ and $\Delta\bar{X}$ corresponds to relative changes (in percent) in respectively costs, prices and production for the average Norwegian producer. ΔL is the relative change in total employment among the domestic producers. ΔP^* and ΔX^* represents relative changes in prices and production for the representative foreign production unit. $\Delta(\Sigma\ \pi_i)$ is the difference between profits after the policy change and today's profits (i.e. average profit 1983-86) for the Norwegian producers. V^E is the value of the reduced electricity consumption in the Norwegian part of the industry. ΔW is the sum of column 8 and 9. $\Delta W'$ is ΔW minus the reduction in the industries labour costs.

	$\Delta\bar{C}$	$\Delta\bar{P}$	ΔP^*	$\Delta\bar{X}$	ΔX^*	ΔL	$\Delta\left(\sum_i \bar{\pi}_i\right)$ 1)	V^E 1)	ΔW	$\Delta W'$
Basis (alt. 2^B)	37.8	24.8	2.0	-74.5	22.6	-76.2	-1497	2607	1110	202
Expanded Market	37.8	22.8	1.0	-76.4	12.3	-77.5	-1560	2651	1090	167
Increased ϱ	37.8	17.4	2.2	-77.9	24.3	-79.4	-1681	2720	1039	94

The first analysis involved an expansion of the number of competitors by 100 percent, and a corresponding increase on the demand side. The results presented in table 2 prove that the results are robust with respect to changes in the market size.

The last row in table 2 presents the outcome of the policy scenario when the substitution parameter on the demand side was increased by 5 percent. The results are robust with respect to the qualitative aspects, both in terms of the consequences as described by the model, as well as with respect to the welfare consequences. However, the quantitative picture is quite sensitive to changes in this parameter. In particular, the reduction in the operating surplus for the Norwegian part of the industry would be larger in this case, as one would expect. Consequently, the net surplus from the policy reform would be smaller, the higher the substitution parameter. Notice however, that even if the workers would be unemployed but fully compensated, there is a net welfare gain to be obtained. And if the workers were able to find alternative jobs, the net surplus would be approximately 1 billion Nkr. per year, according to the model.

5.4 Strategic trade policy

In industries with imperfect competition there are arguments in favour of policy intervention (see Dixit (1987) for a recent survey, and Klette (1987) for an analysis which is close to the case studied in this paper). The basic arguments in the case of purely exporting industries are as follows:

- There is a so-called "profit-pooling" argument in favour of an export tax. That is to say, in order to obtain an export price which is close to the cooperative outcome for the domestic producers, there is a case in favour of an export tax.
- There is also a so-called "profit-shifting" argument in favour of a subsidy to exporting industries. This subsidy will strengthen the competitive position for the domestic producers in the foreign market. Thereby, the domestic firms will increase their market shares. Since there is assumed to be profits in this industry, this increase in market shares will enable the domestic firms to capture more of the profit than they would have done without the subsidy. It turns out that this increase in profit might be sufficiently large to justify a subsidy.

Which of the two arguments dominates depends on the nature of the industry. In Klette (1987), I have discussed this in some detail for the case of a fixed number of foreign and domestic firms, which are facing no capacity constraints. In this section of the paper I will present an analysis of this question under the three alternative responses of foreign firms presented in section 5.1; a) no free capacity nor free entry, b) free capacity but no entry and c) free capacity and free entry.

Alternative	1a	1b	1c	2a	2b	2c
t* (%)	12.9	-3.7	-7.3	7.5	-2.1	-2.9
ΔR (mill.Nkr)	127	15	56	38	3	5

Table 3: The simulation results for an optimal export tax under alternative assumptions with respect to capacity and entry among foreign firms. t^* is the size of the optimal tax rate. Δ R is the changes in total revenue compared to the non- intervention case (mill. Nkr (1984)).

The optimal export tax is determined so that total revenue is maximized (see Klette, 1987). That is, the problem is to solve

$$\max_t \sum_{i \in N} (w_i X_i - C_i(X_i)) \tag{25}$$

where t is an *ad valorem* tax on the exports for all the Norwegian producers. N is the set of all Norwegian producers. The Norwegian producers are of course still assumed to maximize their profits.

The simulation results are presented in table 3. The results show that if there is free capacity and/or free entry there is a case for an export subsidy; from 2.1 to 7.3 percent. The force driving these results are the so called profit-shifting motive: Strengthening the domestic producers competitive position by a subsidy, might increase sales and thereby profits sufficiently to justify a subsidy. If there is no free capacity nor any possibilities for entry, there is a case for an export tax.

However, as table 3 reveals, the changes in net national revenue from an optimal policy intervention in this industry are fairly small, at least in scenarios which allow for the existence of free capacity and/or free entry.

6 Final remarks and conclusions

This paper has presented a model for the Norwegian aluminium industry and its competitors. Policy simulations on this model shows that the consequences of altering the electricity prices will be dramatic. I have discussed some welfare consequences of such changes. For instance the analysis indicate that if the electricity prices were increased to 0.26 Nkr/kWh there will be almost a full close down of the Norwegian aluminium industry. However, if 0.26 Nkr/kWh is the opportunity costs for Norwegian electricity (export to Sweden and/or a freeze in the building of hydro electric power plants) the revenue (or cost saving) from the sales of electricity (or the reduced costs in construction of power plants) is more than sufficient to offset the reduction in the industry's operating surplus and possible costs to compensate the workers if they are not able to find alternative jobs. Net surplus will be, according to this analysis, of the order of magnitude 200 - 1000 mill. Nkr per year, depending on the possibilities of alternative employment for the workers which will leave the industry.

There are some limitations of the present study. I have mentioned that one should be somewhat careful with the exact figures presented above, the order of magnitude is what deserves attention. This is due to the large changes involved in the policy simulation, and possible errors in the global properties of the mathematical model.

The analysis presented in this paper has ignored some possible costs and benefits which deserve attention. One important point is the neglect of the cumulative effects of a close down of this industry on the industry's economic environment. A substantial part of the living houses and different kinds of infrastructure connected with the societies tied to this industry might be valueless if the aluminium industry is closed down, since several of the production plants are located in rural areas with possibly small opportunities for creation of new industry and jobs.

On the other hand it is fact that the aluminium industry produce large amounts of pollution, which has a damaging effect on the environment. Also, many would be inclined to argue that the social costs of the production of electricity exceeds long run production costs as reported above, due to the damage hydro electric power plants impose on their environment. Both these arguments would strengthen the case for escalation of the electricity prices.

The analysis of the scope for strategic policy intervention in this industry revealed that there are relatively small gains to be obtained from policy intervention if there is free capacity and/or free entry for foreign producers.

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