Taxing Pollution in an Open Economy— An Illustration from the Nordic Pulp Industry

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Abstract
This paper extends the analysis of Brännlund and Kriström in considering the imposition of a chlorine tax upon the Swedish forest sector. Here, the effects in both the Swedish and the Finnish forest sectors are modelled. Examined is the situation where a tax-induced increase in the price of chlorine shifts the Swedish supply function, which has repercussions for prices on the European pulp market, and results in a change in the quantity supplied by Finland. Welfare effects are estimated, as are the effects on the environment. It is found that much of the effect on the European market of the Swedish supply shift is dissipated through an increase in price, with only a small production increase appearing in Finland.
Keywords: Cholorine tax, environmental taxes, equilibrium demand curve, forest sector.

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Introduction

When evaluating environmental policies, it is desirable to consider the effects policies in one country have upon other countries. It is not necessarily the case that a policy which succeeds in reducing emissions from one source, or a set of sources, succeeds in reducing overall emissions. Transmitted through the markets, reductions in emissions from one country could have attendant effects in other countries, which result in increased levels of pollution.

One possible instance where this occurs is in the European pulp industry. Both Sweden and Finland supply pulp to European paper producers. Both nations' pulp manufacturers generate pollutants which flow into the Baltic Sea. The concern is that either country, acting unilaterally, may succeed in reducing pollution from one or the other side of the Baltic, yet fail to reduce pollution overall. Such a policy, in the absence of significant local pollution effects, would be successful only in inflicting costs upon its home-country producers.

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This paper examines a specific policy, a Swedish chlorine tax, with a view towards such considerations. This type of tax has been proposed and defeated in the Swedish Parliament on more than one occasion. The interest in reducing the use of chlorine in pulp bleaching processes results from such processes' release of chlorinated organic compounds. Such compounds are usually measured by the parameter AOX, and despite being relatively recent in their discovery, these pollutants have received a great deal of public attention.

The chlorine tax is a particularly interesting example of an environmental tax, in that its initial incidence is largely confined to one industry. Obviously, such industry-specific incidence can be contrasted with that of energy-related environmental taxes, such as carbon and sulphur taxes, whose effects are distributed throughout the economy. Thus, as focused upon in Brännlund and Kriström (1993), analysis of this tax provides an opportunity to consider welfare effects both as they are felt directly in the industry using the taxed input, and in supplier and related industries. Further, as is done here, the fact that the chlorine tax is largely confined to one sector of the economy allows the analysis to be readily extended to include a second country.

Since the net effects on the environment are calculated, what results from the treatment here is a more comprehensive understanding of the benefit side of a given policy. Moreover, in generating measurements of the attendant welfare effects in both Sweden and Finland, we are able to explicitly link net environmental effects with specific sector costs. Thus, in doing so, this analysis goes some distance towards addressing the often raised concern that failure to consider environmental policies in the context of the international economy leads to inaccurate estimates of true attendant costs and benefits.

THE ENVIRONMENTAL PROBLEM AND THE ECONOMIC MODEL

The firms use chlorine in the bleaching process. As many as 300 different types of chlorine substances are discharged into the sea. It takes a long time for these substances to break down and when they do so, some may become even more poisonous than before. Since the composition of bleached pulp mill effluents is very complex, it is almost impossible to characterize the impact of every substance on the environment. Indicators, like AOX (Absorbable Organically Bound Halogen) and EOCL are therefore used as proxies for the potential damages from such effluents. AOX is a broad spectered measure covering several chlorine compounds, including those that are believed to be harmful to the environment and those that have limited effects on the eco-system. One problem with using AOX as an environmental indicator is that there can be large variations in AOX concentrations in undisturbed eco-systems. EOCL is a narrow spectered measure covering those chlorine compounds which currently are believed to be harmful to the environment. In recent studies AOX has therefore been replaced with EOCl (Extractable Organic Chlorine) (see Grimvall *et. al.*, 1992 and Södergren, 1993).

It is clear, though, that the effects are greater close to the factory, but measurable effects have appeared as far away as up to 50 km from the source. The biological effects of the discharge of chlorine are claimed to be injuries to fish spines and changes in their vertebrae, see Auer (1996) for a detailed scrutiny of the ecological evidence. There are also serious physiological effects, such as damage to fish livers and immune systems. Some of these effects, especially lowered reproduction capability, constitute a serious threat to the survival of the population of some species.

The analysis here builds directly upon the model developed in Brännlund & Kriström (1993). There the objective is to estimate the welfare change in Sweden resulting from the imposition of a chlorine tax, and to consider equilibrium effects in three industries—the pulp industry, the forest industry, and the sawmill industry. An econometric model is specified, and the supply and demand curves for the three industries are estimated. The general equilibrium welfare change is shown to be the integral of the general equilibrium demand curve for chlorine over the tax-induced change in chlorine price.

In the analysis here, a similar model is constructed for the Finnish forest sector. Accordingly, profits for individual pulp manufacturers in each country take the following form:

$$\Pi_k^p = \Pi_k^p\left(P_p^k; w_{pl}^k, w_{pe}^k, w_{pv}^k, w_{pc}^k : \overline{K}_p^k\right) \tag{1}$$

where P_p is the price of pulp; w_{pi} are the prices of inputs in the production of pulp with $i = l, e, v, c$ referring to the inputs of labour, energy, pulpwood, and chlorine respectively; and $\overline{K}_p$ is the fixed capital stock. The index $k = S, F$ denotes profits and prices in Sweden and Finland respectively. Included in the price for pulp is the exchange rate, which means that the Swedish and Finnish pulp industry will meet different prices in local currency.

In the forest sector, profits take the form:

$$\Pi_k^f = \Pi_k^f\left(w_{pv}^k, w_{sv}^k, w_{fl}^k : \overline{K}_f^k\right) \tag{2}$$

where w_{sv} is the price of sawtimber; w_{fl} is the wage rate in forestry; and $\overline{K}_f$ is the fixed forest capital stock.

Finally, profits for firms in the saw mill industry take the form:

$$\Pi_k^s = \Pi_k^s\left(P_s^k; w_{sl}^k, w_{se}^k, w_{sv}^k : \overline{K}_s^k\right) \tag{3}$$

where P_s is the price of sawnwood; w_{si} are the prices of inputs in the production of sawnwood with $i = l, e, v$ referring to the inputs of labour, energy, and sawtimber respectively; and again $\overline{K}_s$ is the fixed capital stock.

Underlying this construction is a number of assumptions. The supply function of chlorine is assumed to be completely elastic in both Sweden and Finland. The labour and energy supply functions, as well as the sawnwood demand function, are also assumed to be infinitely elastic in both countries. In addition, although there are regulations on the emissions of chlorinated compounds we do not explicitly include this into the model[1]. Further, the model is viewed as applicable in the short run[2].

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1 Regulations regarding chlorine pollutants were not in effect in Finland during the period examined. Such regulations did come into effect subsequently. In Sweden the regulations on the emissions of AOX is set on the plant level and they generally differs between plants. For an analysis where these plant level emission standards are taken into account we refer to Brännlund & Liljas (1993), Brännlund & Löfgren (1996), and Brännlund & Kriström (1996).

2 One can note that the duration of the short run, over which the capital stock is assumed to be fixed, may, in practical terms, be shorter than what would ordinarily be the case. Both countries' pulp industries have recently made dramatic, chlorine-directed changes in their capital stock over a relatively short period.

Important to note is that we disregard the fact that the sawmills are producing wood chips, as a by-product, which is sold to the pulp mills. Given that wood chips and pulpwood are perfect substitutes, which is a reasonable assumption, we would expect that the price of wood chips equals the price of pulpwood (in terms of fibre content). Thus it should be clear that the profits for the firms in the sawmill industry are affected directly by the pulpwood price. This, however, does not change the structure of the model as long as the wood chips supply per unit of sawtimber is independent of the price[3]. On the other hand, our empirical results might be biased since we obviously have omitted (at least) one variable in the demand equation for sawtimber. In that sense one can say that the model is misspecified. The main reason for not including wood chips into the model is lack of reliable time-series data.

In structuring the model, we place the analysis in an ordinary Marshallian framework. We view the imposition of a chlorine tax as causing a shift backward in the Swedish supply curve for pulp. With Sweden and Finland being two, among several, pulp producers selling onto the European pulp market, this shift of the Swedish supply curve is viewed as resulting in a backwards shift of the European aggregate supply curve. As a result of this reduction in supply, prices on the European pulp market are expected to rise. Such a price increase will cause an increase in Finnish output.

Welfare Measures

As in Brännlund & Kriström (1993) our welfare measure is defined in terms of profit changes. Naturally, a broader definition of welfare change includes the effect on human welfare through the change of environmental quality. Including the value people place on environmental changes is, at least in principle, straightforward. Data limitations preclude such an extension, however.

The welfare measure is then the value of the change in Swedish and Finnish profits, i.e., it is the cost of a chlorine tax. To simplify the exposition somewhat, we assume that input-prices in Finland remain fixed even after a Swedish

[3] If this is not the case we can think of cases in which sawmills buy timber and convert it to chips, which is sold to the pulpmills.

chlorine tax has been imposed. This is an innocuous assumption, whence the impact on Swedish input markets has been found to be small.

DEFINITION 1. *The welfare measure is defined by:*

$$\Delta\Pi_S + \Delta\Pi_F = \Delta\left(\Pi_S^p + \Pi_S^f + \Pi_S^s + \Pi_F^p\right)$$

where capital *S, F* refers to Sweden and Finland respectively, and superscript *s, p, f* to the respective industries. A key finding in Brännlund & Kriström (1993) was that we can measure all welfare effects by simply studying the equilibrium demand curve for chlorine; i.e. the demand curve for chlorine along the equilibrium price path. In the current case, we need to take into account the possible price-repercussions in the market for pulp. Because Sweden and Finland are "big players" on the Western European market, it is reasonable to expect price changes for pulp. This price change will, as we remarked above, be assumed to leave prices intact on the Finnish-input markets. We summarise the result by the following definition and proposition.

DEFINITION 2. *The equilibrium demand curve for chlorine is defined as:*

$$X_{pc}^{S*} = X_{pc}^{S}\left(w_{pc}^{S}, w_{pv}^{S*}, P_p^{S*}, P_p^{F*} \cdot\right)$$

where $w_{pv}^{S*} = w_{pv}^{S}\left(w_{pc}^{S}, \cdot\right)$ is the market-clearing price for pulpwood, and P_p^{k*}, $k = S, F$ is the market-clearing price on pulp in each country.

PROPOSITION 1. *The area under the equilibrium chlorine demand curve measures the welfare impact of price changes in all markets;*

$$\Delta\Pi = \int_d - X_{pc}^{S*} dw_{pc}^{S}$$

where *d* is the path of integration between the initial and after-tax price of chlorine, and the asterix signifies the use of an equilibrium price of pulpwood and pulp.

PROOF.

$$\Delta\Pi_S + \Delta\Pi_F = \Delta(\Pi_S^p + \Pi_S^f + \Pi_S^s + \Pi_F^p)$$

$$\Delta\Pi_S^p = \int_d \frac{\partial \Pi_S^p}{\partial w_{pc}^S}\left(P_p^S\left(w_{pc}^S,\cdot\right), w_{pv}^S\left(w_{pc}^S,\cdot\right), w_{pc}^S\right) dw_{pc}^S =$$

$$\int_d \left\{ Y_p^S\left(P_p^{S*}, w_{pv}^{S*},\cdot\right)\frac{\partial P_p^{S*}}{\partial w_{pc}^S} - X_{pv}^S\left(P_p^{S*}, w_{pv}^{S*},\cdot\right)\frac{\partial w_{pv}^{S*}}{\partial w_{pc}^S} - X_{pc}^S\left(P_S^{p*}, w_{pv}^{S*},\cdot\right)\right\} dw_{pc}^S$$

$$\Delta\Pi_F^p = \int_d \left\{ Y_p^F\left(P_p^{F*}, w_{pv}^F,\cdot\right)\frac{\partial P_p^{F*}}{\partial w_{pc}^F}\right\} dw_{pc}^F$$

$$\Delta\Pi_S^f = \int_d \left\{ Y_{pv}^S\left(P_p^{S*}, w_{pv}^{*},\cdot\right)\frac{\partial w_{pv}^{S*}}{\partial w_{pc}^S} - Y_{sv}^S\left(P_p^{S*}, w_{pv}^{S*},\cdot\right)\frac{\partial w_{sv}^{S*}}{\partial w_{pc}^S}\right\} dw_{pc}^S$$

$$\Delta\Pi_S^s = \int \left\{ X_{sv}^S\left(w_{sv}^{S*}\cdot\right)\frac{\partial w_{sv}^S}{\partial w_{pc}^S}\right\}$$

where Y_j^k and X_j^k are supply and demand of good j in country k respectively.

Now utilise the assumption that all markets are in equilibrium. e.g. $Y_p^S + Y_p^F = X_p$, $Y_j^k = X_j^k$, where $j = pv, sv$, and X_p is the demand for Swedish and Finnish pulp. Then we are clearly left with the statement in proposition 1. Q.E.D.

We need to comment on the way the pulp-market equilibrates. We assume for simplicity that only Swedish and Finnish pulp-suppliers are affected by the Swedish chlorine tax. This assumption does not change the logic of our result, since the key to the result is that markets are always in equilibrium.

Proposition 1 shows that all we need to calculate our welfare measure is the equilibrium demand function for chlorine. However, for non-marginal changes of the tax we must calculate new equilibrium prices. To do this we need to know, apart from the ordinary Swedish demand function for chlorine, the demand and supply functions in the Swedish roundwood market, as well as information about the supply and demand functions for Nordic pulp in the European pulp-market. Given this information we are not only in a position for calculating the total effect, but also in a position for calculating the distributional effects of a chlorine tax, i.e., how much of the tax burden is carried by pulp producers, forest owners, and sawmill industry.

The problem with the European demand function, is solved in the most simple way by assuming that the demand function for Nordic pulp is:

$$X_p = \gamma \cdot P_p^{-1/2} \tag{4}$$

which means that we assume that the demand elasticity for Nordic pulp is 0.5.

The market clearing condition on the European pulp market is then:

$$X_p = Y_p^S + Y_p^F \tag{5}$$

From equation (1) and (5) it is then possible to solve for the equilibrium price for pulp,P_p.

This means that the equilibrium price for pulp will depend on the chlorine tax. This in turn means that in order to obtain an appropriate measure of the welfare change, due to a chlorine tax, the change in consumer surplus in the pulp market has to be added to the change in profits. The change in consumer surplus can be found by integrating equation (4) over the relevant price interval.[4]

EMPIRICAL MODEL AND DATA

In estimating the model outlined in the previous section we follow the approach taken by Brännlund and Kriström (1992) and (1993), which means that we use a Restricted Generalised Leontief functional form (GL) for each profit function in the model. Due to the assumptions we make we only need, for the case of Finland, one profit function, the one for the pulp industry. For the case of Sweden we specify GL profit functions also for the forestry sector and the sawmill industry.[5] Then, by applying Hotelling's lemma we obtain the supply functions for pulp in each country, as well as the input demand functions in each country, i.e.,

[4] In the empirical section we do not include the consumer surplus in our calculations of the welfare change. The reason for this is mainly that the effect on the pulp price is very small, which means that the change in consumer surplus will be very small.

[5] The GL profit function has the desired property of linear homogeneity in prices. Symmetry, on the other hand, is imposed in the estimation process.

$$Y_p^k = \beta_{pp}^k P_p^k + \sum_{j=v,l,e,c} \beta_{pj}^k \left(\frac{w_{pj}^k}{P_p^k} \right)^{0.5} + \beta_{Kp}^k K_p^k, \qquad k = S,\ F \tag{6}$$

$$-X_{pi}^k = \beta_{pi}^k P_p^k + \sum_{j=v,l,e,c} \beta_{ij}^k \left(\frac{w_{pj}^k}{w_{pi}^k} \right)^{0.5} + \beta_{Ki}^k K_p^k, \quad i = v,\ l,\ e,\ c \tag{7}$$

$$Y_{pv}^S = \sum_{j=pv,sv,fl} \alpha_{pvj} \left(\frac{w_j}{w_{pv}} \right)^{0.5} + \alpha_{Kpv} K_f \tag{8}$$

$$Y_{sv}^S = \sum_{j=pv,sv,fl} \alpha_{svj} \left(\frac{w_j}{w_{sv}} \right)^{0.5} + \alpha_{Ksv} K_f \tag{9}$$

$$-X_{sv}^S = \alpha_{ss} \left(\frac{P_s}{w_{sv}} \right)^{0.5} + \sum_{j=sl,se,sv} \alpha_{svj} \left(\frac{w_j}{w_{sv}} \right)^{0.5} + \alpha_{Ksv} K_s \tag{10}$$

From the discussion above it is clear that we do not need, for our particular purpose, estimates of all parameters in each profit function. What we obviously need to estimate is the demand function for chlorine in Sweden and Finland. However, in order to estimate the Swedish equilibrium demand curve for chlorine, X_{pc}^*, the equilibrium prices for pulpwood and sawtimber in Sweden must be calculated, as well as the equilibrium price on the pulp market. Since prices on pulpwood, sawtimber and pulp are determined by the equilibrium conditions on the pulpwood, sawtimber and pulp market respectively, we need estimates of the demand and supply functions for pulpwood, sawtimber and pulp. A minimum requirement to "close" our model is then estimates of eight equations; chlorine demand in Sweden and Finland, pulpwood demand and supply in Sweden, sawtimber demand and supply in Sweden and pulp supply in Sweden and Finland. Gains in efficiency (lower variance of the estimated parameters) would be obtained if all equations in the model were estimated simultaneously. However, because of lack of data, we have chosen to estimate the whole system of supply and demand equations only for the Swedish pulp industry. For the Swedish forestry we estimate only the pulpwood supply and sawtimber supply equations, and for the sawmill industry, only the sawtimber demand equation. For Finland we only estimate the required equations, i.e., pulp supply and chlorine demand.

The data we use are annual time series data, collected from Swedish official statistics (mainly SOS Industry but also from the Yearbook of Forest Statistics). Unfortunately we have no time series data on the capital stock in the pulp industry and sawmill industry. There is, however, data available on production capacity in the pulp industry, which is used as a proxy to the capital stock. In the case of the sawmill industry not even capacity data are available on a time series basis. We have tried various approximations for the capital stock in the sawmill industry, including time and lagged production of sawn wood. The results, however, seems to be quite insensitive to whether we include such an approximation or not. One explanation for this might be that the actual capital stock has been, more or less, constant over the time period considered here. This is strengthened by the fact that there is no clear trend in the use of sawtimber during the period 1960–1988. Therefore, in the final estimations we have chosen to omit this variable. In Finland, time series data was found in the Yearbook of Forest Statistics, the Yearbook of Industrial Statistics, and the annual Statistical Tables. All of these are publications of Statistics Finland. In addition, certain other data for Finland, including the time series for chlorine consumption, was provided by the Federation of Forest Industries.

All time series spans over the period 1963 to 1988. In order to estimate the parameters of the system we used the iterative seemingly unrelated regression (SURE) model with symmetry restrictions.[6]

Results

The regression results are presented in Table A1 in Appendix A. Most of the estimated parameters are significantly different from zero and the goodness of fit, in terms of R^2,

[6] This may not be the best way to estimate the parameters of the model. Since we have endogenous right hand side variables there might be problem with simultaneity bias.

is acceptable for most of the equations. A problem, however, is the low Durbin-Watson statistic for some of the equations, which may be an indication that the model is misspecified.

Given the results in Table A1 it is possible to calculate short-run supply and demand elasticities. We have chosen to present the elasticities evaluated at the mean of all variables.

As expected, for the Swedish pulp industry all of the own price demand elasticities are negative and all own price supply elasticities are positive. Specifically interesting is the negative chlorine demand elasticity, since it may imply that the prevailing regulations on chlorine emissions are not binding. In general, however, the elasticies are quite small in magnitude, which implies that there are small substitution possibilities in the short run.

Other interesting results are the small magnitude, –0.01 and –0.007, of the cross-price elasticities of pulpwood demand and pulp supply with respect to the chlorine price. This implies that a change in the chlorine price has a very small effect on pulpwood demand and pulp supply in Sweden.

If we look at the elasticities in the forestry equations, we find that all own price elasticities have the expected positive sign, and their magnitude resemble the results from other studies.[7] Also it can be seen that pulpwood and sawtimber seem to be substitutes in production, as expected. In other words, an increase in the pulpwood price will redirect cutting capacity towards pulpwood. This latter result, however, is not significantly different from zero. For the sawmill industry, we conclude that the own price demand elasticity is negative as expected.

If we look at the Finnish elasticities we see that they resemble the Swedish ones quite well. An important exception, though, is the very low Finnish chlorine demand elasticity.

[7] In Brännlund (1988), the pulpwood supply elasticity ranges between 0.6 and 0.8, depending on specification, and sawtimber supply elasticity ranges between o.4 and 0.8. The estimation period used is 1953 to 1986.

Table 1. Output Supply and Input Demand Price Elasticities Evaluated at the Mean of All Variables.

	Pulp Industry, Sweden				
	Pulp	Wood	Labour	Energy	Chlorine
Pulp	0.170	–0.124	–0.025	–0.009	–0.007
Wood	0.386	–0.479	0.103	0.002	–0.012
Labour	0.318	0.414	–0.756	0.002	0.022
Energy	0.308	0.021	0.007	–0.264	–0.073
Chlorine	0.682	–0.387	0.178	–0.214	–0.258

	Forestry, Sweden		
	Pulpwood	Sawtimber	Labour
Pulpwood	0.79	–0.07	–0.72
Sawtimber	–0.05	0.30	–0.24

	Sawmills, Sweden			
	Sawtimber	Lumber	Labour	Energy
Sawtimber	–0.40	0.48	–0.78	0.69

	Pulp Industry, Finland				
	Pulp	Wood	Labour	Energy	Chlorine
Pulp	0.11	–0.005	–0.01	–0.05	–0.04
Chlorine	0.004	–0.001	–0.001	0.001	–0.004

To summarise, we have found that all output supply functions have positive own price elasticities, and all input demand functions have negative own price elasticities. The demand elasticities for the pulp industry, in both Sweden and Finland are all less than one, implying that an increase in the price of a specific input will decrease the use of it while its cost share will increase.

Furthermore, the estimated parameters are used to calculate the reduced form for the equilibrium price for pulp, and the equilibrium prices for pulpwood and sawtimber in Sweden which, in turn, is plugged into the demand equation for chlorine. The resulting general equilibrium demand function for chlorine is then used to evaluate our welfare measure $\Delta\Pi$. For comparative reasons, we also evaluate our

TABLE 2. FOREGONE PROFITS IN MILLION SEK AND THE EFFECT ON CHLORINE CONSUMPTION (TONS) FROM A 5 SEK/KG TAX ON CHLORINE IN SWEDEN.

$\Delta\Pi^{i}$	$\Delta\Pi^{ii}$	ΔX_{pc}^{S}	ΔX_{pc}^{F}
467.1	462.1	-76859 (-52 %)	6.8 (0.004 %)

[i] Includes price adjustment on pulpwood and sawtimber

[ii] No price adjustment on pulpwood and sawtimber

welfare measure with the ordinary demand curve, i.e., the case when the chlorine tax does not have any effect on other prices. The change in profit is evaluated for 1988, and the tax imposed is the proposal put forward by SOU 1989:21, 5 SEK/kg chlorine. We also present the effect on chlorine consumption.

To interpret these numbers, let us begin with the conventional partial equilibrium view. In this case, the quasirent loss is 462.1 million SEK for the pulp industry.

When we allow for repercussions in the Swedish roundwood market, the change in loss in the entire Nordic forest sector is approximately 467.1 million SEK. This means that the partial equilibrium estimate, in this case, is a good approximation to the "true" general equilibrium estimate. The similarity between the partial and general equilibrium measures implies that the ordinary demand curve and the general equilibrium demand curve are very similar. An explanation of this result is the low magnitude of the cross-price elasticity of pulpwood demand with respect to the chlorine price, –0.01, which simply means that there will be a very small change in pulpwood demand as a result of the chlorine tax. The low elasticity can, in turn, be explained by a small cost share for the chlorine input in combination with a small elasticity of substitution between wood and chlorine. In addition, the low cross-price elasticity of pulp supply with respect to the chlorine price in Sweden, 0.007 implies a very moderate decrease in pulp supply in spite of the sharp increase in the chlorine price. This together with the low Finnish pulp supply elasticity explains the similarity between the partial and general measure. To obtain an estimate of the net loss for society, we have to subtract the revenue from the chlorine tax, approximately 370

Table 3. Effects on Pulpwood, Sawtimber and Pulp Volumes and Prices from a 5 SEK/KG Tax on Chlorine in Sweden (Percentage Changes).

ΔX^S_{pv}	ΔX^S_{sv}	ΔY^S_p	ΔY^F_p	Δw^S_{pv}	Δw^S_{sv}	Δp_p
–1.41	0.07	–1.0	0.07	–2.16	–0.18	1.01

million SEK, which means that the deadweight loss is approximately 90 million SEK.

If we look at the effect on chlorine consumption, and hence on the environment, in the two countries we see that there is a considerable reduction in Sweden (52 %), while the increase in Finland is almost neglectable. Thus, it does not seem to be the case that a unilateral Swedish policy action in this area is offset by an increase in Finnish consumption.

Distributional Effects

The effects on the Swedish forest owners and the Swedish sawmills, in terms of roundwood prices and volumes, as well as the effects on market for pulp are illustrated in Table 3.

The equilibrium prices of pulpwood and sawtimber in Sweden are both marginally reduced, suggesting that the sawmills make slightly higher profits since they are able to enjoy a lower price on sawtimber. While the equilibrium prices of sawtimber and pulpwood go down slightly, the equilibrium volumes of sawtimber rise marginally, and the pulpwood volume is reduced somewhat. As a result of the repercussions the forest owners profits will decrease, to some extent, due to the direct effect, i.e. the shift of the demand curve for pulpwood, but at the same time they will increase due to the indirect effect, i.e. the shift of the supply curves for pulpwood and sawtimber. It can, however, using a revealed preference type of argument[8], be shown

[8] Let **p** be a vector containing the initial price of pulpwood and sawtimber, **p'** be the corresponding vector after the introduction of a chlorine tax. Then we have that **p** > **p'**. Suppose further that **q** is the profit maximising output bundle at price **p**, and **q'** is the profit maximising bundle at price **p'**. Then we have that **pq** ≥ **pq'** and **p'q'** ≥ **p'q**. However, since **p** > **p'**, we have that **pq'** > **p'q'**, which implies that **pq** ≥ **pq'** > **p'q'**, which means that the initial profit is larger than the final profits.

that the net effect on the forest owners are negative since the price of both pulpwood and sawtimber are lower after the introduction of a tax on chlorine. It should be pointed out, however, that this effect is very slight due to the small changes in prices and volumes. Due to the upward shift of the Swedish supply curve for pulp, the equilibrium price for pulp will increase, but only with 1 %. The reason for this small effect is, as we already mentioned, the small magnitude of the cross-price elasticity of pulp supply with respect to the chlorine price, i.e., the shift of the supply curve is very small. As a consequence, the loss in Swedish market share to the Finnish industry, due to a unilateral policy shift, is almost neglectable.

CONCLUSIONS

The above analysis suffers from a number of limitations. Primarily, the analysis here must be viewed as static. A more developed approach would allow for subsequent price and quantity adjustments. As such, the results here likely represent an upper bound of possible effects. Secondly, the analysis here does not extend over a time horizon in which the capital stock is allowed to change, and, as has been noted, the pulp industry has modified its capital stock dramatically in response to environmental considerations. Finally, it must be recognised that Sweden and Finland are large producers on the European pulp market. Thus the industry, in a further analysis, could perhaps be better modelled as one with a higher level of industrial concentration than has been done here. Due to this it might have been more accurate to do the analysis in a game-theoretic setting. For example, the Swedish and Finnish governments could be considered as two players in a simple pollution-tax game. One outcome from such a setting would probably be that neither country launches the tax.

Nonetheless, as pollution problems are increasingly recognised as ones, which extend across national borders, and as economists increasingly seek to model such cross-nation effects, this paper provides one possible framework of analysis. Moreover, while this analysis cannot speak to productivity losses, changes in profits for a given industry are found. Thus it permits some linkage between two often associated, but rarely explicitly modelled issues, those of environmental regulations and competitiveness.

In the specific case here, the effects on Sweden were shown to be reasonably well approximated by the Sweden-only analysis. Extension of the analysis to consider effects as transmitted through the European pulp market does show the benefits of policy to be lessened, but to a very little extent. It should be stressed that underlying this result are the particular elasticities of the pulp industry.

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APPENDIX A.

TABLE A1. ESTIMATES OF THE RESTRICTED PROFIT FUNCTIONS FOR SWEDEN AND FINLAND.

	PULP INDUSTRY, SWEDEN							
	Pulp	Wood	Labour	Energy	Chlorine	Capital	R^2	DW
Pulp	3731.5	−224.7	−73.9	−18896	−173.0	191.3	0.58	0.54
	(1.89)	(−2.14)	(−1.32)	(−3.42)	(−2.42)	(4.98)		
Wood		−9.83	−10.6	−134.3	10.9	0.20	0.04	1.13
		(−0.92)	(−2.48)	(−0.29)	(1.80)	(0.77)		
Labour			7.04	−75.3	−8.21	0.17	0.84	0.25
			(0.70)	(−0.11)	(−1.08)	(0.90)		
Energy				42722	7078.8	−50699	0.43	1.46
				(0.06)	(2.26)	(−3.16)		
Chlorine					−73.6	−0.75	0.22	0.24
					(−0.88)	(−0.36)		

	FORESTRY, SWEDEN					
	Pulpwood	Sawtimber	Labour	Capital	R^2	DW
Pulpwood	43.32	−3.56	−68.1	0.02	0.56	1.71
	(3.25)	(−0.52)	(−4.63)	(3.51)		
Sawtimber	3.01	−23.4	0.02	0.42	0.95	
	(0.22)	(−1.42)	(3.84)			

	SAWMILLS, SWEDEN						
	Lumber	Sawtimber	Labour	Energy	Capital	R^2	DW
Sawtimber	651.5	−63.8	−19.6	60143	−0.33	0.81	1.50
	(4.46)	(−4.86)	(−4.33)	(5.89)	(−4.39)		

	FOREST INDUSTRY, FINLAND							
	Pulp	Pulpwood	Labour	Energy	Chlorine	Capital	R^2	DW
Pulp	6762.2	−11.45	−43.4	−44600	−822.4	0.04	0.77	0.80
	(3.98)	(−0.28)	(−2.59)	(−1.55)	(−0.56)	(8.11)		
Chlorine		45.2	−73.4	−22086	−124141	−1.22	0.54	0.49
		(1.14)	(−4.64)	(−0.72)	(−13.06)	(−5.49)		