Damned if you do, Damned if you don't –
Reduced Climate Impact vs. Sustainable Forests in Sweden

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Abstract

The main objective of this paper is to analyze the potential goal conflict between two of Sweden's environmental objectives: *Sustainable Forests* and *Reduced Climate Impact* – or, more precisely, the conflict between forest conservation and the supply of wood fuel. To accomplish this, we use a forest sector model that includes the suppliers and major users of roundwood. The econometric results, based on a data set that spans 40 years, show that all the own price elasticities have the expected signs. Among the three forestry products, the supply and (long-term) demand of forest fuel seems to be most sensitive to a price change. In a second step, the estimated model is used to simulate the effect of increased forest conservation -- the *Sustainable Forest* objective -- on the supply of wood fuel. If oil is used as a substitute, Swedish emissions of greenhouse gases will increase by almost 0.92 percent, which indicates a clear conflict with the *Reduced Climate Impact* objective.

Keywords: Goal conflict, Wood fuels, Forest sector model, Roundwood markets, Forest conservation

JEL Classification: C30, L73, Q41, Q48

1. Introduction

Goal conflicts exist in all policy areas and environmental policy is no exception. Certain goal conflicts are more obvious than others, e.g. the trade-off between conserving and using a natural resource. One example is that a Swedish domestic policy objective in the biofuel area, can conflict with forest conservation ambitions. It is, to put it simply, not possible to burn a forest and at the same time conserve it for future generations. This is an example of how two different - eachworthwhile - environmental objectives may conflict. The basic reason for such conflicts is that the underlying resource -- in this case, the forest -- is limited.

Swedish environmental policy is in large part informed by the 16 environmental objectives established by the Swedish Parliament (the Riksdag) in 1998 (Swedish Parliament, 1998). Several directly or indirectly affect the management of the forest and the use of primary forest products. This should come as no surprise given that 23 million of Sweden's 43 million hectares are covered by forest[1]. The forest sector is a very important part of the Swedish economy. In 2007 the value of all Swedish exports was 1,200 billion million SEK. Of this value 127 billion SEK, or 11 percent of total exports, originated from the forestry and forest industry sector of the economy.

Two of Sweden's environmental objectives are *Sustainable Forests* and *Reduced Climate Impact*. These environmental objectives are specified in a number of concrete sub-goals making it possible to analyze and present a number of different scenarios. The *Sustainable Forests* objective states that an additional 900,000 hectares of forestland of high conservation value[2] should be excluded from forest production by the year 2010. Furthermore, by 2010 the amount of hard dead wood on all forestlands should increase by at least 40 percent, the area of mature forest with a large deciduous element should increase by at least 10 percent, and the area of old forest should be increased by at least 5 percent. Measures to reach this environmental objective will imply that the area of forest land available for timber production

[1] Sweden has 23 million hectares of forestland according to the domestic definition by the Swedish National Forest Inventory, but almost 28 million hectares according to the international definition by the FOA (Food and Agriculture Organization).
[2] Conservation value is determined by the area's cultural, social (e.g. recreation) and environmental features. The environmental concerns are mainly in line with the Swedish obligations in accordance with the UN Convention on Biological Diversity and the Sixth Environment Action Programme of the European Community, "Environment 2010: Our future, Our choice".

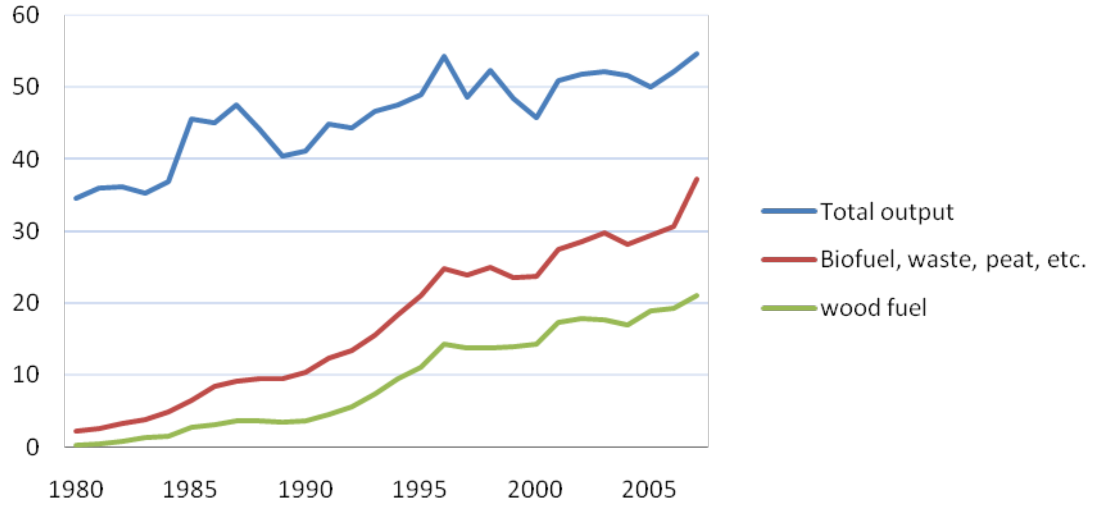
will decrease. As a result, the total volume of primary products from the forest will be reduced, *ceteris paribus*.[3]

The environmental objective *Reduced Climate Impact* states that, as an average for the period 2008–12, Swedish emissions of greenhouse gases should be at least 4 percent lower than in 1990. Emissions are to be calculated as carbon dioxide equivalents and include the six greenhouse gases listed in the Kyoto Protocol and defined by the IPCC (Intergovernmental Panel on Climate Change). In assessing progress towards the target, no allowance is to be made for uptake by carbon sinks or for flexible mechanisms (Miljömålsportalen, 2004). This environmental objective is to be achieved by economic policy measures such as increased taxes on fossil fuel energy sources, and/or quota systems for electricity and fuels (which mandate a certain share of renewable energy supplies. This implies that energy intensive sectors that can substitute away from non-renewable fuels will likely do so. Power and district heating plants in Sweden, which tend to have good fuel substitution possibilities, have largely switched to renewable energy sources.

A historical overview clearly shows that biofuels have had an increasing role in the Swedish energy system in the last 25 years, especially within the heating sector. In 1980, the use of biofuels, waste, peat, etc., accounted for less than 7 percent of the primary energy input for district heating. Twenty-seven years later, the corresponding share has increased by almost ten times, to approximately 69 percent. A large part of this shift can be traced to the increased use of wood fuels. In 1980, the use of wood fuels only amounted to 0.3 TWh, or less than one percent of total input, rising to 21 TWh, or almost 40 percent of the total input by 2007 (Swedish Energy Agency 2008). Based on available forecasts and scenarios (Swedish Energy Agency 2007), this positive trend for the use of biofuels, especially wood fuels, is likely to continue. Part of the explanation lies in the expected continued expansion of district heating -- largely based on wood fuels -- as well as general increases in other sectors. A driving force in the latter is both domestic and European climate policy, which aims to increase biofuel use in the transport sector[4].

[3] This is certainly true in the short run. In the long run we cannot rule out that the decrease in supply is at least partially compensated for by an increase in productivity on the remaining forest land.
[4] Further reading about the driving forces behind the development of forest energy in Sweden can be found in Björheden (2006)

Energy input for district heating in TWh.



The Swedish forest sector has been subject to a number of econometric analyses. The most recent include Bergman & Brännlund (1995), Brännlund & Kriström (1996), Ankarhem *et al.* (1999), Lundgren & Sjöström (1999), Brännlund & Kriström (2001), Brännlund *et al.* (2004), Sjöström (2004) and Ankarhem (2004).

There are also several studies of the economic consequences on the forest sector of increased forest conservation. Studies performed on the Finnish forest sector include e.g. Hänninen and Kallio (2007), Leppänen *et al*. (2005), and Linden and Uusivuori (2002). These studies conclude that forest conservation impacts supply, demand and prices in the Finnish round wood market. In Leppänen *et al*. (2005), and Linden and Uusivuori (2002), the supply of the wood assortments under consideration decreased and their corresponding prices increased, as the available timber stock decreased through forest conservation. The same pattern could be found in Linden and Uusivuori (2002) concerning saw logs, but both price and supply increased for pulp wood. This finding was due to pulp and paper production remaining at their base levels, while the demand for pulpwood increased as a consequence of the reduced supply of sawlog chips.

Bolkesjø et al (2005) investigated the economic impacts on timber and forest product markets of increased forest conservation in another Scandinavian country Norway. Their results suggest that the effect on prices and production would be substantionally higher if conservation was not only carried out in Norway, but abroad as well. Focusing on Western Europe, Kallio et al (2006) find that conservation raises prices -- and decreases traded quantities -- of different round wood assortments. In Sohngen et al (1999), the economic effects of large European and North American conservation policies are analyzed in the (extreme) long run, resulting in a forecast spanning nearly 150 years.

A shortcoming in the available literature – with the exception of Ankarhem *et al.* (1999) and Ankarhem (2004) - is that the supply and demand for wood fuels, and its interplay with other wood assortments, is rarely analyzed within the framework of a consistent forest sector model. There are a number of reasons for this. Besides the lack of good data, a problem arises because wood fuels are often regarded as a forest by-product. If this by-product always a constant share of the main products, then there is little point in doing a deeper analysis, since the quantity can be determined as a residual. However, there are very strong reasons to believe that the supply of wood fuel is not only a byproduct, independent ofenergy prices and prices on other wood assortments. Thus, we develop a forest sector model that takes wood fuel explicitly into account.

The purpose of this paper is to analyze the potential goal conflict between two Swedish environmental objectives -- *Sustainable Forests* and *Reduced Climate Impact.*. The main reason for studying this issue is that the presence, or non-presence, of goal conflicts has implications in a cost-benefit analysis. If there is a goal conflict in the sense that measures taken to fulfill one specific target negatively affect the possibilities to fulfill another specific target, then the costs for reaching the target will be underestimated. The implication is of course that if we fail to consider such goal conflicts, targets may be set in a non-optimal way. To study this issue we extend the econometric forest sector model presented in Ankarhem et. al. (1999). This model includes demand and supply of the major wood assortments, implying that most market interactions within the forest sector is taken into account. The model is then used to assess effects on the whole forest sector and forest industry of an increase in forest conservation. The key feature of the model is its general equilibrium setting which can account for market interactions within the entire forest sector. Of specific interest in this study is the extent to which forest conservation affects the supply of wood fuel (and other wood assortments), and hence the possibilities to replace fossil fuels with wood fuel in the Swedish energy system. This in turn affects the possibilities to reach the Swedish climate policy objective. In contrast with the previous studies, this data set has been updated to 2006 (the latest year available at the time of study), resulting in a time series of no less than 40 years.

The rest of the paper is structured as follows. Section 2 introduces our model of the Swedish forest sector. This is followed in Section 3 by a presentation of the empirical specification and the data. The empirical results are presented and discussed in section 4. Finally, section 5 concludes with a discussion of policy implications and options for future research.

2. The forest sector model

The forest sector model we use is a modified version of the models used in Ankarhem et al. (1999). The model differs from Ankarhem et al. (1999) not only in the updated data set, but also in the sense that we allow for technological development, and that we allow for lags in the adjustment to price changes. This means that if a price changes, demand does not necessarily adjust completely within one period. This also means that we can estimate both short run (within one year) and intermediate run effects.

It is worth pointing out that potentially important feedbacks in certain markets are missing in the model, such as the sale of wood chips from the sawmills to the fiber board industry and the energy sector, as well as the flow of wood chips between the sawmill and pulp industry[5]. It is well known that there is competition between the fiber board industry and the energy sector for chips from sawmills, although this competition cannot be analyzed within this model. However, in the analysis of the different scenarios this competition will be analyzed qualitatively.

The model consists of four actors. The first actor is the forest owners who supply three types of raw forest material: pulpwood, saw timber and wood fuels. The forest owners are assumed to choose the quantities of different assortments that maximize profits at given prices. This is made conditional on the forest assets and cutting costs. The remaining actors in the model are the ones using raw materials from the forest as an input in their production process; the pulp industry, the sawmill industry and the heating industry.

Thus, there are four separate but related industries: pulp, sawmills, the heating industry and forestry. We assume perfect competition in all these industries, as well as fixed capital stocks in the short run. Furthermore, we assume profit maximizing behaviour.

The specification of the forest owner's decision problem is conventional. We assume that a forest owner is supplying three different products: pulpwood which is used as an input in the pulp industry, saw timber which is used as an input in the sawmill industry, and wood fuel which is used in the heating industry. Labour is viewed as a flexible input while forest capital

[5] A study of the interdependence between the saw log, pulpwood and saw mill chip markets in Finland can be found in Kallio, (2001).

is regarded as fixed, at least in the short run. Given the assumptions of profit maximizing behaviour and perfect competition, the forest owners profit function can be written as:

$$\Pi^f = \Pi^f(p_{pw}, p_{st}, p_{wf}, p_{fl}; \bar{K}_f), \tag{1}$$

where p_{pw}, p_{st}, and p_{wf} are the prices of pulpwood, saw timber, and wood fuel respectively, p_{fl} the wage rate in forestry, and $\bar{K}_f$ the fixed forest capital. Applying Hotelling's lemma to (1) we obtain the supply of pulpwood, saw timber, and wood fuel, as well as the demand for labour in forestry: denoted y_{pw}, y_{st}, y_{wf} and x_{fl} respectively in the sequel.

The specification in (1) suggests that at least some of the cross price effects should be negative. The argument is that an increase in, for example, the price of wood fuel would transfer some of the wood -- which otherwise could be sawn or used by the pulp industry -- to the market for wood fuel. There is, in addition, an effect which stems from the fact that a higher price for pulpwood makes a thinning more profitable than before. This will persuade some of the forest owners to carry out a thinning instead of a final felling, which in turn will decrease the supply of saw timber. We cannot, however, rule out the possibility that some of cross-price effects are positive, implying complementarity between any two products. The signs and magnitudes of these cross-price effects are, however, an empirical issue which we will return to below.

Applying Hotelling's lemma to (1) gives us the supply of the three assortments of wood, y_{pw}, y_{st}, y_{wf}, and the derived demand for the flexible factors of production, x, as:

$$y_i(p_{pw}, p_{st}, w_{wf}, p_{fl}; \bar{K}_f) = \frac{\partial \Pi^f}{\partial p_i}, \quad i = pv, sv, fv \tag{2}$$

$$x_{fl}(p_{pw}, p_{st}, p_{wf}, p_{fl}; \bar{K}_f) = -\frac{\partial \Pi^f}{\partial p_{fl}} \tag{3}$$

Concerning the pulp mills we assume that they make use of labour, energy and capital to convert pulpwood into pulp. For the forest owner, we assume that the pulp mills maximize profits and operate on a perfect market. Given this, we write the profit function for a representative pulp firm as:

$$\Pi^p = \Pi^p(p_p, p_{pw}, p_{pl}, p_{pe}; \bar{K}_p) \tag{4}$$

where p_p is the price of the final product (pulp) and p_{pi} are the prices of the inputs in the production of pulp. The subscripts $i = w,l,e$ refer to inputs of pulpwood, labour and energy respectively. Finally, $\overline{K}_p$ is the fixed capital stock.

Again, applying Hotelling's lemma to (4) gives us the supply of pulp, y_{pw}, and the derived demand for the flexible factors of production, x_{pi} (i = w, l, e).

In the same way sawmills are assumed to supply one output (sawn wood), using labour, energy, saw timber and capital as inputs. As for the pulpmills, labour, energy and saw timber are assumed to be flexible inputs while capital is regarded as fixed. The profit function for a representative sawmill is then defined as:

$$\Pi^s = \Pi^s(p_s, p_{st}, p_{sl}, p_{se}; \overline{K}_s) \tag{5}$$

Where p_s is the price of sawn wood and p_{si} are the input prices. The subscripts $i=t,l,e$ refer to saw timber, labour and energy respectively. Finally, $\overline{K}_s$ is the fixed capital stock. The supply function (y_{st}) and the derived demand functions (x_{si}) for the sawmills can again be obtained via Hotelling's lemma.

Similarly, heating plants are assumed to supply heat (and/or electricity), using labour, primary energy in the form of oil and/or wood fuels, and capital as inputs. Wood fuel and fossil fuels are assumed to be flexible inputs while capital is regarded as fixed. The profit function for a heating plant is then defined as:

$$\Pi^h = \Pi^h(p_h, p_{wf}, p_{hl}, p_{hf}; \overline{K}_h) \tag{6}$$

We proceed by defining market equilibrium conditions for pulpwood, saw timber and wood fuel.

$$\sum_{i=1}^{m_1} x^i_{pw}(p_p; p_{pw}, p_{pl}, p_{pe}, \overline{K}_p) = \sum_{i=1}^{n} y^i_{pw}(p_{pw}, p_{st}, p_{wf}; p_{fl}, \overline{K}_f) \tag{7}$$

$$\sum_{i=1}^{m_2} x^i_{st}(p_s; p_{st}, p_{sl}, p_{se}, \overline{K}_s) = \sum_{i=1}^{n} y^i_{st}(p_{pw}, p_{st}, p_{wf}; p_{fl}, \overline{K}_f) \tag{8}$$

$$\sum_{i=1}^{m_3} x_{wf}^{i}(p_h; p_{wf}, p_{hl}, p_{hf}, \overline{K}_h) = \sum_{i=1}^{n} y_{wf}^{i}(p_{pw}, p_{st}, p_{wf}; p_{fl}, \overline{K}_f), \tag{9}$$

where n is the number of forest owners, m_1 is the number of pulp-producing firms, m_2 the number of sawmills, and m_3 the number of heating plants.

Solving (7), (8) and (9) for p_{pw}, p_{st}, and p_{wf} respectively, gives the reduced form for the equilibrium prices of pulpwood, saw timber and wood fuel. Let p_{pw}^{*}, p_{st}^{*} and p_{wf}^{*} denote these equilibrium prices, and let $\tilde{p}_f$, $\tilde{p}_p$, $\tilde{p}_s$ and $\tilde{p}_h$ denote vectors of input and output prices (other than wood), referring to forestry, pulp, sawmill and heating industries, respectively, and $\overline{K}_i$ is a vector including the capital stock in each industry.

We can now define the industry, or aggregate, profit functions as:

$$\tilde{\Pi}^f = \tilde{\Pi}^f(p_{pw}^{*}, p_{st}^{*}, p_{wf}^{*}, \tilde{p}_f; \overline{K}_f) \tag{10}$$

$$\tilde{\Pi}^p = \tilde{\Pi}^p(p_{pw}^{*}, \tilde{p}_p; \overline{K}_p) \tag{11}$$

$$\tilde{\Pi}^s = \tilde{\Pi}^s(p_{st}^{*}, \tilde{p}_s; \overline{K}_s) \tag{12}$$

$$\tilde{\Pi}^h = \tilde{\Pi}^h(p_{wf}^{*}, \tilde{p}_h; \overline{K}_h) \tag{13}$$

These equations incorporate all the possible indirect effects that we allow for in this study, and which we have described earlier in this section. Input factors used in forestry or in the demand side industries -- but not included in the model -- are assumed to be utilized according to a fixed input-output ratio. To estimate the parameters in the profit functions, we need to parameterize the model. This will be done in the next section.

3. Empirical specification and data

To parameterize the model we assume that the technology in each industry can be represented by a restricted Generalized Leontief (GL) profit function, which is a second order differential approximation of any arbitrary profit function (see Diewert 1973). Given the specific functions and estimates of the parameters, the calculation of elasticities is straightforward.

As shown previously, by applying Hotelling´s lemma to the profit functions, we obtain an equation system consisting of three supply functions for the forest owners - one for each assortment – and a set of demand functions for wood, labour and energy in the pulp, sawmill and heating sectors, respectively. To estimate the model taking into account the market equilibrium, we must estimate at least six equations:[6] three supply equations from forestry, and one demand equation for wood in each wood-consuming industry. Given GL profit functions, these six derived demand and supply functions become :

Forestry – supply of wood assortments

$$y_{i(t)} = \sum_j \alpha_{ij} \left(\frac{p_{j(t)}}{p_{i(t)}} \right)^{\frac{1}{2}} + \alpha_{ik} K_{f(t)} + \alpha_{it} t \qquad (14)$$

$$i = st, pw, wf \quad j = st, pw, wf, l$$

Sawmills – demand saw timber

$$-x_{st(t)} = \sum_j \beta_j \left(\frac{p_{j(t)}}{p_{st(t)}} \right)^{\frac{1}{2}} + \beta_k K_{s(t)} + \beta_t t + \beta_{x-1} x_{st(t-1)} \qquad (15)$$

$$j = s, st, sl, se$$

Pulp industry – demand pulpwood

$$-x_{pw(t)} = \sum_j \lambda_j \left(\frac{p_{j(t)}}{p_{pw(t)}} \right)^{\frac{1}{2}} + \lambda_k K_{p(t)} + \lambda_t t + \lambda_{x-1} x_{pw(t-1)} \qquad (16)$$

$$j = p, pw, pl, pe$$

[6] We have six endogenous variables (three prices and three quantities), which demands at least six equations.

Heating industry – demand wood fuel

$$-x_{wf(t)} = \sum_j \delta_j \left(\frac{p_{j(t)}}{p_{wf(t)}} \right)^{\frac{1}{2}} + \delta_k K_{h(t)} + \delta_t t + \delta_{x-1} x_{wf(t-1)} \qquad (17)$$

$$j = h, wf, hl, hf$$

where subscript t denotes time. This specification deviates from a standard GL specification by the inclusion of a linear technological progress term (t), and a partial adjustment term ($x_{i(t-1)}$). Together with the equilibrium conditions these equations constitute our estimated model used in the analysis below.

We rely on annual time series data, spanning the 40-year period, 1966–2006. Most of the data are collected from Swedish statistics (e.g., Statistics Sweden, the Swedish Forest Agency, the Swedish Energy Agency or the Swedish University of Agricultural Sciences).

As expected, this relatively long time period leads to some heterogeneity in the data (e.g., which agency collects the data, what they measure and how they measure it). As a result, two subseries of data have sometimes had to be fitted against each other with help of a scalar, e.g. the cost of electricity and the real capital stocks for sawmills and the pulp industry. Descriptive statistics of the data set are displayed in Table 1. The reason for the chosen time period is based on the availability of relevant variables for our study.

Gross felling destined for sawmills, the pulp industry and the heating industry is used as the supplied (and demanded) quantities. The corresponding prices are the average domestic price for saw timber, pulpwood and wood fuel. Unfortunately, data for the supply of wood fuel has not been collected annually. To fill the gaps, the agency responsible for collecting these data (the Swedish Forest Agency) has chosen to present the same amount over multiple years rather than attempting to approximate the change using other sources of information. This problem is handled in two steps. First, for the last seven years, we approximate the change in the total supply of wood fuel based on the change in wood fuel usage in the heating sector. Secondly, we add a variable for last year's supply of wood fuel to its supply function.

Table 1: Descriptive statistics.

Sector	Variable	Unit	Mean	St. Dev	Min	Max
Forestry						
Sawtimber supply	y_{st}	M. m^3	26.55	6.80	19.0	56.5
Pulpwood supply	y_{pw}	M. m^3	25.78	3.89	20.5	36.9
Woodfuel supply	y_{wf}	M. m^3	3.36	1.61	1.2	5.9
Sawtimber price	p_{st}	SEK/m^3	481.69	110.77	279.1	761.2
Pulpwood price	p_{pw}	SEK/m^3	309.81	74.86	184.7	495.1
Wood fuel price	p_{wf}	SEK/m^3	339.08	100.19	198.2	557.7
Timber stock	K_f	M. m^3	2701.80	269.06	2330.7	3230.0
Sawmills						
Output price	p_s	SEK/m^3	1850.00	273.17	1437.7	2647.4
Energy price	p_{se}	SEK/MWh	41.14	9.32	21.9	54.8
Labor price	p_{sl}	SEK/hour	97.56	9.75	71.9	115.5
Capital	K_s	M.SEK	20843	5938	8K	29K
Pulp industry						
Output price	p_p	SEK/K.kg	4141.38	918.86	2882.3	6649.4
Energy price	p_{pe}	SEK/MWh	25.57	4.89	18.6	38.5
Labour price	p_{pl}	SEK/hour	116.06	14.71	75.8	139.9
Capital	K_p	M.SEK	40403	9429	19K	49K
Heating industry						
Output price	p_h	SEK/MWh	324.17	73.70	211.4	448.5
Fossil fuel price	p_{hf}	SEK/MWh	107.61	44.21	37.6	211.9
Labour price	p_{hl}	SEK/hour	115.76	14.46	81.7	144.9
Capital	K_h	M.SEK	33367	10254	16K	46K

Note: The supplied quantities and output prices in the forest sector are also included as demanded quantities and input prices for respective demand side sector. The two variables $x_{i(t-1)}$ ($i = st,pw,wf$) and (t) for lags in the adjustment to price changes and technologic growth is also included for respective demand side sector. All prices are expressed at the 2000 level.

The price for both energy and labour in the wood-using industries is calculated implicitly from industry-specific cost and quantities, except for the last years where data concerning wages within different occupations have been used to approximate the wage rate. Since we lack data on the wage rate within forestry, the wage rate from the sawmill industry is used as a proxy. Export prices for (sawn and planed) softwood and wood pulp (sulphate - unbleached) are used as output prices for sawmills and the pulp industry. For the energy industry we have used an implicit output price defined as the ratio between the total revenue from delivered heating and the delivered quantities. All prices are normalized with respect to the consumer price index.[7]

Standing inventory of timber is used as real capital stock for the forest owners. In the demand side real capital to each industry consists of the value of machines and buildings. For the heating sector we have used (one tenth of) the value of the entire energy industry's capital as a proxy for the development of capital in the heating industry.

[7] Note that the demand functions in the GL system are functions of relative prices, making normalization unnecessary for estimation purposes.

4. Estimation results

The parameters are estimated with three stage least squares (3SLS), where all the exogenous variables are used as instruments. One of the main advantages with system estimating methods like 3SLS, compared to single equation methods, is that it uses all of the available information in its estimates and therefore gives a smaller asymptotic variance-covariance matrix. The 3SLS estimator is generally asymptotically more efficient than two stage least squares (2SLS) estimators and is, in the limiting case where the demand and supply equations are uncorrelated, reduced to exactly a 2SLS estimate (Kennedy, 1998). Prior to estimating the system, we include a dummy variable for the 2005 storm "Gudrun" in all the supply functions (parameter α_{iG}, $i=s,p,w$). Since more than seventy-five million cubic meters of trees were felled by the storm, this event naturally affected the supply of forest products. We also include a dummy for the first oil crisis (1973-1974) in the supply function for wood fuel (parameter α_{wOC}), and a dummy for the Swedish financial crisis (1992-1994) in the demand function for forest fuel (parameter δ_{hV}). We also impose symmetry in the supply functions of forestry products by requiring that $a_{ij} = a_{ji}$, $i, j = st, pw, wf$. Variance and standard errors are computed by White´s heteroscedasticity corrected standard errors.

Table 2 presents the estimated coefficients and White´s heteroscedasticity corrected standard errors.

Table 2: Three stage least squares parameter estimates of the Swedish forest sector model.

Forestry								
Sawtimber			Pulpwood			Wood fuel		
Par.	Est.	s.e.	Par.	Est.	s.e	Par.	Est.	s.e.
α_{ss}	74.82	519.53	α_{pp}	1753.9	511.7*	α_{wh}	21.00	7.20*
α_{sp}	-1.02	5.09	α_{ps}	-1.02	5.09	α_{ws}	-20.0	4.00*
α_{sw}	-20.0	4.00*	α_{pw}	-1.84	3.55	α_{wp}	-1.84	3.55
α_{sl}	-5.00	20.06	α_{pl}	-5.95	14.58	α_{wl}	29.32	8.47*
α_{sk}	0.015	0.014	α_{pk}	0.037	0.013*	α_{wk}	-.37E-2	0.002*
α_{st}	-0.035	0.278	α_{pt}	-0.92	0.27*	α_{y-1}	0.99	0.16*
α_{sG}	23.11	1.83*	α_{pG}	7.81	1.35*	α_{wG}	-4.78	0.96*
						α_{wOC}	3.92	0.93*
R^2 = 0.88			R^2= 0.45			R^2 = 0.75		

Sawmills			**Pulp Industry**			**Heating Industry**		
Par.	Est.	s.e.	Par.	Est.	s.e	Par.	Est.	s.e.
β_{st}	-179.0	635.0	γ_{pw}	333.5	376.0	δ_{wf}	1.74	0.85*
β_{s}	-10.0	7.87	γ_{p}	-2.90	1.10*	δ_{h}	-1.17	1.17
β_{se}	100.3.	31.9*	γ_{pe}	-14.5	16.6	δ_{hf}	-0.32	0.86
β_{sl}	-98.85	41.60*	γ_{pl}	13.9	17.4	δ_{hl}	-1.29	1.39
β_{k}	.37E-3	.31E-3	γ_{k}	.30E-3	.12E-3*	δ_{k}	-.92E-5	.86E-5
β_{x-1}	-0.05	0.13	γ_{x-1}	-0.19	0.07*	δ_{x-1}	-0.85	0.14*
β_{t}	0.09	0.33	γ_{t}	-0.18	0.19	δ_{hV}	0.13	0.33
R^2 = 0. 66			R^2 = 0.48			R^2 = 0.95		

Note: * denote significance at the five percent level. For all subscripts of parameters α, s=st, p=pw and w=wf.

Around half of the parameters are significantly different from zero at the five percent level. The reader should remember that the demand side estimates are the negative of the parameters' effect on demanded quantity. The parameters for the lags in the adjustment to a price change are thus positive and indicate that the long-term effect is larger than the short-term effect. Capital appears to be a substitute for wood input in both the sawmills and the pulp industry, but is a complement in the heating industry. According to the estimates, the storm Gudrun caused a rather big increase in the supply of saw timber and pulpwood, but decreased the supply of wood fuel. This seemingly strange result for the wood fuel supply might partly be explained by the high average temperature during 2005, which might have decreased the overall need for heating and thus demand for all types of primary energy. Since the model specification does not really allow for any easy interpretation of the size of the parameters alone, we will instead turn to the short and long run elasticities.

In Table 3 we use these parameter estimates to calculate the short and long run elasticities. We have chosen to evaluate all elasticities at the average value of all variables between 2000 and 2004. Our reasoning is as follows: Since we want to forecast future changes in relative prices and quantities, and assume that the future relative prices and quantities, without any new policy measures, will be closer to the recent ones than, say, the relative prices and quantities during the eighties, we want to base the calculations on as present relative prices and quantities as possible. On the other hand, there is a lot of variation over the years, which means that the relative prices and quantities during a single year might be a bad estimate. Finally, the reason we choose the average values between 2000-2004, instead of the average of the last five year period of our dataset, is to avoid oddities in the data from the supply chock caused by the storm Gudrun in 2005.

Table 3: Elasticities for supply and demand of sawtimber, pulpwood and wood fuel, evaluated at the average prices and quantities for year 2000-2004.

Supply Forestry				
	P_{ST}	P_{PW}	P_{WF}	P_{Labour}
Saw timber	0.28*	-0.01	- 0.22*	-0.04
Pulpwood	-0.03	0.14	-0.04	-0.08
Wood fuel	-1.85*	-0.13*	0.55*	1.43*

Demand Sawmills								
	$P_{Sawn\ goods}$		P_{ST}		P_{Energy}		P_{Labour}	
	SR	LR	SR	LR	SR	LR	SR	LR
Saw timber	0.31	.33	-0.71	-.75	-0.38*	-.41*	0.77*	0.81*

Demand Pulp Industry								
	P_{Pulp}		P_{PW}		P_{Energy}		P_{Labour}	
	SR	LR	SR	LR	SR	LR	SR	LR
Pulpwood	0.23*	.38*	-0.12	-.15	0.09	.11	-0.20	-.25

Demand Heating Ind.								
	P_{Heat}		P_{WF}		P_{Oil}		P_{Labour}	
	SR	LR	SR	LR	SR	LR	SR	LR
Wood fuel	0.11	.73	-0.20	-1.33	.02	.13	0.07	.47

Note: * denote significance at the five percent level; SR = short run, LS = long run, P_{ST} = Price sawtimber, P_{PW} = Price pulpwood, P_{WF} = Price wood fuel,

All the own price elasticities have the expected signs, i.e. the supply of a specific forest product is increasing, and the demand is decreasing, with respect to its own price. Of the three forestry products, the supply and (long-term) demand of wood fuel seem to be most sensitive to a price change. The supply and demand of saw timber is somewhat less elastic with respect to its own price and, unlike the case of wood fuel, the majority of the adjustment appears to take place within a year. Finally, the supply and demand of pulpwood seems to be rather inelastic. Also, all of the forest products are substitutes to one another – indicating that the profit maximizing forest owner not only has to deal with the question “cut or not to cut”, but also has to make decisions concerning the mix of assortments to supply. This result is consistent with results from previous research, e.g Ankarhem et al. (1999).

A majority of the remaining elasticities also have the expected signs. Demand for forest input is increasing for all the demand side industries, as the price of their output is increasing. The cost of logging has the expected sign in two out of three cases, but the supply of wood fuel obviously should not increase with the cost of labour. Furthermore, the fact that wood fuel and saw timber appear to be substitutes for labour in the heating industry and for sawmills is somewhat unintuitive. In sawmills and pulp factories you would expect the demand for energy to be a complement to the demand for forestry input, and thereby decrease as the price of energy increases. In this case only the parameter for sawmills is carrying the expected sign. For the energy sector, oil is instead a substitute to wood fuel, which is intuitively correct.

4.2. Simulation

In the final stage, the estimated parameters are used to simulate the effects of implementing the environmental objectives *Sustainable Forests* and *Reduced Climate Impact*. More specifically we focus on the issue of a potential goal conflict between conservation of forest land and the supply of wood fuel. As previously stated, one of the interim targets within the environmental objective *Sustainable Forests* is to exclude a further 900.000 hectares of forest land from production by the year 2010. Given a total of 23 million hectares of forest land in Sweden, this objective aims ostensibly to exempt four percent of the total forestland from production. However, there are primarily, two reasons why this might be an overestimate of the lost timber inventory. First, some of this forestland is already excluded from production because of recreational use, military training, existing environmental protections etc – albeit a rather small part of total forestland. The second reason is that forests of high conservation value are often forests that are relatively untouched by human activityimplying that it is not likely to be the most profitable forest land to begin with. To simplify, we will approximate by assuming a three percent reduction in the total inventory of standing timber, which assumes that the ratio of forestland profitable for logging is 25 to 30 percent lower than average[8].

[8] Even if the amount of forest profitable for logging of course depends on the prices of forestry products, and therefore might be bigger *post* conservation than *pre* conservation.

The simulation is then done by reducing the standing inventory of timber by 3 percent, and solving for new equilibrium prices and quantities given the short and long run equations and equilibrium conditions.

Table 4: Simulation of a 3 percent decrease in the standing inventory of timber, based on the Swedish environmental objective *Sustainable Forests*.

		Short run		Long run	
		Absolute change	**% Change**	**Absolute change**	**% Change**
Saw timber	Δ *Supply*	-3.20	-9.48	-1.60	-4.72
	Δ *Price*	56.35	14.89	25.02	6.62
Pulpwood	Δ *Supply*	-1.71	-6.67	-1.78	-6.96
	Δ *Price*	200.21	91.01	153.50	69.80
Wood Fuel	Δ *Supply*	-0.46	-6.43	-0.68	-9.52
	Δ *Price*	94.27	42.94	17.01	7.75
TOTAL	Δ *Supply*	**-5.37**	**-8.07**	**4.06**	**-6.11**

Note: Absolute change in supply in M. m^3, and in prices in SEK/m^3.

According to the simulation, a decrease in the stock of standing timber will lead to a decrease in the supply of all roundwood assortments, and an increase in all roundwood prices. As expected, the price of pulpwood will increase the most because of the inelastic demand with respect to its own price. Since the demand for wood fuel is also quite inelastic in the short run, its own price will rise sharply as well. The biggest decrease in supplied quantity will, in the short run, occur in the market for saw timber. The reason for this is partly due to the relatively high own price elasticity with respect to demand, but primarily due to the cross-price effect with respect to the price of wood fuel. In fact, in the long run, half of the initial decrease in supplied saw timber will be restored due to falling prices on wood fuels. Even though the price of wood fuel adjusts downward, the long run own price effect is sufficiently high to cause a further decrease in the demand for wood fuel.

As mentioned earlier this model neglects the flow of chips from the sawmills to the fiber board industry and the energy sector. In the scenario above it is likely that the fiber board industry will be affected as well. The reason is that the sawmills will be able to shift part of the price increase on saw timber to the fiber board industry and the energy sector in the form of higher prices on chips. This implies that the sawmills can compensate themselves to some extent for the price increase in raw material through the sale of a by-product.

In total, the simulation results in a 6.4 percent decrease of supplied wood fuel (eight percent decrease of supplied roundwood) in the short run and about 9.5 percent (6.1 percent roundwood) decrease in the long run. According to the Swedish Energy Agency, the usage of wood fuels in district heating plants contributed with an energy output of 21 TWh in the year 2007. If the output of energy decreases in the same amount as the input of wood fuel, a 9.5 percent decrease in wood fuel supply will decrease the output from district heating plants by two TWh. If (crude) oil is used as a substitute the emissions of carbon dioxide will *increase* by 600.000 tones.[9] These emissions would amount to almost 1.16 percent of Sweden's total emissions of carbon dioxide, or 0.92 percent of Sweden's emissions of greenhouse gases calculated as carbon dioxide equivalents. This can be contrasted with the ambition stated in the environmental objective *Reduced Climate Impact* to reduce emissions of greenhouse gases by four percent.

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[9] - We use the guidelines from the IPCC (2006) to calculating the carbon dioxide emissions from oil and assume 90 percent thermal efficiency.

5. Discussion

Goal conflicts are all too common in environmental policy. Decisions are made that society should strive towards reaching, individually, worthwhile goals without contemplating whether these goals may actually be contradictory. One consequence of goal conflicts of the type illustrated here is that the cost of achieving a specific individual target may be underestimated if no effort is made to account for such conflicts. One practical implication is that a cost-benefit analysis of different target levels for a specific environmental objective will be contingent on target levels for other environmental objectives. Thus, environmental policy should be viewed in a comprehensive way that includes all environmental objectives that affect our resource use. This paper has analyzed the potential goal conflict between the Swedish environmental objectives *Sustainable Forests* and *Reduced Climate Impact.* We assessed the possible effects of implementing the objective *Sustainable Forests* on the supplied quantity of biofuel from the forest sector which then impacted the national target for greenhouse gas emissions.

The analysis reveals an intricate interplay between different submarkets within the forest sector. Climate policy, through the environmental objective *Reduced Climate Impact*, increases the demand for biofuels. Simultaneously, the environmental objective *Sustainable Forests* will reduce the supply of raw material from the forest. Based on a data set that spans 40 years our results show that all the own price elasticities have the expected signs. Of the three forestry products, the supply and (long-term) demand of wood fuel seems to be most sensitive to a price change. This means that a three percent reduction in the total inventory of standing timber, as a consequence of an implementation of the objective *Sustainable Forests*, will lead to price increases in all three forest markets: pulp wood, saw timber, and wood fuels. Should the price increase in wood fuels lead to a substitution in favour of oil in district heating plants, it implies that a fulfilment of current conservation goals could lead to an increase in the Swedish emissions of greenhouse gases by almost 0.92 percent, which can be contrasted with the Swedish ambition to *reduce* emissions of greenhouse gases by 4 percent. Another way to put it is that a fulfilment of both objectives implies that additional measures have to be taken to fulfill the greenhouse gas reduction objective. However, this will take resources. From a cost-benefit view this means that the cost of conservation will be underestimated if we fail to take into account that forest conservation implies less quantities of biomass that can be used (among other things) for replacing fossil fuels.

It should be remembered that although the three major forest markets in Sweden -- pulp wood, saw timber, and wood fuels -- are captured in the forest sector model, it does not include all flows between the markets. One such important flow is the flow of chips from the sawmills to the fiber board industry and the energy sector. Furthermore, many of the estimated parameters had large standard errors and often were not statistically significant explanatory variables, but were still a part of the 3SLS model used in the simulation. Furthermore, the coarse resolution of the model and the absence of a spatial dimension make it less suitable for studying regional consequences and goal conflicts connected to the objective *Sustainable Forests*. This will be addressed in future research.

That the economic consequences of Sweden's environmental objectives have not been estimated, and that the analytical basis for political decisions thus is largely missing, has been pointed out by others. This paper - a small contribution to filling this gap – shows that a serious goal conflict between the environmental objectives *Sustainable Forests* and *Reduced Climate Impact* exists. Future research will undoubtedly reveal others.

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