Goal Conflicts and Spillover Effects in Swedish Environmental Policy

Erik Geijer
Faculty of Forest Sciences
Department of Forest Economics
Umeå

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Abstract

This thesis consists of a summary and four appended papers on conflicts in inter-related goals in Swedish environmental policies and projects.

Paper I analyses conflicts between two of these goals *Reduced Climate Impact* and *Sustainable Forests* or, more precisely, the conflict between conserving forests and supplying forest fuel. This is done with the help of a forest sector model including four actors: forest owners, sawmills, the pulp industry and the heating industry. The parameters of the model are estimated, and then used to simulate effects of additional forest conservation actions on forest fuel supplies. According to the results, protection of an additional four percent of forest land would lead to a decrease in the supply of forest fuel, and can lead to an increase in Swedish emissions of carbon dioxide from non-renewable sources by about 0.9 percent.

Paper II examines another goal conflict, between the two Swedish environmental goals maintaining *A Rich Diversity of Plant and Animal Life* and *Increasing Use of Renewable Energy Resources* or, more precisely, effects of stump harvests on forest fuel supplies and the abundance of saproxylic beetles in northern Sweden. The analysis uses a model similar to the one described and applied in Paper I, but parameter estimates are derived from regional data. According to the results, large-scale implementation of stump harvests would result in a 3% increase in the use of renewable energy sources in heating plants, but a 5% reduction in abundance of saproxylic beetles on future clear cuts, compared to a scenario with no stump harvests.

Paper III describes the wind power park on Smöla, Norway, and examines the conflict between clean energy generation and protection of the island's white-tailed eagle (WTE) population. The paper presents a Resource Equivalence Analysis (REA) addressing the required compensation for damage done to the WTE population. It also contains some general remarks on the practical implementation of REAs.

Paper IV considers eutrophication, and the two interconnected sub-goals of nitrogen and phosphorus reduction. The paper maps the set of possible outcomes that a policy maker could choose from, and discusses how their choice could be informed by an environmental index (EI). The paper also discusses the benefits of formulating *a priori* the eutrophication goal in terms of an EI instead of, as today, in terms of separate nitrogen and phosphorus reduction goals. Finally, it suggests an eutrophication index and discusses how the presented results could have practical value although they are based on very crude data.

Keywords: Goal conflict, Multiple goals, Forest sector model, REA, Forest conservation, Renewable energy, Biodiversity, Eutrophication

Author's address: Erik Geijer, SLU, Department of Forest Economics,
SE-901 83 Umeå, Sweden
E-mail: Erik.Geijer@ slu.se

Sammanfattning

Avhandlingen består av fyra fristående artiklar angående konflikter och synergier i mellan mål i framförallt svensk miljöpolitik.

Artikel I analyserar en konflikt mellan de två miljömålen *Begränsad Klimatpåverkan* och *Levande Skogar* eller, mer exakt, konflikten mellan att bevara skog eller leverera skogsbränsle. Detta görs med hjälp av en skogssektormodell innehållande fyra aktörer: skogsägare , sågverk, massa och värme industrin. Modellens parametrar estimeras med hjälp av ett datasett som sträker sig över 40 år. Modellen används sedan för att simulera vilka effekter ytterligare skogsbevarande skulle få på utbud och efterfråga av skogsbränsle. Enligt resultaten skulle ett bevarande av ytterligare fyra procent av skogsmarken leder till en minskning av utbudet av skogsbränsle och, givet att olja användes som substitut, till en ökning av de svenska utsläppen av koldioxid från icke förnyelsebara källor med omkring 0,9 procent.

Artikel II undersöker ytterligare en målkonflikt, denna gång mellan de två miljömålen *Ett Rikt Växt-och Djurliv* och *Begränsad Klimatpåverkan* eller, mer specifikt, effekter av stubbrytning på skogsbränsletillgång och mängden av vedlevande skalbaggar i norra Sverige. Även denna analys använder sig av en skogssektormodell, liknande den som beskrivs i artikel I, men parameterskattningarna härrör från regionala data. Resultaten antyder att en storskalig implementering av stubbrytning skulle resultera i en 3% ökning i användningen av förnybara energikällor i värmeverk, men en 5% minskning i mängden av vedlevande skalbaggar på framtida kalhyggen, jämfört med ett scenario utan stubbrytning.

Artikel III beskriver vindkraftparken på Smøla, Norge, och undersöker konflikten mellan förnyelsebar energiproduktion och skydd av öns havsörnspopulationen. Minst 39 örnar dog på grund av kollision med vindkraftsturbiner på Smöla mellan 2005 och 2010, och verksamhet i vindkraftsparken antas fortsätta till åtminstonne 2027. Artikeln presenterar en Resource Equivalence Analysis (REA) angående vilken ersättning, eller vilka kompenserande åtgärder, som krävs för att ersätta för skadorna på havsörnspopulationen. Artikeln innehåller även några allmänna kommentarer angående det praktiska genomförandet av REA.

Artikel IV handlar om miljömålet *Ingen Övergödning*, och de två delmålen angående kväve och fosforreduktion. Artikeln försöker visualisera uppsättningen av möjliga utfall som en beslutsfattare kan välja mellan, och diskuterar hur valet skulle kunna informeras av, och kommuniceras via, ett miljöindex. Analysen utgör ett exempel på en situation där många av åtgärderna riktade mot ett mål (t.ex. fosforreduktion) har effekter på ett annat mål (t.ex. kvävereduktion), vilket i sin tur implicerar ett behovet av en övergripande analys innehållande båda målsättningar istället för sekventiell analys av ett mål åt gången. Slutligen diskuteras hur de presenterade resultaten skulle kunna användas trotts att analysen troligtvis inte omfattar alla relevanta åtgärder, eller alla effekter förknippade med de åtgärder som inkluderats i analysen.

Dedication

To Nellie, Axel and Noah.

Contents

List of Appended Papers

This thesis is based on the work contained in the following papers, which are referred to in the text by the corresponding Roman numerals.

I Geijer, E., Bostedt, G. & Brännlund, R. (2011). Damned if you do, Damned if you don't – Reduced Climate Impact vs. Sustainable Forests in Sweden. Resource & Energy Economics, 33, 94-106.

II Geijer, E., Andersson, J., Bostedt, G., Brännlund, R. & Hjältén, J. (2014). Safeguarding Species Richness vs. Increasing the use of Renewable Energy – the Effect of Stump Harvesting on Two Environmental Goals. Journal of Forest Economics, Accepted for publication.

III Geijer, E. (2014) A Dynamic Resource Equivalence Analysis of Damage to White-Tailed Eagles in the Smöla Windpark and some General Remarks about the Resource Equivalence Method

IV Geijer, E. (2014). Eutrophication Reduction from a Holistic Perspective.

Paper I is reproduced with permission of the publishers.

1 Goal Conflicts and Synergies

Measures intended to achieve a specific social goal generally have effects on other social goals as well, sometimes positive and sometimes negative. Socio-economic impact assessments of policy instruments designed to achieve individual targets need to take these kinds of conflicts and synergies into account. A partial economic analysis of a project intended to achieve a particular environmental objective may demonstrate that the project would meet its specific objective, but fail to show that it will impede achievement of other environmental goals – i.e. that there is a goal conflict. Conversely, a project may both have positive side effects and facilitate achievement of other environmental goals. For example, measures taken to reach the Swedish national environmental objective "*Reduced Climate Impact*" lead to increases in the use of the forest as a source of firewood, through more intensive utilization of logging residues and intensive cultivation of forests, both of which have negative impacts on the environmental objective "*A Rich Diversity of Plant and Animal Life* ". In contrast, if efforts were made to achieve the “Reduced Climate Impact” objective by using the forest as a carbon sink, they might impede the possibility of achieving the goal "*A Varied Agricultural Landscape*.

More generally, if there were only, say, five goals that we wanted to achieve then determining whether actions taken to achieve one of them would have any effects on possibilities of meeting the others would be relatively easy. We would only have to deduce effects of the actions with respect to five variables. If there were 100 goals, the problem would be more difficult to resolve. However, it may be justifiable to limit and/or simplify the analysis, by assuming that some goals would be largely unaffected by potential actions, and/or that some actions would only affect the targeted objective, and/or that rather than considering individual goals we could group them (e.g. assess actions in terms of effects on baskets of goods rather than individual goods). In the real world, where people care about millions of outcomes, it is crucial to find ways to limit and simplify the analysis since it is impossible to explicitly model all the effects of actions, and changes in every goal, simultaneously

The purpose of this summary is to discuss the goal-setting problem in socio-economic cost-benefit terms, what to consider when choosing potential alternative scenarios and deciding upon the scope of analyses, i.e. what to include and exclude. A cost-benefit assessment is generally an applied partial equilibrium analysis and, thus, the credibility of the results depends on the validity of the *ceteris paribus* assumptions regarding an action's or project's impact on the economy.. The summary also considers the issue of path dependency, i.e. that the cost of a particular project may depend on whether another project is carried out before or after it, and the resulting possible trade-offs..

2 The goal-setting problem in CBA

The choice of decision options is one of the most important steps in cost-benefit analysis (CBA), but also one of the least discussed in the literature. The choice of calculation option will greatly affect the outcome of the socio-economic calculations, thus it is important to select only realistic and relevant options. Even definition of the so-called "zero- project" or "baseline" scenario often causes problems. An appropriate definition of the "baseline" scenario in many analyses is the "reality in the absence of any of the various calculation options." For example, if we want to evaluate actions that could be applied to combat acidification, the baseline might be stated as not taking any actions at all, which in reality may not be very likely. It is also important to state, clearly, all the uncertainties in the assumptions underlying the baseline scenario. To continue the example, it may be difficult to forecast future acidification trends in the absence of any measures.

Unrealistic calculation options here means options designed in such a way that it could be concluded *a priori* that, for various reasons, they are very unlikely to be economically or politically viable. However, it is important to evaluate all reasonable calculation options in order to identify the best. As usual, there are no general rules concerning how to operationalize this insight, instead it largely depends on the judgment of the economist conducting the analysis. Also, since the economist might lack expertise related to the focal phenomena, there is usually a need for a dialogue with experts from other fields.

One of the problems that can arise in CBAs is that the analysis becomes too partial, or sequential, in the sense that each action or policy is evaluated separately, without considering other policies or actions that are about to be implemented. Guidelines concerning economic impact assessments are often accompanied with statements indicating that all "relevant" values and costs are to be taken into account, and that they should be estimated at their opportunity costs. The opportunity costs that are, and the values and costs that may be, relevant, are sources of disagreement among economists, due to differences in their assumptions and opinions. Thus, analyses often ignore the possibility that two projects, each economically profitable in the absence of the other, might have counteractive effects on each other. Furthermore, there might be a path dependency problem, i.e., whichever project is evaluated and implemented first may be deemed profitable, but not the other, simply because it was evaluated after the first one (or, more precisely, because of the environmental changes caused by the first project). Thus, in order to include all relevant factors in an analysis it is not always sufficient to know the current state of the world. Knowledge of other actions that are about to be implemented is also often important and it is not always appropriate to evaluate individual goals in isolation. These complications are addressed in more detail later.

3 Scope

The problem of conflicting objectives is related to the problem of scope, or to what extent it is reasonable to use *ceteris paribus* assumptions. Socio-economic impact assessments are generally partial equilibrium analyses. This means that although every change in economic activity (such as the construction of a hydroelectric plant) generates ripples through the entire economic system, the researcher *de facto* closes parts of the economy by referring to other things being equal, i.e. that all other conditions remain unchanged. In some cases, this procedure can be defended on the basis that the ripples generated by the project are so small that they do not substantially alter relative prices and/or the availability of public goods in other parts of the economy (Johansson, 1991). This means that economic impact assessments, as local solutions to a partial equilibrium model, depend on the assumption that the rest of the economy remains near the initial equilibrium solution (Boadway & Bruce, 1991; Jones, 2005).

However, some projects have sufficient scale to affect prices, production and environmental quality in economic sectors beyond their focal sector. One way to manage impacts on several sectors of the economy is to use a so-called general equilibrium model (Computable General Equilibrium, CGE) connected to a so-called Social Accounting Matrix or SAM. A SAM describes trade flows between different sectors of society, i.e. production of goods and services and how they are used during a given time period in all sectors of society, as well environmental impacts such as emissions and waste. A solution of a SAM must satisfy equilibrium conditions, i.e. the demand must be equal to the supply of all goods, services and production factors, with zero economic profit in all activities, and a balance between revenue and expenditure. A SAM could, for example, be used for deriving multipliers that show the magnitude of the economic impact of a sector on other sectors. One limitation of SAMs is that all relative prices are assumed to be fixed and exogenous, which is not always reasonable, especially in evaluations of large projects. In order to obtain a greater degree of realism, a SAM could be coupled to a general equilibrium model of the economy, allowing relative prices to be determined endogenously. A CGE consists of a set of equations that describe relationships between different sectors of the economy. With the assumption of equilibrium in all markets it is possible to calculate the effects of a change in an exogenous variable, such as a tax, on all sectors of the economy and the economy as a whole. A general equilibrium model uses, as mentioned, a SAM as its starting point, but unlike a SAM it allows nonlinear relationships between actors in an economy and the simulation of adaptations to changes through changes in relative prices as well as through changes in quantities. However, a CGE model implies that decisions must be made about functional forms and additional parameter values. In some cases these decisions are based on estimated relationships, but in practice one must often rely on the individual researcher's opinion and a stylized understanding of the economic system to be examined. This has been a major criticism of general equilibrium models.

It is important to emphasize that there is no theoretical difference between partial and general equilibrium approaches, in both cases the aim is to maximize the sum of consumer and producer surplus. The difference is in the scope of analysis. In most cases, it is neither justified nor possible to include the whole (global) economy. In these cases, as in the studies discussed below, the term "general equilibrium analysis" simply implies that the model includes a plurality of, but not necessarily all, affected markets. A CBA based on a general equilibrium analysis will therefore include more, if not all, of the effects that a change is expected to cause than a partial equilibrium analysis. There are also, of course, intermediates between partial models (which only analyze and "endogenize" single markets) and general equilibrium models that consider spillover effects in an entire economy. Such intermediates are sometimes called "partial general equilibrium models" or "sector models." The pros and cons of the variants are discussed below.

4 Partial or general equilibrium analysis

4.1 In the best of all worlds ...

Let us consider an economy with no market failures, except in one market, for good A. This failure consists of the production of the good that causes an externality. If we impose an optimal tax T (i.e. equal to the marginal external effect) on good A, the price rises from PA1 to PA2 and the produced/consumed quantity falls from QA1 to QA2, which in turn means that the environmental damage is reduced and we have a positive welfare effect similar to the black triangle marked in Figure 1. In other words, in this case, it is relatively straightforward to calculate the welfare effects of such an environmental tax: the only thing we need to know is the elasticity of demand.

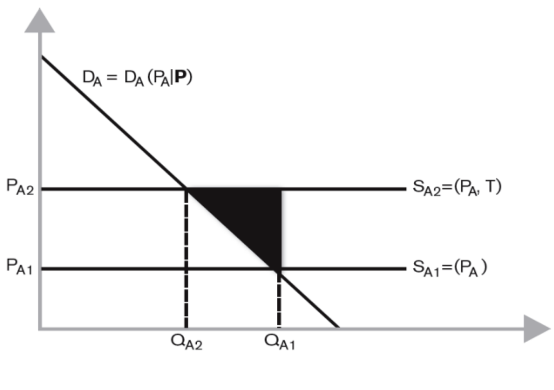

Figure 1. Market for good A.

If we extend this model to a general equilibrium model, the produced/demanded quantity, after price changes in other markets, is likely to differ from QA2. This is, however, irrelevant from a welfare economics perspective. The price in this market now reflects the true opportunity cost and the same is true, according to our initial assumption, for other goods/activities. Regardless of how consumers choose to act, it will lead to the best of all possible worlds (in which things are produced/consumed if and only if the social benefit of production is greater than the social cost of production). Thus, these assumptions allow extreme simplification of the analysis, as we do not have to consider any other goals or effects.

4.2 ... We would not need to take this into account.

In the example above, there is only one market imperfection, and no other taxes or regulations. The reality is different. First, there are always other market imperfections, and most goods and services are taxed differently. In many cases existing regulations and environmental taxes might not be optimally set. There may be many reasons for this, including practical limitations, ideological factors, lack of knowledge and heterogeneous interests. In some cases, the transaction costs associated with a tax may be significantly higher than the potential benefits, and even in the best circumstances it might be difficult to update regulations in line with fluctuations in the economy. In such a world, general equilibrium effects are no longer irrelevant. For example, if a carbon tax is introduced energy becomes more expensive for the consumer, thereby reducing energy consumption. However, the price increase in energy also means that the consumer's purchasing power, or the real wages, decrease, making it less profitable to work. This, in turn, may affect the consumption of leisure, which ultimately leads to changes in the tax revenue for the community from work. Finally, given a fixed level of public spending, the community has to change the tax rate on labor, or other taxes, in order to maintain a balanced budget. This represents a type of "conflict of interests", climate versus funding of the public sector. Such "general equilibrium" effects must be taken into account in the analysis. The example below highlights the problem of general equilibrium effects.

Suppose, as before, that a tax equal to the marginal damage caused by the production of good A is introduced and thus its production/consumption decreases. Given a reasonably efficient economy, the resources that were previously used for producing good A do not simply disappear from the system, but are instead allocated differently. The consumers who cut back on their spending on good A now look for other ways to spend their money. We expect to see the biggest changes with respect to goods that a large proportion of the consumers consider to meet a similar (substitute) or complementary need. In other words, we can expect an increased demand for goods that are substitutes, but not taxed (such as gasoline - ethanol) and a decreased in the demand for goods that are directly complementary to the taxed product (e.g. motor oil and soda as complements to gasoline and whisky, respectively); see figure 2.

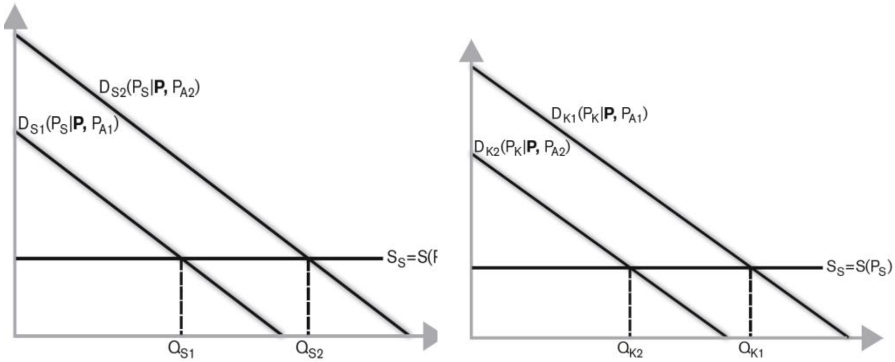

Figure 2. Markets for S (substitute) and K (complement)

In the above examples, the demand for good S (substitute) and good C (complement) is affected by the initial price change in the market for good A ($P_{A1} \rightarrow P_{A2}$). Consumers want to buy more of the substitute, and less of the complement, at every price level. If the production of these goods causes negative externalities, which for some reason are not internalized in each product's price, this represents an example of a conflict/synergy. In the first case, a CBA based on a partial equilibrium model would overestimate the benefits of the introduction of the tax, and in the second case underestimate the benefits. This is because the initial tax, in addition to its effect on the market for good A, also has both undesirable and desirable effects on other parts of the economy. When the change in P_A results in an increase in the demand for good S, we do not necessarily improve the resource allocation, but rather shift the problem to another area. A tax on oil or pesticides, for example, could lead to deforestation (for fuel or food production), and a general energy tax could reduce the relative advantages of renewable fuels over fossil fuels.

The magnitude of effects that are not included in the analysis can be partially estimated by examining the sizes of resource flows that leave or enter the model. If the initial change in terms of consumer spending in the market for A, in the example above, caused a corresponding increase in consumer spending for S (assumed to be a substitute), the analysis could easily have covered the main effects. However, one of the effects that still lack an explicit consideration is the potential effect of redistribution (through the tax) between the state and the individuals who are still buying the product. If the "ripple effect" instead had led us to a market for an item of type C (which was a complement), the size of the resource flow which we exercised a "ceteris paribus" assumption of increasing rather than decreasing. This does not mean that the analysis has become "worse". The initial change would in this case give rise to large spillovers, whether we knew it or not - and the sector model analysis gives us at least one additional effect to consider.

4.3 Path dependency.

Path dependency is a term that is often used to describe the simple fact that the choices we face today (or in the future) often depend on decisions made earlier (or taken today). Path dependency can often lead to lock-in effects where the current regime, which might be suboptimal if we were to introduce it today, is retained since the switching costs are too great There are also situations where most people would agree that something should have been done differently from the start, but still decide to stay on the current path given the bad decisions that have already been implemented. For example, in time period one, two separate CBAs could lead to the conclusion that it would be a good idea to subsidize expansion of a district heating network and establish a protected area for conserving biodiversity. Suppose, further, that nature conservation is the most profitable investment of the two. If the district heating system is expanded immediately, while nature protection is delayed, a CBA at a later date could show that the nature protection project is no longer profitable due to increases in the forest products' value as raw material for the expanded district heating system. As the district heating network is unlikely to have many alternative uses, even the long-term optimal equilibrium, ex-post, may well differ from the ex-ante equilibrium (where conservation was the most efficient use of the resources).

For obvious reasons, in this hypothetical example it would have been beneficial if the original studies had not only evaluated whether a single project would be beneficial, *ceteris paribus* - but instead had taken into account the interactions between the environmental objectives and included how the achievement of one would affect the ability to achieve the other.

4.4 Feedback

In the preceding discussion about goods A and S (a substitute for A), there was a unilateral cause-effect relationship between the change in the market for good A on the market for good S. However, given that the supply of good S is not completely elastic, its price will increase if the price of good A increases, which in turn might lead to an increase in the demand for A. Thus, a partial equilibrium analysis may not only neglect consequences in other markets, but also miss potentially important feedback mechanisms that might affect both quantities and prices (or other forms of outcome and incentive structures) within sectors targeted by a given action. This is not a conflict of interests in the strict sense, but rather shows that we cannot set goals or instruments correctly unless we take relevant types of feedback effects into account.

5 Aim of the thesis

One of the aims of the *PlusMinus* program, which financed my PhD studies, was to address the fact that actions taken to meet one environmental goal also generally affect the ability to achieve other environmental goals. Thus, the overall aim of the studies was to analyze and quantify goal conflicts and spillover effects between different environmental objectives. For this purpose partial equilibrium, resource equivalence, and cost efficiency analyses were used, as summarized in the summary of this thesis and described in detail in the appended papers.

As increasingly holistic views of the objectives of environmental policy are being adopted — as illustrated by comparisons of the EU's "Nitrate Directive (1991)" and "Waste-Water Treatment Directive (1991)" with the later "Water Framework Directive (2000)" and "Marine Strategy Framework Directive (2008)" — it is becoming increasingly apparent that measures that might previously have been implemented to address a specific issue have wide-ranging effects. The first three of the appended papers focus on quantification of the goal conflicts, or multiple effects of single measures. The fourth paper also does this, but the main focus is on the other side of the equation – given that we should consider effects on multiple goals simultaneously, and view these goals as interconnected, should we even consider them as separate goals?

6 Example of a goal conflict.

Paper II examines to what extent an increase in the use of wood fuel can be assumed to be in conflict with ambitions to protect biodiversity. The problem can be summarized in that the welfare of numerous animals and insects depends on the amount of dead wood left in the forest after a clear cut (see e.g. Hjälten et al. 2007, 2010, 2012). However, increases in the demand for wood fuel have started to make stump removal profitable. Since stumps constitute a relatively large proportion of the wood that is left after harvesting, there is a conflict, but the question is whether this conflict is large enough that it matter according to one or another criteria.

In order to estimate future changes in stump removal, a partial equilibrium model (or sector model) was used including four actors – forest owners, sawmills, pulp and heating plants. Next, behavioral (supply/demand) equations were estimated, telling us how the actors have changed their decisions with respect to changing conditions in the past. Endogenous variables in the final model include, but are not limited to, prices and quantities of saw timber, chips and wood fuel and the quantities of pulpwood. On the supply side, fuel wood is divided into two categories, branches and treetops (the previous main components) and stumps. The potential ecological impact of this withdrawal is calculated using an ecological model, tied to the economic model. The ecological model, in turn, tells us that a change in the volume of stumps will cause a change in biodiversity (increasing their harvest will have a negative effect). Finally, this model is used to simulate effects of a 30% exogenous increase in the demand for wood fuel (at current prices). Table 1 presents results from a scenario taking general equilibrium effects into account (GE), and another scenario where those effects are disregarded (PE).

As Table 1 shows, there is a "goal conflict", or conflict of interests, whether we use a partial or general equilibrium analysis. In both cases, the change leads to an increase in the extraction of stumps, and thus to a smaller amount of dead wood and less biodiversity. However, we also see that the difference between the partial and general equilibrium approach is relatively small.

Thus, in this case, concerns about uncaptured feedback effects in a partial equilibrium model would have been relatively unfounded. If the goal had been to find, for instance, a subsidy that shifted actual use of wood fuel by X%, a partial equilibrium model would have worked reasonably well. Nevertheless, there is a conflict, regardless of the approach.

Table 1: Changes in the endogenous variables (in percent) due to an exogenous increase in the demand for wood fuel of 350 000 m^3.

Simulation	**PE**	**GE**
ΔF	1.52	1.22
ΔBIO	**-4.4**	**-4.06**
Δy_{ST}	-	-0.42
Δy_{PW}	-	-0.38
Δy_{FF}	**28.1**	**27.07**
Δy_{BRAT}	10.01	9.35
Δy_{STUMP}	675	622
Δp_{FF}	19.3	9.45
Δp_{ST}	-	1.02
Δy_{CHIP}	-	-0.22
Δp_{CHIP}	-	1.63
Δy_S	-	-0.10
Δy_P	-	-0.01

F = total supply of biomass from the forest. BIO = reduction in the density of saproxylic beetles on future clear cuts. ST = saw timber. CHIP = wood chips. PW = pulp wood. FF = wood fuel (= BRAT, branches and treetops) + stumps, STUMP). S = sawn goods. P = pulp.

It is important to take negative effects of harvesting stumps on biodiversity into account. The general equilibrium model also suggests there would be a slight increase in total net removal from the forest, implying that there is a more serious conflict of interests with the environmental objective S*ustainable Forest* (which, among other things, suggests that additional forest land should be excluded from logging activities).

Finally, this example shows how defining a cost-benefit assessment too narrowly might lead to a social sub-optimization. We have also previously shown that spillover effects, at times, might make the partial equilibrium approach less suitable, and found that one way to manage impacts on several sectors of the economy is to use a so called general equilibrium model (or sector model). Furthermore, economic impact assessments are often carried out as a result of a specific request. Thus, it is essential to keep path dependency in mind - that the implementation of a project can make it significantly more expensive (or cheaper) to implement another project later, a kind of lock-in (Right, Hueth & Schmitz, 2005).

7 Overview of Appended Papers

In this section each of the appended papers is briefly summarized. The methods used and main results are also presented. For details, turn to the specific papers.

7.1 Damned if you do, Damned if you don't – Reduced Climate Impact vs. Sustainable Forests in Sweden (Paper I)

The first appended paper examines the 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 forest fuel. The conflict occurs since climate policy, through the Swedish environmental objective *Reduced Climate Impact*, will increase demand for biofuels, while another Swedish environmental objective - Sustainable Forests – will reduce the supply of raw materials from the forest.

Earlier analyses of effects on the forest sector of various environmental and energy objectives have revealed a complex interplay between different submarkets within the forest sector (e.g. Ankarhem 2004 and Ankarhem et. al. 1999). Paper I presents a forest sector model designed to capture those interactions. The model includes the suppliers of biomass, the forest owners, as well as the major users of forest biomass, i.e. the energy, pulp and paper industries, and sawmills. The parameter estimates, obtained from a data set spanning 40 years, show that all the price elasticities have the expected signs. Of the three forestry products, the supply of and (long-term) demand for forest fuel seem to be the most sensitive to a price change. In a second step the model is used to simulate effects of increasing forest conservation on the supply of forest fuel. The results show that an increase in forest conservation decreases the supply of forest fuels. Assuming that the substitutes for forest fuel are fossil fuels (oil), the alternative energy input will lead to an increase in Swedish emissions of carbon dioxide by almost 1.2%, or a 0.9% increase in total emissions of greenhouse gases calculated as carbon dioxide equivalents. Thus, there is a clear conflict between the two environmental objectives.

7.2 Safeguarding Species Richness vs. Increasing the use of Renewable Energy – the Effect of Stump Harvesting on Two Environmental Goals. (Paper II)

Paper II addresses another goal conflict, between the two Swedish environmental goals *A rich diversity of plant and animal life* and *Increased use of renewable energy resources* or, more precisely, effects of harvesting stumps on the supply of forest fuel and the abundance of saproxylic beetles in northern Sweden. The analysis is based on a model similar to the one presented and applied in Paper I, i.e. it describes the supply of forest biomass by the forest owners and the demand for forest biomass by pulp mills, sawmills and the heating sector. However, the parameter estimates are obtained from regional data. Finally, the economic model is linked to an ecological model, describing the effect of harvesting stumps on the abundance of saproxylic beetles.

Assuming that the heating plants' demand for forest fuel will increase by 350 000 m^3 (30% more than used at current prices), the model suggests that, after taking general equilibrium effects into account, the final use of forest fuel will increase by 274 000 or 328 000 m^3 depending on whether harvesting stumps is allowed or not. The difference implies that use of renewable energy sources in heating plants will increase by three percent if harvesting stumps is allowed, while the overall population of saproxylic beetles on future clear-cuts will decrease by almost five percent, compared to a scenario with no stump harvesting.

7.3 A Dynamic Resource Equivalence Analysis of damage to white-tailed eagles in the Smöla wind park and some general remarks about the Resource Equivalence method (Paper III)

This paper focuses on Resource Equivalence Analysis (REA), an area which falls somewhat outside the main aim of the studies, as stated above. The paper has sprung from an attempt to make a REA and in the process discovering methodological problems with the established practice in conducting REA´s. The present paper is an attempt to resolve some of these problems.

The paper describes the wind power park on the Smöla island, and the conflict between clean energy generation and protection of the island's white-tailed eagle (WTE) population. Between 2005 and 2010, at least 39 WTEs died due to collisions with turbines at the park. One possible compensatory action would be to retrofit electrical pylons, in order to prevent electrocutions of WTEs. In this paper, we try to find the compensation that would be appropriate according to the Resource Equivalence Analysis (REA) method.

The paper also includes some general remarks about the practical application of REA with respect to damage to birds. First, we point out that it is the relative value of the "discounted bird years" associated with birds with different characteristics or actions taken in different time periods that matters with respect to the demanded compensation – not their absolute value. This, in turn, implies that assumptions should be made in such a way that they can be expected to produce the correct relative values, and sometimes it is even unnecessary to calculate any absolute values at all.

The second remark concerns the frequently used methodology of simply assuming that following a given action a population will recover to a given baseline x (generally a few, or even 1-2) generations in the future. This assumption implies that there is a population limit for each family of birds, rather than for the species as a whole. In effect, birds with similar characteristics, living in the same time period, will be treated differently depending on (for instance) whether the analyst's model assumes that it was their grandfather or father that avoided death due to some compensatory action. Zafonte et al. (2005) have previously criticized this methodology on the grounds that provided justifications for the occurrence of such recoveries are not generally valid, and thus that some REAs might underestimate the absolute damage. I, on the other hand, cannot even find any attempt to explicitly justify this asymmetric treatment of similar birds. I am, however, under the impression that it has to do with a failure to appreciate the first point. It is a methodology that will produce relatively robust absolute values (which will not differ by a factor of, say, 10 between different studies and applications). However, the methodology is likely to produce biased relative values compared to a symmetric treatment of similar birds (thus conflicting with the recommendation arising from the first remark).

In contrast, we do not find it at all problematic that e.g. the absolute damages in our own REA of the WTE population on Smöla differ a lot depending on scenario. While we do have an idea about what the current fecundity and survival rates are, we do not know much about either the complete population model or to what extent the effects of e.g. compensatory actions will depend on the future size of the population. In order to still derive a result, we assume rather different scenarios and population models in order to show that the results are relatively robust. As expected, the absolute values of (for instance) the damages vary substantially depending on population model. The relative values are, however, more robust, and thus so are the results in terms of required compensation.

7.4 Eutrophication reduction from a holistic perspective (Paper IV)

Single measures that are implemented in order to reach some goal often have effects on other goals as well. Sometimes, the individual goals might even have little value in themselves. Instead, the goals, often together with many other goals, have an instrumental value in the sense that their fulfillment is assumed to promote fulfillment of an actual, intrinsically valuable, goal. Paper IV addresses the Swedish environmental goal *Zero eutrophication*, and the two interconnected sub-goals of nitrogen and phosphorus reduction. Eutrophication of waters primarily depends on nitrogen (N) and phosphorous (P) loadings, and there are separate goals for N and P emissions. However, measures taken to reduce N emissions often affect P emissions, and vice versa. Thus, a cost-efficient set of measures must be identified by determining ways to reach both goals simultaneously, rather than through separate analysis for each goal. Furthermore, it is questionable whether there should be separate goals for N and P reduction at all. As numerous combinations of N and P loading reductions would lead to the same level of expected eutrophication reduction, the goal should not define which of these combinations should be reached, but rather aim at a level of eutrophication reduction and choose the most cost-efficient way to reach it.

The paper maps the set of possible outcomes that a policy-maker could choose from, and discusses how the choice could be informed by an environmental index (EI). The paper also discusses the benefits of formulating the eutrophication goal *a priori* in terms of an EI instead of, as today, in terms of separate nitrogen and phosphorus reduction goals. Finally, the paper suggests a eutrophication index and discusses how the presented results could have practical value, despite being based on very crude data.

References

Ankarhem, M. (2004). Effects of increased demand for biofuels: a dynamic model of the Swedish Forest Sector. In: Ankarhem,M., *Bioenergy, Pollution, and Economic Growth*. Ph.D. Thesis, Umea Economic Studies No. 661, University of Umea.

Ankarhem, M., Brännlund, R., Sjöström, M. (1999). Biofuels and the forest sector. An econometric model of the Swedish forest sector. In: Yoshimoto, A., Yukutake, K. (Eds.), *Global Concerns for Forest Resource Utilization; Sustainable Use and Management.* Kluwer Academic Publishers, Dordrecht.

Boadway, R.F. & Bruce, N. (1991). *Welfare Economics*. Blackwell, Oxford.

Geijer, E., Andersson, J., Bostedt, G., Brännlund, R., & Hjältén, J. (2012). Is Stump Harvesting a Remedy for the Climate Crisis or a Curse for Biodiversity? An Interdisciplinary Study of Conflicting Goals. *CERE Working Paper* 2012:5, CERE, Umeå.

Hjältén, J., Johansson, T., Alinvi O, Danell K., Ball J.P., Pettersson R., Gibb, H., Hilszczański, J., 2007. The importance of substrate type, shading and scorching for the attractiveness of dead wood to saproxylic beetles. Basic and Applied Ecology 8, 364-376.

Hjältén, J., Stenbacka, F., Andersson, J. 2010. Saproxylic beetle assemblages on low stumps, high stumps and logs: Implications for environmental effects of stump harvesting. Forest Ecology and Management 260, 1149-1155.

Hjältén, J., Stenbacka, F., Pettersson, R., Gibb, H., Johansson, T., Danell, K., Ball, J. P. and Hilszczański, J. 2012 Micro and macro-habitat associations in saproxylic beetles: implications for biodiversity management. PLoS ONE 7(7): e41100.

Johansson, P-O. (1991). *An Introduction to Modern Welfare Economics*. Cambridge University Press, Cambridge,

Jones, C. (2005). *Applied Welfare Economics*. Oxford University Press, Oxford.

Just, R.E., Hueth, D.L. & Schmitz, A. (2005). *The Welfare Economics of Public Policy: A Practical Approach to Project and Policy Evaluation*. Edward Elgar, Cheltenham.

Zafonte, M., and S. Hampton. (2005). Lost bird-years: quantifying bird injuries in natural resource damage assessments for oil spills. *2005 International Oil Spill Conference:* p 1019-1024

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