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WHO GAINS FROM CREDITED FOREST CARBON SINKS: FINLAND AND OTHER ANNEX I COUNTRIES IN COMPARISON

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Abstract: In the Kyoto Protocol carbon sinks became a tool for releasing the economic burden of achieving the emission target. For Finland, credits from carbon sinks might be important since the amount of carbon sequestered in total forest area has been large relative to total emissions. It was agreed in Bonn, however, that only part of the sinks resulting from forest management is allowed to be credited. Here we use the multi-region computable general equilibrium model GTAP-E to analyse (i) which countries benefit from carbon sinks, (ii) how benefits are distributed within the economy, (iii) whether carbon sinks reduce the economic burden for Finland as such and relative to other countries and (iv) what is the economic importance of the larger sinks allowed for Japan and Canada, both for themselves and for other countries.

For Finland, where the costs of achieving the emission target were already originally high, the inclusion of credited forest carbon sinks provides only a slight release from economic burden in the first commitment period. The credited carbon sink decrease the necessary emission reduction only slightly because the amount to be credited in the first commitment period is low, and a part of that is used to compensate the source of carbon under Article 3.3. New Zealand gains most from the inclusion of sinks; but Sweden, Canada and Japan also benefit considerably. Of these countries, only Canada has high costs without sinks. Thus credited sinks only partly reduce the difference in economic burden of achieving the Kyoto target among countries. Even though country-specific sinks clearly benefit Canada and Japan, their effect on other countries, either on the economy-wide or on the sectoral level, remains marginal. For example, paper and pulp industry in Finland does not seem to lose competitiveness. Sectors that are fossil fuel intensive, like the iron and steel or the chemical industry, benefit from the inclusion of sinks while the other sectors, like machinery, may suffer.

Keywords: Bonn Agreement, Carbon sequestration, CGE model, Global economic analysis, Emission reduction, GTAP-E, Kyoto Protocol

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Tiivistelmä: Hiilinielut hyväksyttiin Kioton pöytäkirjassa keinoksi helpottaa päästötavoitteen saavuttamista. Suomelle nieluhyvitys on potentiaalisesti tärkeä, sillä metsiin sitoutuneen hiilen määrä on ollut huomattava suhteessa päästöihin. Bonnin osapuolikokouksessa päätettiin kuitenkin, että vain osa metsienhoidon tuottamista hiilinieluista voidaan hyvittää. Tässä tutkimuksessa arvioidaan usean alueen numeerista yleisen tasapainon mallia (GTAP-E) käyttäen i) mitkä maat hyötyvät hiilinieluista ii) miten hiilinieluista aiheutuvat kustannussäästöt jakautuvat eri sektorien kesken iii) alentavatko hiilinielut Suomen taloudellisia kustannuksia absoluuttisesti ja suhteessa muihin maihin sekä iv) mikä on Japanille ja Kanadalle myönnettyjen suurempien hiilinielujen taloudellinen merkitys niille itselleen ja muille maille.

Suomessa nieluhyvitys alentaa ensimmäisellä sitoumuskaudella vain hieman alunperinkin korkeita taloudellisia kustannuksia. Tämä johtuu mm. siitä, että hiilinielu on ensimmäisellä sitoumuskaudella alhainen ja osa siitä joudutaan käyttämään 3.3 artiklan hiilen lähteen kompensoimiseen. Uusi Seelanti hyötyy eniten nielujen mukaan ottamisesta, mutta myös Ruotsissa, Kanadassa ja Japanissa kustannukset alenevat merkittävästi. Näistä maista vain Kanadan kustannukset ovat korkeat ilman nieluja. Täten nieluhyvitykset tasoittavat Kioton tavoitteiden aiheuttamaa taloudellista taakkaa vain osittain. Vaikka Kanadalle ja Japanille myönnetyt maakohtaiset, suuremmat nielut hyödyttävät niitä selvästi, niiden kokonaistaloudellinen tai toimialakohtainen vaikutus muihin maihin jää vähäiseksi. Esimerkiksi sellu- ja paperiteollisuus Suomessa ei näytä menettävän kilpailukykyään. Fossiilisia polttoaineita intensiivisesti käyttävät toimialat, kuten hiili- ja terästeollisuus tai kemianteollisuus, hyötyvät nielujen mukaan ottamisesta, kun taas työ- ja pääomaintensiivisten sektorien, kuten koneiden valmistuksen, tuotanto kasvaisi enemmän ilman nieluhyvityksiä.

Asiasanat: Bonnin sopimus, Hiilen nielu, YTP-malli, Päästövähennys, GTAP-E, Kioton pöytäkirja

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1. Introduction

The economywide and sectoral effects of implementing the Kyoto Protocol have been estimated in numerous studies (e.g. reviewed by Weyant, 1999). Previous analyses tended, however, to exclude carbon sinks. Only after the COP6 in Bonn, where the rules for crediting of carbon sinks were established, were sinks included in the economic simulations for analysing the costs of the Kyoto Protocol in the global level (see e.g. Böhringer, 2001; Jakeman et al., 2001 and 2002; Babiker et al., 2002; den Elzen and de Moor, 2001 and 2002). Böhringer, and den Elzen and de Moor estimated the costs both with and without sinks. Since their studies focused on the effects of US withdrawal and the decisions made in Bonn in general, with special attention to emission permit markets, the importance of carbon sinks is not thoroughly discussed. The studies analysing the costs of Kyoto Protocol for Finland have not taken into account the credits from carbon sinks[1], (see e.g. Forsström and Honkatukia, 2001; Haaparanta et al., 2001; Perrels et al., 2001).

The objective of this study was to analyse in detail both the economywide and the sectoral effects of inclusion of carbon sinks as agreed upon in Bonn and Marrakech for the first commitment period of 2008-12. The impacts are estimated with a multi-region, multi-sector model, GTAP-E. We identify the Annex I countries, which may benefit from credited carbon sinks and analyse how the effects are allocated within the sectors of the economy. Since the model includes 13 countries/regions, we are able to estimate the impacts for a larger number of countries/regions than earlier analyses did. Finland is analysed as a separate case. Furthermore, we analyse the economic importance of the larger carbon sinks allowed for Japan and Canada, how the country-specific carbon sinks affect their economies and whether the possible impacts have repercussions for the other Annex I countries.

In Section 2, the potential and politically agreed role of carbon sinks in mitigating climate change is discussed. In Section 3, the major characteristics of the global, computable general equilibrium model GTAP-E used in the policy simulations are outlined. In Section 4, the baseline and policy scenarios are described with estimates of the emission reduction needed with and without Kyoto sinks. In section 5, the results of model simulations are presented and discussed.

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[1] Pohjola (1999) takes into account the carbon sinks but policy scenarios are not fully in line with the Kyoto Protocol.

2. Forest carbon sinks under Articles 3.3 and 3.4

The amount of carbon dioxide in the atmosphere can be reduced by decreasing emissions from fossil fuels and other sources and by increasing the amount of carbon in the biomass. To prevent global warming efficiently, all of these options should be brought into use. In the Kyoto Protocol, forest carbon sinks have been included as one of the mechanisms for mitigating climate change (UNFCCC, 1997). Globally, forest carbon sinks might contribute markedly to mitigation of climate change (Schulze et al., 2002) and measures for increasing them are in general considered to be low- or moderate cost options compared to energy alternatives (IPCC, 2001). The net terrestrial uptake of 2.6 Gt CO_2 yr^{-1} corresponded to one tenth of the emissions from combustion of fossil fuels (23.1 Gt CO_2 yr^{-1}) (IPCC, 2000). The largest forest carbon sinks of the industrialised (Annex I) countries are in Russia and the USA, which reported that in the year 1990 their sinks were 587 Mt CO_2 and 272 Mt CO_2, respectively (UNFCCC, 2002). Relative to CO_2 emissions, forest carbon sinks are, however, largest in New Zealand and Sweden, in the year 1990 corresponding to 70% and 60% of their emissions, respectively.

According to the Kyoto Protocol, carbon sinks resulting from direct human-induced land-use change and forestry activities, limited to afforestation, reforestation and deforestation since 1990, are to be credited under Article 3.3. Furthermore, according to Article 3.4 of the Kyoto Protocol and the Bonn agreement (July 2001), Annex I countries may choose to account for anthropogenic greenhouse gas emissions by sources and removals by sinks resulting from revegetation, forest management, cropland management and grazing land management. Of all these activities, forest management has the greatest potential to contribute large carbon sinks in the first and subsequent commitment periods (IPCC, 2000).

Knowing the large potential of forest carbon sinks and the difficulties to separate human-induced sinks from those arising from climate change or former forest management practices, the countries agreed (COP6 in Bonn, July 2001) that for the first commitment period forest carbon sinks resulting from forest management (under Article 3.4 of the KP) will be only partly credited. In the Bonn agreement the country- specific maximum values for a carbon sink to be credited were defined (Table 1, according to UNFCCC (2001) and the accompanying Appendix). For most countries, these values were calculated on the basis of the preliminary country-specific data concerning potential carbon sinks (FAO, 2000; UNFCCC/SBSTA, 2000). In general, in order to prevent the non-human-induced part of the sink from being credited, the credited amount from forest management is strictly limited to 15% of the estimated sink. Furthermore, in order to limit the role of sinks in achieving the given emission target, the amount of sink from forest management was limited to 3% of the base-year emissions.

As an outcome of political negotiations, Canada and Japan were, however, given relatively larger carbon sinks. The maximum amount allowed for Japan is 13 Mt C (47.7 Mt CO_2) and for Canada 12 Mt C (44.0 Mt CO_2), rather than 3.9 Mt C (14.3 Mt CO_2) and 0.75 Mt C (2.8 Mt CO_2), which would have been their maximum amount if the common accounting formula had been applied. Furthermore, the maximum value calculated for Russia was not recognised by the Russian Federation; and in a decision taken by countries in the COP7 in Marrakech (November 2001), that figure was revised from 17.63 to 33 Mt C yr^{-1}, which is equivalent to 121.1 Mt CO_2. The revised figure means that the biomass of trees is expected to be increased by 807 Tg CO_2 yr^{-1}, which is consistent with assessment of forest carbon sinks based on the most recent (1998) forest inventory data (UNFCCC, 2000) but which is lower than the 1578 Tg CO_2 yr^{-1} reported by FAO TBFRA 2000 (FAO, 2000) and higher than that estimated in IIASA (Nilsson et al., 2000).

Table 1 gives the estimates of the country-specific emissions and removals of CO_2 calculated under the Articles 3.3 and 3.4 and used in our study to adjust the assigned amounts of emissions for the Parties. The amounts of sinks to be credited under Article 3.3 are based on the Parties' own submission in August 2000 (UNFCCC/SBSTA, 2000)[2]. Thus, they are estimated by national authorities on the basis of previous changes in land use. For carbon sinks under Article 3.4 we apply in our analysis the maximum amount allowed for sinks arising from forest management[3]. Other sinks are not included in our analysis[4].

[2] The Parties' own submissions are also used in Jakeman et al. (2001, 2002), except for Australia and New Zealand. Den Elzen and de Moor (2001, 2002), on the other hand, based their estimations on FAO data. The implied figures for sinks are similar to ours except for New Zealand, for which we provide a somewhat larger figure. Böhringer (2001) does not include sinks under Article 3.3.

[3] These figures are also used in Böhringer (2001) and in den Elzen and de Moor (2001, 2002). Jakeman et al. (2001, 2002), however, use the country's own estimation in the August submission if that figure is lower than the one allowed in the Appendix.

[4] Sinks from agricultural activities are taken into account in Böhringer (2001), in Jakeman et al (2001, 2002) and in den Elzen and de Moor (2001, 2002); the latter two use figures from the August submission for a majority of the countries. In addition, sinks from CDM, corresponding to one percent of base year emissions, are included in Böhringer (2001) and in den Elzen and de Moor (2001, 2002).

Table 1: CO_2 emissions in the year 1990, assigned emission targets under the Kyoto Protocol for the first commitment period (2008-12), forest carbon sinks to be credited under Articles 3.3 and 3.4 of the Kyoto Protocol, and assigned emission target adjusted according to these forest carbon sinks.

	CO_2 emissions in 1990	Assigned target		Credited sink		Adjusted target
				Art.3.4.[1)]	Art.3.3.[2&3)]	
	Mt CO_2	% of base year	Mt CO_2	Mt CO_2	Mt CO_2	Mt CO_2
Finland	53.9	100	53.9	0.6		54.5
Sweden	51.3	104	53.4	2.1		55.5
Rest of EU	3025.6		2749.7	16.3	7.5	2773.4
Austria	46.7	87	40.6	2.3		42.9
Belgium	104.2	93	96.4	0.1		96.5
Denmark	51.5	79	40.7	0.2	0.4	41.2
France	357.7	100	357.7	3.2		360.9
Germany	986.8	79	779.6	4.6		784.1
Greece	77.3	125	96.6	0.3		96.9
Ireland	29.6	113	33.4	0.2	3.4	37.0
Italy	398.3	94	372.4	0.7	1.7	374.8
Luxembourg	12.1	72	8.7	0		8.8
Netherlands	159.0	94	149.5	0		149.5
Portugal	39.0	127	49.6	0.8		50.4
Spain	205.7	115	236.5	2.5		239.0
UK	557.7	88	488.0	1.4	2.1	491.4
EFTA	67.7		65.0	3.3	0.1	68.4
Iceland	1.7	110	1.8	0		1.8
Norway	26.4	101	26.6	1.5	0.1	28.2
Switzerland	39.7	92	36.5	1.8		38.3
USA	4840.5	93	4501.6	36.7		4538.3
Canada	415.7	94	390.7	44.0		434.8
Japan	1053.0	94	989.8	47.7		1037.5
New Zealand	22.4	100	22.4	0.7	21.7	44.8
Australia	265.3	108	286.5	0		286.5
CEA	911.8		847.5	13.8		861.5
Bulgaria	76.8	92	70.6	1.4		72.0
Czech Reb.	160.1	92	147.3	1.2		148.5
Hungary	68.1	94	64.0	1.1		65.1
Poland	371.4	94	349.1	3.0		352.2
Romania	165.4	92	152.1	4.0		156.2
Slovakia	56.7	92	52.2	1.8		54.0
Slovenia	13.3	92	12.2	1.3		13.5
FSU	3069.7		3061.8	127.8		3189.6
Estonia	37.2	92	34.2	0.4		34.6
Latvia	24.2	92	22.3	1.2		23.5
Lithuania	37.3	92	34.3	1.0		35.3
Russia	2298.9	100	2298.9	121.1		2420.0
Ukraine	672.1	100	672.1	4.1		676.2
TOTAL	13776.8	95	13022.4	293.1	29.4	13344.9

1) Maximum amounts allowed to be credited from forest management under Article 3.4 as agreed in COP6 in Bonn, 2001 (UNFCCC, 2001).
2) Amount of carbon sink under Article 3.3 as reported by Parties for UNFCCC in their submission August 2000 (UNFCCC/SBSTA, 2000).
3) Net carbon sources resulting from ARD activities under Article 3.3 are not shown here, since they were subtracted from the amount to be credited under Article 3.4 when the decision was made concerning maximum amounts to be credited (UNFCCC, 2001).

Credited carbon sink from forest management under Article 3.4 is small compared to the amount carbon sequestered in total forest area in all countries except in Canada and Japan, since only 15% is allowed to be credited. Carbon sink credited for Finland is, however, surprisingly low compared to the ones credited for other countries, since Finland is well known as a country with large forest resources. Within EU countries, larger credited sinks are reported for Austria, France, Germany, Italy, Portugal, Spain and UK (Table 1). The size of carbon sink in Finland has diminished substantially since the beginning of 1990s from 30 Mt CO_2 to 12 Mt CO_2 in year 2000 (UNFCCC, 2002) due to the increased amount of fellings. Also, the forested land area is estimated to decrease and therefore the part of sink resulting from forest management has to be used to compensate the source of carbon from afforestation, reforestation and deforestation under Article 3.3.

The figure for annual carbon sink, that Finland reported for UNFCCC for calculation of the maximum amount of sink allowed to be credited under Article 3.4 in the first commitment period, is based on the Finland's National Forest Program. According to that Program, the targeted average level of fellings is 63-68 million m^3. With a fellings level of 65 million m^3, annual carbon sink is estimated to be 8 Mt CO_2 (MMM, 2000), thus remaining in low level in the first commitment period. This figure was still adjusted downwards due to the uncertainties related to defining and measuring the sink. If the source of carbon under Article 3.3 is 1.3 Mt CO_2 as estimated, Finland needs to verify a sink that is only 5.2 Mt CO_2 in order to obtain the maximum amount to be credited (0.6 Mt CO_2) under Article 3.4. [5]

In the Kyoto Protocol, the assigned amounts of emissions are set as CO_2 equivalents to the total emissions of all six greenhouse gases. In our study, however, we refer to CO_2 emissions from combustion only because this is consistent with the GTAP-E model, where only CO_2 emissions from combustion are reported.

[5] Liski et al (2002) have estimated that if forest rotation length would be increased by 20 years in order to increase the amount of carbon sequestered, the area in which rotation length should be increased to provide the amount of sink allowed to be credited would be 2 Mha in case of Scots pine and 0.8 Mha in case of Norway spruce. In their study it was found out that for Scots pine, increasing rotation length decreases the amount of carbon in soil. This impact is not however taken into account in the estimate for area needed.

3. Description of the model

The simulations are performed with a global computable general equilibrium (CGE) model and related database, GTAP-E (Burniaux and Truong, 2002)[6]. GTAP-E has been extended from the basic GTAP model (Hertel, 1997) for analysis of climate change policy, as part of the Global Trade Analysis Project (GTAP, 2002). In order to include various energy components and implied emissions in the model, the energy volume and price information have been integrated into the original GTAP database. The GTAP database (version 4; see McDougall et al., 1998) covers 45 regions and 50 sectors, which in this study have been aggregated to 13 regions and 15 sectors (Table 2).

Table 2: Regions and sectors in this study.

Regions		Sectors
USA	USA	Agriculture
Canada	CAN	Forestry
Sweden	SWE	Paper and pulp industry
Finland	FIN	The wood products industry
The rest of EU countries	EU	Iron and steel industry
EFTA	EFT	Chemical industry
Central European Associates (transition countries)	CEA	Electrical equipment
Former Soviet Union	FSU	Machinery and other equipment
Japan	JPN	Other industry
Australia	AUS	Services
New Zealand	NZL	Electricity and heat
Non-Annex I paper and pulp exporters	NPX	Production of oil
Non-Annex I paper and pulp importers	NPM	Production of coal
		Production of gas
		Production of fossil fuel products

The model can be applied in the analysis of the economywide and sectoral effects of the Kyoto Protocol. As a global model, it brings forth the issues of competitiveness and the relative position of countries in changing patterns of production and trade flows. Compared to bottom-up or hybrid models that include a detailed description of existing and potential technologies, CGE-models use more general functions to describe production technology. Thus, they give a less accurate estimate of the direct costs of emission reduction than the energy sector models do, but on the other hand, they also take into account indirect costs that follow from adjustment in other parts of the economy, such as labour markets or foreign

[6] Burniaux and Truong (2002) refer to a model derived from version 6.1 of the GTAP model and version 5 of the data instead of the version 4 that we use. The main properties of the model versions are the same and differences are explained in their paper.

trade. CGE models are aggregate in their treatment of macroeconomic and technology issues, but they bring forth regional differences and the trade effects of mitigation.

Assigned amounts of emissions impose the constraints to which economies must adjust. In the simulations represented here, the carbon sinks are treated exogenously by adjusting the assigned amounts of emissions with carbon sinks outside the model and calculating the corresponding reductions in emissions, which are given as inputs to the model. All direct and indirect effects from increasing sinks are excluded; implying that sink enhancement is costless. Thus inclusion of sinks merely means lower reductions in emissions. The same approach is utilised in most of the economywide model simulations that include carbon sinks (e.g. in Böhringer, 2001; Jakeman et al., 2001 and 2002, for carbon sinks under Articles 3.3 and 3.4).

With regard to carbon sinks from forest management under Article 3.4, treating sinks exogenously is quite realistic since many countries, like Sweden and Finland, may achieve the maximum amount allowed to be credited without any further action. Carbon sinks arising from afforestation, reforestation and deforestation after 1990 could, in principle, be used as active measures for achieving the emission target. However, since forests grow quite slowly in most of the Annex I countries, AR activities performed now would be of minor importance during the first commitment period. Only AR activities that took place already in the early 90's would have some importance. In addition, many ARD activities are based on the "business as usual" land-use policy, performed for reasons other than C sequestration and thus in this context cost nothing. This applies, e.g. for the ARD figure for New Zealand used in our study.

The economies adjust to the emission constraints by substituting less carbon-intensive fossil fuels for more carbon-intensive ones, and energy with other inputs and contracting activities that produce emissions. The model finds an optimal way to achieve the emission target by choosing the least-cost options for reducing emissions. The shadow-price for emission reductions is expressed as a carbon tax. Substitution possibilities depend on original input shares and substitution elasticities, both of which vary among fossil fuels, namely coal, oil, gas and petroleum products. Energy is a composite commodity of the above-mentioned fossil fuels and electricity. In the next phases, capital can be substituted with energy composite and labour with capital-energy composite. This simplistic production technology is assumed to prevail in every country, and it determines the implied marginal costs of reducing emissions.[7]

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[7] The aggregation procedure allows the factors of production to be treated also as aggregates. For simplicity and computational compatibility, we have treated skilled and unskilled labor as one composite and added the natural resources to the capital composite. Our treatment of natural resources reduces the estimate for carbon tax.

Efficiency losses due to limited substitution possibilities of energy commodities imply higher costs for industries that are energy-intensive. A contraction in certain activities does not leave idle capacity, as factors of production (land, labour, and capital) are assumed to be used fully, moving to other sectors and increasing their production. Adjusting prices balances the demand and supply for each commodity.

For determining the impacts on competitiveness in the international market, modelling of international trade plays a crucial role. In the GTAP framework, domestic and foreign products in the same product category are assumed to be imperfect substitutes[8]. Increasing costs and prices, e.g. for domestic energy-intensive products, diminish their demand but are not totally displaced by foreign products. Assumptions about the size of the substitution parameters heavily affect the induced impacts in the international market. The larger the substitution, the less powerful the country is in the international market and the greater the losses of competitiveness due to cost increase[9].

In the analysis of competitiveness in the Kyoto studies, the issue of leakage is crucial. In the GTAP model all endowments are, according to a standard assumption, assumed not to move across borders[10]. So the leakage is borne solely by increasing production due to reallocation of resources within non-restricting countries. As factors of production still move freely inside countries, the wage rate and the price of capital are equalised across sectors in a given region.

[8] I.e. the Armington assumption. Alternatively the products could be modelled as homogeneous products where an increase in the costs should lead to relocation of production to countries where production costs are lower.

[9] In this study we have used default assumptions of the GTAP model on Armington elasticities, which vary from 1.9 to 5.2. These values for elasticities imply some market power for even the smallest countries in the world market.

[10] There is still an investment good that is allocated globally based on the expected rate of return in different countries. As the model is static, the investments do not accumulate to the capital stock.

4. Scenarios

Baseline projections

Estimates of the baseline emissions in the first commitment period strongly influence the costs of mitigation. They are especially important for evaluating the effect of including carbon sinks, as it depends on how large the carbon sink is relative to reduction in emissions. For evaluation of the first commitment period (2008-2012), we choose to obtain estimates for emission levels from outside studies instead of letting the model produce them freely. Relying on energy scenarios for information on projected emissions is rather standard procedure when mitigation costs are estimated (see e.g. Böhringer et al., 2000).

We make projections on the world economy for 2010 with the GTAP-E model by exogenously assuming the growth rate for the GDP, labour, capital and productivity in different sectors. Projections applied in this study are described in Haaparanta et al. (2001). The emission estimates utilised in this study for the year 2010 are from the European Union Energy Outlook to 2020 (European Commission, 1999) for EU countries and from emission scenarios provided by the ABARE Research Institute (Jakeman et al., 2001) for other Annex I countries. With a highly disaggregated country and regional level it is, however, difficult to get the model to produce emission levels that would be in line with outside information. As we prefer to use the GTAP-E description of the world markets in 2010 and outside information for emissions, we have calculated the emission reductions needed to achieve the targets outside the model[11]. These percentage emission reductions with or without adjustment with sinks (Table 3) are given as input to the projected database. The forest carbon sinks (Table 3) are estimated as described in Section 2. By estimating how the inclusion of sinks affects the actual reduction in emissions needed in 2010, we expand the commonly used approach in which the importance of carbon sinks has been demonstrated by examining the effect of sinks only on Kyoto targets (see e.g. Schwarze, 2001) or on the assigned amounts of emissions.

Adjusting emission targets with forest carbon sinks has the largest effect on emission reductions in New Zealand, since that country does not have to reduce its emissions at all. On the contrary, in case of allowing international emission trading, it could sell emission permits on the international market. In Sweden, the estimated amount of emission reduction decreases by almost 20 percent. Allowing larger sinks for Canada and Japan considerably reduce the emission reductions needed for them to achieve the Kyoto target. In the other regions, the inclusion of sinks has only a slight effect on the amount of emission reduction.

[11] In Böhringer et al. (2000), as in some other studies, methods of getting consistent results on emissions are developed e.g. by adapting energy efficiency parameters to balance the two sources of information.

For Finland, that had originally a relatively tight emission target, credits from sinks do not provide any significant releases. This can be seen in Table 3.

Policy scenarios

The emission targets in the simulations are based on the Kyoto Protocol and on EU burden sharing. In our simulations, international emission trading is not allowed, which implies that the emission target has to be achieved by domestic actions only.

We perform the following policy scenarios:

Sink: no. Annex I countries, excluding the USA, reduce their emissions as assigned in COP3 in Kyoto 1997 (see Table 1).

Sink: common rule. As above, but carbon sinks are credited and the amounts to be credited are calculated by common accounting rules, thus also applying to Canada and Japan (adjusted targets are shown in Table 1, except for Canada and Japan these figures were 2.8 Mt CO_2 and 14.3 Mt CO_2, respectively).

Sink: larger. As in 'Sink: common rule', but country-specific carbon sinks are allowed for Canada and Japan as agreed in COP6b in Bonn 2001 (see adjusted targets in Table 1).

US in. USA ratifies the Kyoto Protocol and carbon sinks are credited according to common accounting rules as in the 'Sink: common rule' scenario.

The first three scenarios are used in order to evaluate the importance of allowing credits from carbon sinks. To capture only the impact of including sinks, the scenarios are identical in other respects, e.g. we have assumed in all of these scenarios that the USA does not reduce emissions according to the Kyoto Protocol nor does it have any other emission constraint. The third scenario is in line with the actual situation. The fourth scenario is an additional one used to illustrate the impact of US withdrawal on Canada and Japan. Even though the USA announced already in the summer of 2001 that it would not ratify the agreement, analysing its participation forms a reference case for the negotiation positions of Canada and Japan.

Table 3: Projections of CO_2 emissions for the year 2010[12], estimates of annual carbon sinks to be credited for the first commitment period (2008-2010) and estimated emission reductions needed to achieve the Kyoto targets (Table 1) with and without credited sinks.

	CO_2 emissions in 2010	Credited sink	Emission reduction			
			without sink	with sink	without sink	with sink
	Mt CO_2	Mt CO_2	%	%	Mt CO_2	Mt CO_2
Finland	77.1	0.6	-30.1	-29.3	-23.2	-22.6
Sweden	65.2	2.1	-18.1	-14.8	-11.8	-9.7
Rest of EU	3214.7	23.8	-14.5	-13.7	-465.0	-441.2
Austria	46.7	2.3	-13.0	-8.0	-6.1	-3.8
Belgium	123.0	0.1	-21.6	-21.5	-26.6	-26.5
Denmark	53.6	0.5	-24.0	-23.0	-12.9	-12.3
France	397.1	3.2	-9.9	-9.1	-39.3	-36.1
Germany	858.5	4.6	-9.2	-8.7	-78.9	-74.4
Greece	119.0	0.3	-18.8	-18.6	-22.4	-22.1
Ireland	42.3	3.5	-21.0	-12.6	-8.9	-5.3
Italy	442.1	2.4	-15.8	-15.2	-69.7	-67.3
Luxembourg	10.1	0.0	-13.3	-12.9	-1.3	-1.3
Netherlands	213.1	0.0	-29.9	-29.8	-63.6	-63.6
Portugal	66.3	0.8	-25.3	-24.1	-16.8	-16.0
Spain	279.7	2.5	-15.4	-14.6	-43.2	-40.7
UK	563.2	3.4	-13.4	-12.8	-75.3	-71.9
EFTA	91.2	3.5	-28.8	-25.0	-26.2	-22.8
Iceland	2.2	0.1	-18.3	-14.3	-0.4	-0.3
Norway	35.5	1.5	-25.0	-20.7	-8.9	-7.3
Switzerland	53.4	1.8	-31.7	-28.3	-16.9	-15.1
[**USA**	6915.8	36.7	-34.9	-34.4	-2414.2	-2377.5]
Canada	605.7	44.0	-35.5	-28.2	-214.9	-170.9
Japan	1163.4	47.7	-14.9	-10.8	-173.6	-125.9
New Zealand	30.2	22.4	-25.8	48.6	-7.8	14.7
Australia	379.0	0	-24.4	-24.4	-92.5	-92.5
CEA	858.6	13.8	-1.3	0.3	-11.0	-2.8
Bulgaria	72.3	1.4	-2.3	-0.4	-1.7	-0.3
Czech Reb.	150.8	1.2	-2.3	-1.5	-3.5	-2.3
Hungary	64.1	1.1	-0.2	1.5	-0.1	0.9
Poland	349.8	3.0	-0.2	0.7	-0.6	2.4
Romania	155.7	4.0	-2.3	0.3	-3.6	0.5
Slovakia	53.4	1.8	-2.3	1.1	-1.2	0.6
Slovenia	12.5	1.3	-2.3	8.3	-0.3	1.0
FSU	2379.8	127.8	28.7	34.0	682.0	809.8
Estonia	35.0	0.4	-2.3	-1.3	-0.8	-0.4
Latvia	22.8	1.2	-2.3	3.2	-0.5	0.7
Lithuania	35.1	1.0	-2.3	0.6	-0.8	0.2
Russia	1769.6	121.1	29.9	36.8	529.3	650.5
Ukraine	517.3	4.1	29.9	30.7	154.8	158.8

[12] Since only the CO_2 emissions from combustion are included in the model used in the simulations, emission reduction target is set here to CO_2 emissions instead of GHG emissions.

5. Results and discussion

Which countries benefit from carbon sinks?

The burden on the economy of implementing the Kyoto Protocol is measured with two variables; carbon tax and welfare (Figs. 1 and 2, and Appendices A and B, respectively). Differences in the estimated carbon taxes and welfare between countries reflect differences in both the amount and the costs of reducing emissions. For both of these variables, the qualitative results obtained when sinks were included are relatively similar.

New Zealand benefits most from the credited carbon sinks since it does not have to reduce emissions at all. Due to the positive world market effects, its welfare is actually increasing slightly compared to business-as-usual without a climate policy (Fig.2). In Sweden and in EFTA, the carbon tax is also considerably lower and welfare higher if credits from forest carbon sinks are allowed. In other countries like in Finland, the forest carbon sinks have only a minor influence on the carbon tax (Fig.1) or welfare (Fig.2) since the sinks are relatively small compared with reduction in emissions.

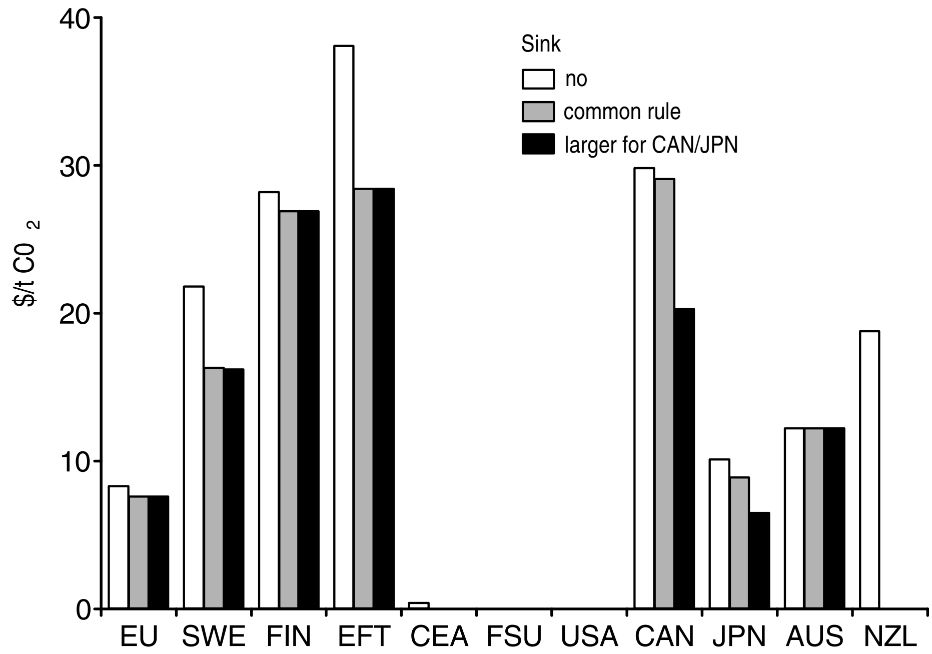

Fig.1. Carbon tax needed to reach the Kyoto target without US participation in the year 2010 for Sweden, Finland, the rest of the EU, EFTA, Central European Associates (transition countries), former Soviet Union, USA, Canada, Japan, Australia and New Zealand when (i) sinks are not credited, (ii) sinks are credited according to common accounting rules, (iii) country-specific sinks are allowed for Canada and Japan as agreed in Bonn.

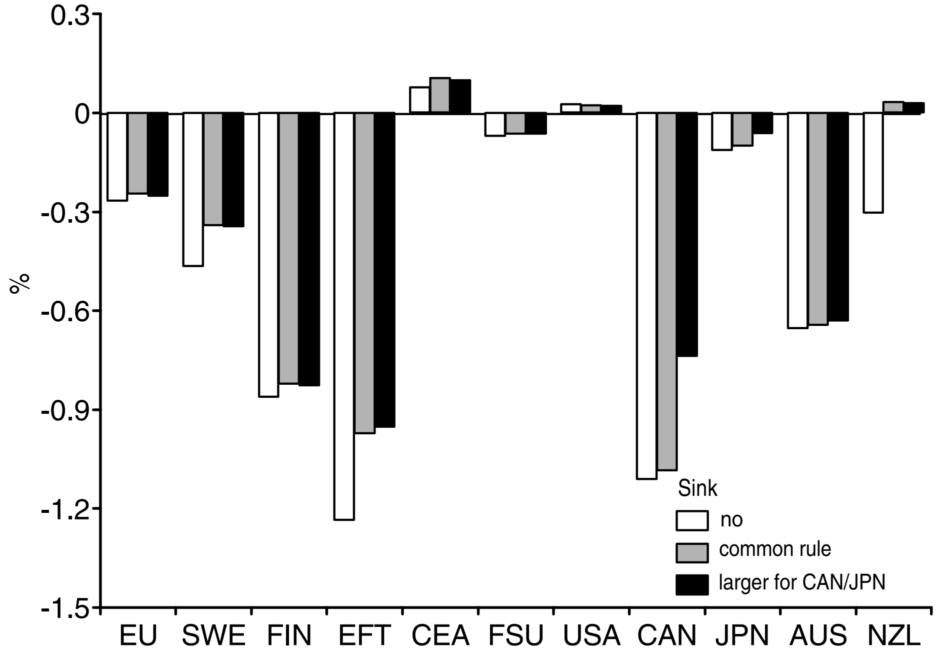

Fig.2. Percentage change in welfare in 2010 in Annex I countries without US participation. Credits of carbon sinks as in Fig.1.

As a result of the political agreement in Bonn (UNFCCC, 2001), Canada and Japan are allowed to credit larger forest carbon sinks than other countries are. These larger forest carbon sinks clearly benefit Canada and Japan, unlike the sinks calculated according to common rules. The economywide costs are reduced by one third in Canada and by more than one-third in Japan compared to the 'common rule' scenario (Fig.2).

The impact of inclusion of sinks, as agreed upon in Bonn, is also illustrated by Böhringer (2001). According to his study, the gain from sinks is notably larger for Canada than for Japan. Canada would benefit more than in our study as its economywide costs measured by consumption are nearly halved. The gain for Japan is somewhat less than that found in our study. The benefits for Europe and the USA are significantly larger than those estimated here. According to Böhringer, their costs would be reduced by one fifth instead of by about 15% for Europe and 4% for the USA, as estimated in the present study. The differences in results can be explained partly by the difference in amounts of sinks. Both Böhringer's and our study include sinks from forest management under Article 3.4. In addition, our study includes sinks under Article 3.3, while in Böhringer sinks arising from agricultural activities under Article 3.4 and from CDM are included. In Böhringer, the amount of sinks is considerably larger for Europe and the USA and slightly larger for Canada than in our study.

The Kyoto Protocol and EU burden sharing do not allocate the costs of implementation of the Protocol equally across Annex I countries. Inclusion of sinks partly reduces the difference in economic burden of achieving the Kyoto target among countries. Some of the countries/regions with high costs, namely Canada and EFTA, gain from sinks since their costs are reduced. However, the inclusion of sinks also reduces costs in countries such as New Zealand, Sweden and Japan, where the costs are already relatively low even without credits from sinks.

Do carbon sinks reduce the economic burden for Finland in absolute terms and relative to other countries?

For Finland, the starting point in emission reductions is not very encouraging as the emissions are projected to increase faster than in other countries. The necessary cut in emissions for Finland is almost 30% of the projected emissions for 2010[13]. E.g. compared to Sweden, with whom the emissions in 1990 were at about the same level, the projected emissions for Sweden result in much lower emission reductions needed. Compared to other EU countries, the position is also weak.

Since in Finland the credited carbon sink is small relative to emission reduction needed, the inclusion of sinks reduces the costs of achieving the emission target only slightly. Sinks in Sweden on the other hand, that also absolutely is reported higher, play a more significant role in relative terms. In fact, inclusion of carbon sinks weakens the relative position of Finland compared to EU countries and Sweden. However, in the economywide level even the cost-advantage obtained by Sweden has a marginal impact for Finland. Compared to Canada, the original position in Finland was largely similar before inclusion of extra sinks. After the country specific rules for Canada and Japan, Finland carries the heaviest burden from cutting a ton of CO_2 when measured by a carbon tax.

As sinks in Finland are marginal, they do not affect the industry results as such. Instead we can study whether sinks improve the competitiveness of other countries relative to Finland. In international trade, this is reflected in deteriorating terms of trade (Fig. 7a). For industries competing in international markets, cost pressures at the margin affect the acceptability of the Protocol. This applies especially for industries, where the price of energy intensive inputs plays a significant role. We explore the iron and steel sector, and paper, pulp and publishing sector in more detail.

In paper markets Sweden is the major competitor of Finland. As stated above (in chapter 4), committing to the climate convention is a heavier burden for Finland

[13] In the Finland's National Climate Strategy the corresponding emission reduction has been estimated to be 22%. Thus we are assuming that emissions would grow faster. Here, we prefer to use the common reference for all EU countries in order to have consistent estimates for growth of emissions and implied emission reduction.

than for Sweden. This can be seen in the projected emissions, required emission reductions and the respective carbon taxes (Table 3, Fig. 1). In world markets for pulp and paper, Finland and Sweden compete equally with market shares of c.a. 7 percent of global pulp and paper exports (GTAP database 4). In table 4 the estimated changes in pulp and paper production are described. Activities in paper industry contract almost ten times more in Finland (ranging from –2% in Finland to –0.2% in Sweden). This is due to the fact that electricity is mainly produced with nuclear and hydropower in Sweden and thus carbon tax does not increase the costs in paper and pulp industry. Thus even though inclusion of sinks reduces the carbon tax considerably, the effect on the paper and pulp industry remains smaller[14]. Since there is only small impact in Sweden, inclusion of carbon sinks does not decrease the competitiveness of paper and pulp industry in Finland. On the other hand, lower carbon tax in Sweden due to carbon sinks reduces the increase in energy costs in iron and steel industry and thus the impact of sinks on production of iron and steel is larger than on paper and pulp in Sweden. The larger sink in Sweden has also some impact on iron and steel industry in Finland, which would gain slightly more from the lower tax in Finland if it did not lose competitiveness relative to Sweden.

The higher sinks allowed for Canada do not effect the production of paper, pulp and publishing in Finland either, since the impact on production costs for the total industry in Canada is small. For papers produced with mechanical pulp, like newsprint where energy costs cover approximately 20% of the total costs, the cost impacts might be somewhat larger. Also in Canada the inclusion of carbon sinks have more impact on the production of iron and steel than on the production of paper, pulp and publishing since the production of iron and steel is more fossil fuel intensive.

[14] Even though sinks are related to forests, they do not benefit only forest or paper industries but are to be credited at the national level by changing the adjusted target for emissions.

Table 4: Change in production of paper, pulp and publishing and iron and steel in selected countries/regions resulting from achieving the assigned emission targets with various assumptions about crediting forest carbon sinks, %.

Regions	No credits from C sinks	C sinks credited according to common rules		C sinks credited with country specific rules for Canada and Japan
		USA out[1)]	USA in[2)]	
Paper and pulp				
Finland	-1.78	-1.69	-1.99	-1.67
Sweden	-0.17	-0.14	-0.18	-0.14
Rest of EU	-0.15	-0.13	-0.24	-0.12
Canada	-0.21	-0.19	0.29	-0.17
USA	-0.10	-0.09	-0.55	-0.07
Iron and steel				
Finland	-5.93	-5.91	-5.98	-5.92
Sweden	-2.50	-1.68	-1.49	-1.7
Rest of EU	-0.89	-0.83	-0.92	-0.82
Canada	-2.38	-2.37	0.45	-1.89
USA	0.23	0.22	-1.86	0.19

1) KP ratified by the other Annex I countries but not the USA
2) KP ratified by all Annex I countries (including the USA)

How are other countries and different sectors affected by the larger sinks allowed for Canada and Japan?

The larger carbon sinks credited to Canada and Japan have only a minor influence on the amount of the carbon tax or the welfare of other countries (Figs. 1 and 2 and Appendices A and B). On a global level, even for Japan, one of the most important exporters, its share does not exceed 10 percent of the total exports. Canada's share of world exports is less than 5 per cent. The results indicate that these countries do not have a dominant position in the regional markets either[15]. Thus, although the economywide impacts of allowing higher sinks are considerable for Canada and Japan, the influence on other countries through trade impacts remains minor.

Impacts on production in other countries are also very small (Fig.3). Allowing larger sinks for Canada and Japan decreases production of chemicals in all regions and that of iron and steel in almost all regions. However, even in Australia, where the impact is greatest, the production of iron and steel is only 0.2 percent-

[15] Since markets are segregated, due to limited possibilities to substitute goods from different places of origin, the country may have more market power regionally than globally.

age units lower when larger sinks are allowed. Larger sinks decrease the producer price of fossil-fuel-intensive goods in Canada and Japan. Changes in relative prices between regions are, however, moderate. Since changes in competitiveness in the world market and imports from Japan and Canada remain small[16], the impact on domestic production cannot be large either. Larger sinks weaken the competitiveness of labour- and capital-intensive sectors in Japan and Canada; consequently, in most of the other regions, the machinery sector is found to benefit from larger sinks (Fig.3). Again, however, the absolute effects are very small.

Compared to the US withdrawal (US in scenario), allowing larger sinks for Canada and Japan is a considerably smaller shock to world economy. Firstly, allowing larger sinks cuts emission reductions in Canada and Japan by 20-30%, while US withdrawal cuts its reduction in emissions to zero. This implies that price adjustment in the country in question, and thus the change in competitiveness in the world market, are notably smaller in the case of larger sinks than in the case of US withdrawal[17]. Secondly, Canada and Japan are less important trading partners than the USA is. Thus US withdrawal has considerably more serious effects on the other regions (Appendices A and B) and sectors than allowing higher sinks for Canada and Japan does. Trade impacts are summarised in the changes in the terms of trade (the relation between export and import prices). Declining terms of trade describe deteriorating purchasing power for imports with given exports. Allowing larger sinks for Canada and Japan has a small impact on the terms of trade for other countries (Fig.4a), while US withdrawal clearly affects them (Fig.4b). It should also be noted that the terms of trade for Canada and Japan are affected more by US withdrawal than by allowing them larger sinks (Figs. 4a and 4b).

[16] For example, For example, without larger sinks, the price of iron and steel is 1.0% higher in Australia than in Japan, which increases Japanese exports by 2.2% compared to the reference scenario. When larger sinks are allowed, the price of Australian iron and steel is 1.2% higher than the Japanese price and exports from Japan are 2.8% higher than in the reference scenario.

[17] For example, For example, in case the USA participates in the Kyoto Protocol, its production price for iron and steel will be 2.0% higher than the price in the EU. On the other hand, with US withdrawal, the price in the USA is 0.8% lower than the price in the EU.

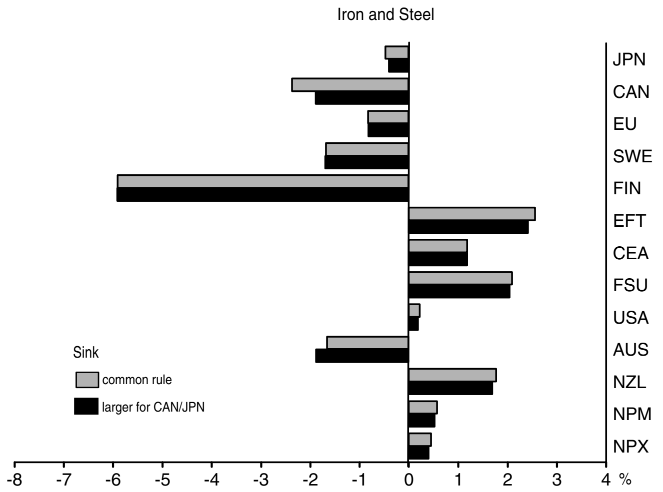

Fig.3a.

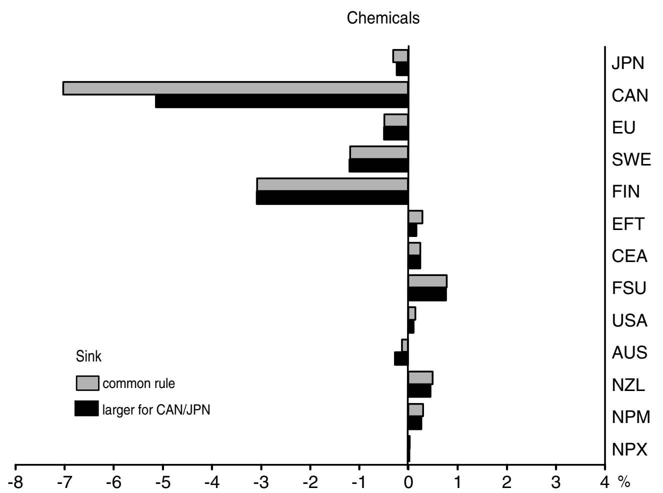

Fig.3b.

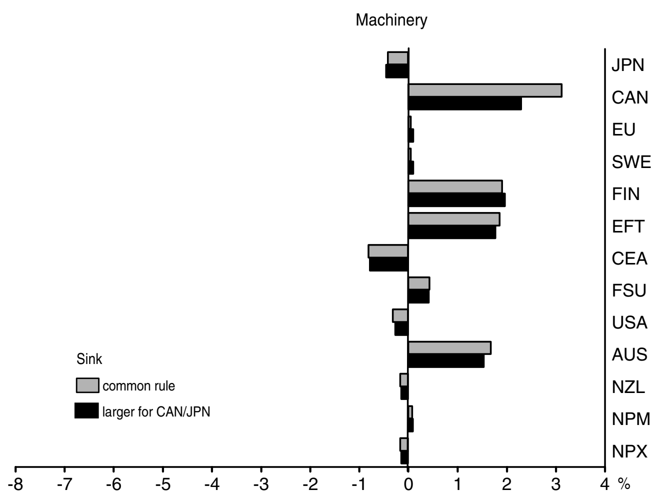

Fig.3c.

Fig.3. Percentage changes in production of (a) iron and steel, (b) chemicals and (c) machinery without US participation in Annex I countries, NPM (non-Annex I countries, which are net importers of paper, pulp and publishing) and NPX (non-Annex I countries, which are net exporters of paper, pulp and publishing). Emission targets were adjusted with forest carbon sinks calculated (i) according to common accounting rules or (ii) allowing country-specific sinks for Canada and Japan.

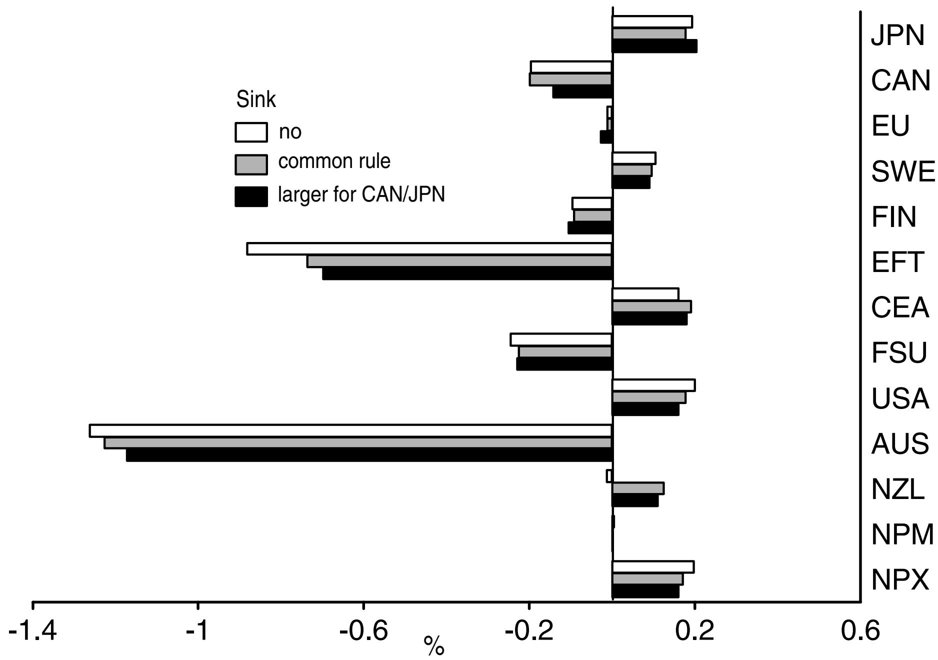

Fig.4a. Percentage change in terms of trade in 2010 in Annex I and non-Annex I countries under different credits for carbon sinks.

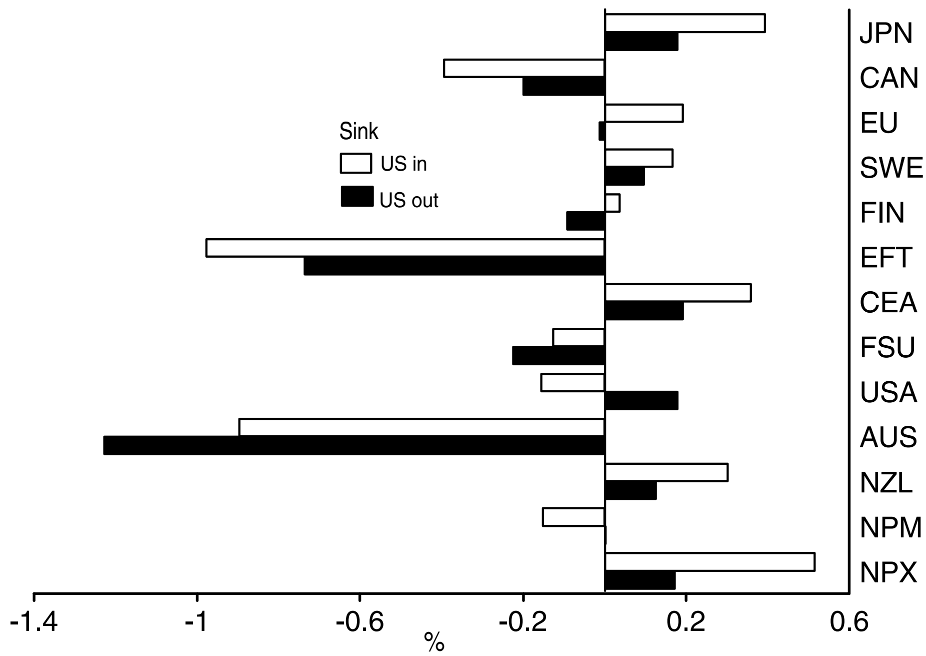

Fig.4b. Percentage change in terms of trade in 2010 in Annex I and non-Annex I countries with and without US participation.

Can we find any basis for allowing country-specific sinks for Canada and Japan?

Withdrawal of the USA from the Kyoto Protocol might affect, in particular, its neighbour Canada since its competitors are not hit by the carbon tax. According to our simulations, exports of fossil-fuel-intensive goods from Canada, like iron and steel and chemicals, do indeed decrease as a result of US withdrawal. The negative effects are, however, exceeded by the positive ones, implying that withdrawal of the USA actually benefit Canada moderately (Appendix B).

Although US withdrawal reduces exports of fossil-fuel-intensive goods from Canada to the USA, the total exports are increased. This is mainly due to the increase in exports of fossil fuels, especially oil and gas, whose consumption remains high in the USA when it does not face the emission constraint. Export of machinery and other equipment, which is the major exporting industry in Canada, is also increasing due to the better competitiveness in labour- and capital-intensive goods[18]. In addition to these reasons, the higher real income in the USA increases the demand for both domestic and foreign goods, also benefiting exports of all goods from Canada through the income effect. The impact of US withdrawal on the total exports of Canada was also positive, although exports of some goods, like machinery, to countries other than the USA were decreased.

Böhringer (2001) also found that Canada benefits from US withdrawal, but in that study the gain was found to be more important than in our study. The considerable impact is explained by the fact that the net exporters of fossil fuels, like Canada, gain from the fact that prices of fossil fuels do not drop so much. In the model used in this study, this effect is likely to be smaller since the treatment of fossil fuels is different. In both studies, the US withdrawal improves the terms of trade in Canada. However, in our study this is due mainly to the decrease in import prices, which consist mainly of US prices, instead of an increase in export prices.

For Japan, the effect of US withdrawal is opposite to the effect on Canada since Japanese welfare decreases moderately. For some other regions, like the EU, however, the negative welfare effect is greater. In conclusion, US withdrawal cannot be used as argument for allowing higher, country-specific sinks for either Canada or Japan.

According to our simulations, Canada, due largely to its high abatement task, bore one of the highest costs of implementation of the Kyoto Protocol without credits from sinks. Böhringer (2001) and Jakeman et al (2002) support this finding. Even after allowing a larger sink, the welfare costs for Canada are among the

[18] When the USA does not reduce its emissions, the prices of capital and labour are not adjusted downwards. Thus the production costs and prices of labor and capital goods remain higher than in the scenario in which the USA ratifies the Kyoto Protocol.

highest. Thus larger sink does not provide an unreasonable advantage for Canada, especially since other countries are not affected. On the other hand, in Japan the costs of achieving the emission target are estimated to be very low and were made even lower by allowing a larger sink.

How are benefits from carbon sinks distributed within the economy?

We showed above that economic gains from carbon sinks are not evenly distributed among countries, but they are not evenly distributed within the economy either. However, carbon sinks reduce the difference in economic burden among production sectors more than in the case of countries/regions. Fig.5 illustrates nicely that sectors, which originally benefit from climate policy, suffer from inclusion of sinks, while those sectors that originally suffer will eventually gain. In general, the greater the amount of reduction in emissions, the larger is the adjustment in industry structure. Thus, the inclusion of carbon sinks cuts down the structural adjustment.

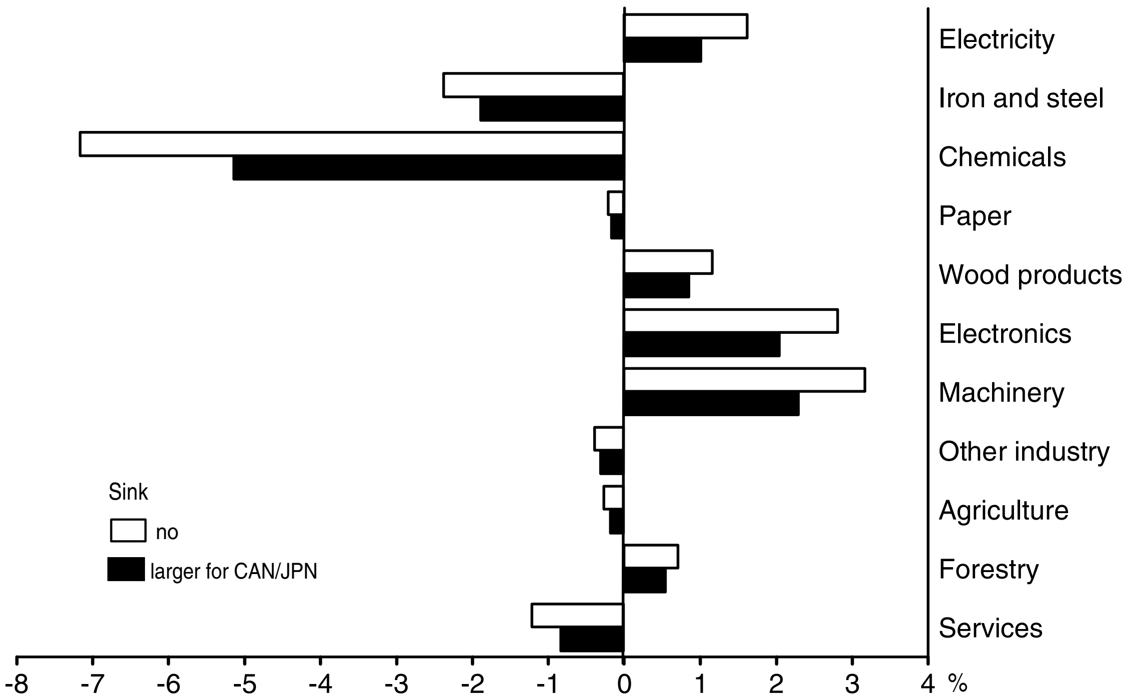

Fig.5. Percentage changes in production levels in Canada in 2010 without US participation when (i) sinks are not credited, (ii) country-specific sinks are allowed for Canada and Japan.

The impacts on all sectors, excluding production of fossil fuels, are illustrated in Fig.5 for Canada in the case of allowing larger sinks. Sectors producing fossil fuels, such as coal, oil, gas and petroleum products, or fossil-fuel-intensive goods, such as iron and steel, chemical products and services (including traffic) benefit from inclusion of carbon sinks into the Kyoto Protocol in all those countries that have considerable sinks. The sector that gains most varies among countries. In Canada, the production of services benefits most from inclusion of sinks, while in Sweden the iron and steel industry gets the greatest advantage. In New Zealand, which has no binding emission limit in the case of allowing credits from sinks, the production levels of iron and steel and chemicals are higher than in the business-as-usual scenario, while without credits from sinks their production levels are 4.5% below the BAU levels. The paper, pulp and publishing industry, other industries and agriculture gain in all other countries except in New Zealand. In those countries in which sinks are insignificant compared to reduction in emissions, the trade effects may dominate as, e.g. in the case of Australia where production of iron and steel suffer from inclusion of sinks.

On the other hand, the machinery and wood products industries, where the cost share of fossil fuels is negligible, suffer in all countries that have a large sink compared to reduction in emissions, except in Japan. For example, in Canada the production of machinery increases by 3% in the 'no sinks' scenario and by 2% in the 'larger sinks' scenario compared to the BAU scenario. For the electronic industry the effects are diverse.

A large carbon sink may actually hurt the exporting sectors[19]. As seen in Fig.6, inclusion of sinks decreases total exports from New Zealand, Canada (larger sinks), Japan (larger sinks) and EFTA compared to the scenario in which sinks are not allowed to be credited. The only exception is Sweden. On the other hand, in countries with a relatively small sink, exports are increasing slightly.

How does inclusion of carbon sinks affect non-Annex I countries?

Even though non-Annex I countries do not face an emission target, they are affected by climate policy through effects on the world market. In the model we have two non-Annex I regions, of which the net exporters of paper and pulp (NPX) benefit from reduction in emissions while the net importers of paper and pulp (NPM) suffer slightly (see Fig.7). Impacts on the non-Annex I countries are due to carbon leakage and changes in fossil fuel prices.

The inclusion of carbon sinks has no impact on welfare in the non-Annex I regions included in the model. Countries that have the largest sinks relative to emission reduction are not major players in the markets where non-Annex I regions operate, at least at the aggregation level used in the model. However, for some individual developing countries, the extra sinks allowed for Japan might have some influence.

[19] The similar mechanism explains why US withdrawal has a negative effect on its exports.

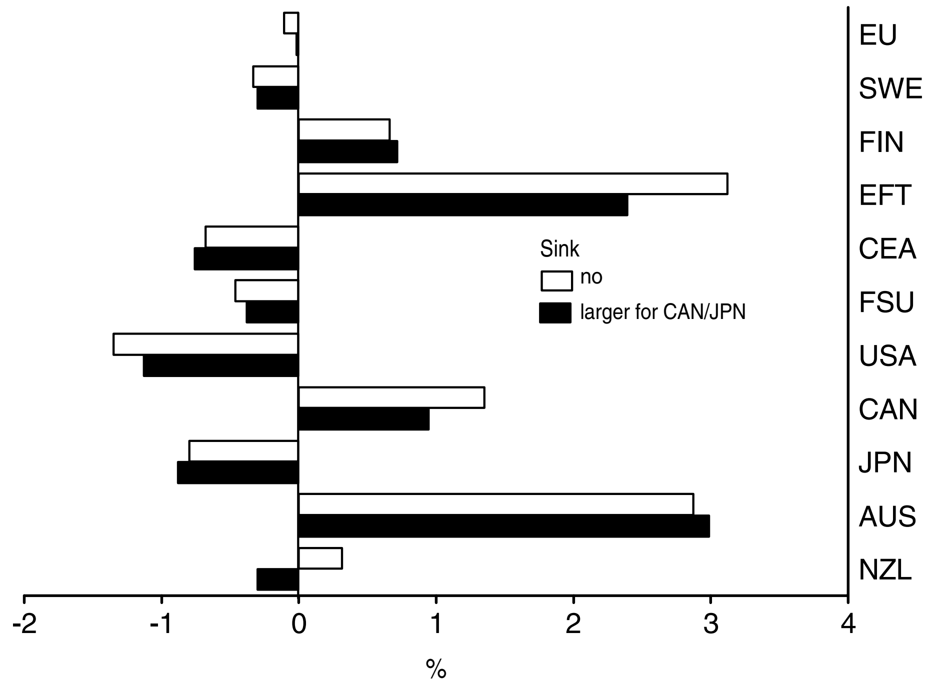

Fig.6. Percentage change in exports in Annex I countries in 2010 when (i) sinks are not credited, (ii) country-specific sinks are allowed for Canada and Japan.

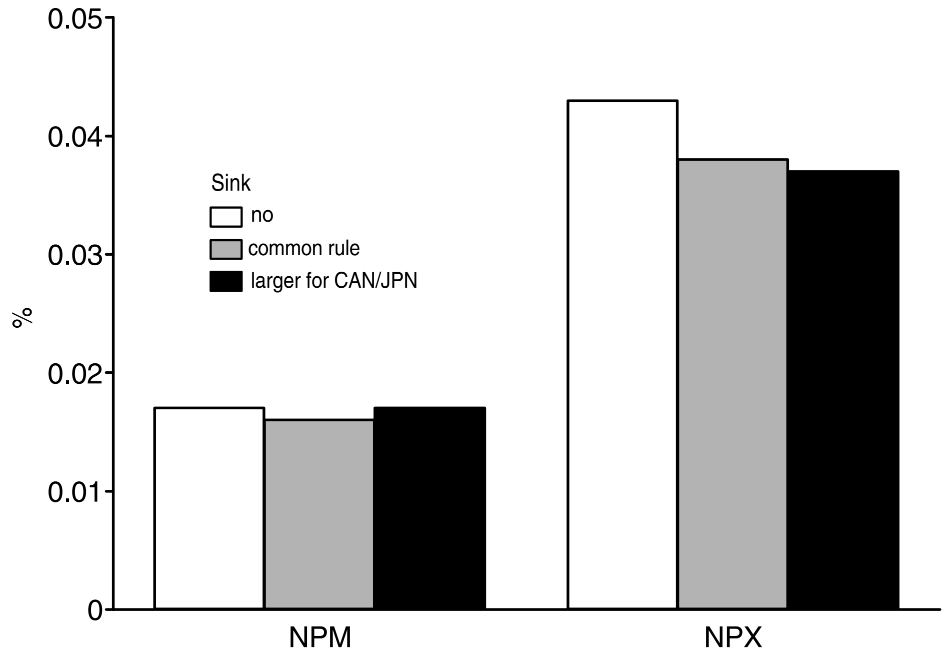

Fig.7. Percentage change in welfare in 2010 for the non-Annex I countries which are net importers (NPM) or net exporters (NPX) of paper, pulp and publishing without US participation. Credits of carbon sinks as in Fig.1.

Carbon leakage occurs because the competitiveness of fossil-fuel-intensive sectors decrease in Annex I countries due to the emission constraint. The production of iron and steel increases moderately in both non-Annex I regions and production of chemicals in the NPM region. Carbon leakage to non-Annex I countries is limited due to the fact that also some Annex I countries, namely FSU and the transition countries, do not face the binding emission constraint. Production of iron and steel, in particular, increases more in FSU than in developing countries. Inclusion of carbon sinks dampens the carbon leakage to non-Annex I countries since the cost increase in fossil-fuel-intensive sectors is lower.

Production of coal, oil and gas decreases in both NPM (incl. OPEC) and NPX regions, although the decrease is more moderate than in Annex I countries. As expected, inclusion of carbon sinks weakens the decrease since the reduction of emissions is lower in Annex I countries.

The magnitude of carbon leakage and overall impact on non-Annex I countries depends on the assumptions used in the model. Since capital and labour are not allowed to move across regions, the increase in production possibilities is limited. Moreover, changes in trade flows are restricted by the Armington elasticities.

6. Conclusions and caveats

The results of this study indicate that the gains from carbon sinks are not distributed evenly among countries. Within countries, New Zealand gains most from the credited carbon sinks, as it does not have to reduce emissions at all. Also in Sweden, EFTA, Canada and Japan the carbon tax is considerably lower and welfare loss smaller if credits from forest carbon sinks are allowed. In other countries, the forest carbon sinks have only a slight influence on the carbon tax or welfare, since sinks are relatively small compared with the reduction in emissions. For Finland, the role of sinks is marginal. Gains achieved by its competitors worsen Finland’s relative position but the impact is negligible in the economywide level.

Of those countries that gain the most from sinks, Canada and EFTA have originally high costs while New Zealand, Sweden and Japan have low costs. Thus carbon sinks only partly reduce the difference in economic burden of achieving the Kyoto target among countries. Those countries that had bargaining power in the negotiations manage to obtain important gains from sinks. The country-specific, larger sinks allowed for Canada and Japan provide considerable benefit for these countries, while carbon sinks calculated according to common rules would have only a minor effect on their costs for implementing the Kyoto Protocol. The higher carbon sinks allowed for Canada and Japan do not, however, influence other countries, as Finland, either economywide or on the sectoral level since the trade-induced effects are small. For example, paper and pulp industry in Finland does not seem to lose its competitiveness.

With respect to cost differences between sectors, sinks equalise the costs to some extent, as the inclusion of sinks dampens the adjustment in the industry structure by lowering the reduction in emissions. Sectors producing fossil fuels or fossil-fuel-intensive goods, like iron and steel or chemicals, benefit from inclusion of sinks while the other sectors, like machinery, might suffer.

In the simulations presented here, the emission limit has to be achieved by domestic measures. In the case of allowing international emission trading, all countries, except those selling permits, would benefit from carbon sinks inside the trading area, as the price of an emission permit would drop. Thus for example Finland could benefit from sinks located in other countries like in Canada. According to Böhringer (2001), the permit price would drop from 17 \$/t CO_2 to 11 \$/CO_2 in the case of US participation and from 2 \$/CO_2 to 0 \$/CO_2 without the USA. Countries having sinks would, however, benefit most since they could sell the credits from sinks.

Another limitation of this study is that the carbon sinks are treated as exogenous input, which implies that the costs of carbon sequestration are not considered.

Although for the first commitment period this approach can be considered quite realistic, for the later commitment periods there might exist more possibilities to use forests actively to sequester carbon. Cost-efficiency would imply that, in order to choose the least-cost options to achieve the emission target, the costs of increasing the amount of carbon sequestered should be compared to the costs of reducing emissions from fossil fuels. Increasing carbon sinks would probably have direct impacts on the timber market, which might in turn influence relative prices, competitiveness, production structure and trade flows. On the other hand, the size of sink is likely to be affected by reduction in the use of fossil fuels, e.g. due to the substitution of wood for fossil fuels, and the lower demand for timber if the production of energy-intensive paper is reduced. In order to capture all the effects, the cost curve for supplying forest carbon sinks in existing and new forests, as well as global timber markets, should be added into the model.

In this study, the role of carbon sinks has been found to be rather limited in the first commitment period due to fact that the size of credited sinks is relatively small since only a minor proportion of the carbon sinks on forested land are to be credited. As the assigned amounts of emissions were already agreed upon in Kyoto, it was sensible to limit the role of sinks. However, in the future the importance of sinks for Finland may increase, partly as the potential for carbon sequestration is high due to large forested area. Indeed, the amount of carbon sequestered is estimated to be increasing after year 2010. Also, it is an open question how large a share of carbon sequestered is to be credited in the later commitment periods. For forest management, the role of sinks in climate policy offers challenges, as in addition of timber production also other options for using forest, such as carbon sequestration and biodiversity should be considered.

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Appendix A.

Table
Carbon taxes needed to achieve the assigned emission target by domestic activities, \$/t CO_2

Regions	No credits from C sinks	C sinks credited according to common rules		C sinks credited with country specific rules for Canada and Japan
		USA out[1)]	USA in[2)]	
Rest of EU	8.3	7.6	7.8	7.6
Sweden	21.8	16.3	16.8	16.2
Finland	28.2	26.9	27.2	26.9
EFTA	38.1	28.4	28.9	28.4
Central European Associates	0.4	0	0	0
Former Soviet Union	0	0	0	0
USA	-	-	22.9	-
Canada	29.8	29.1	29.3	20.3
Japan	10.1	8.9	9.1	6.5
Australia	12.2	12.2	12.3	12.2
New Zealand	18.8	0	0	0

1) KP ratified by the other Annex I countries but not the USA
2) KP ratified by all Annex I countries (including the USA)

Appendix B.

Table
Change in welfare resulting from achieving the assigned emission targets with various assumptions about crediting forest carbon sinks, %.

Regions	No credits from C sinks	C sinks credited according to common rules		C sinks credited with country specific rules for Canada and Japan
		USA out[1)]	USA in[2)]	
Rest of EU	-0.27	-0.25	-0.16	-0.25
Sweden	-0.47	-0.34	-0.29	-0.35
Finland	-0.86	-0.82	-0.77	-0.83
EFTA	-1.24	-0.97	-1.08	-0.95
Central European Associates	0.08	0.11	0.19	0.10
Former Soviet Union	-0.07	-0.07	-0.04	-0.06
USA	0.03	0.02	-0.47	0.02
Canada	-1.11	-1.09	-1.17	-0.74
Japan	-0.11	-0.10	-0.09	-0.06
Australia	-0.65	-0.64	-0.56	-0.63
New Zealand	-0.30	0.03	0.09	0.03
NPM[3)]	0.02	0.02	-0.04	0.02
NPX[4)]	0.04	0.04	0.11	0.04

1) KP ratified by the other Annex I countries but not the USA
2) KP ratified by all Annex I countries (including the USA)
3) non-Annex I countries which are net importers of paper, pulp and publishing
4) non-Annex I countries which are net exporters of paper, pulp and publishing

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