Climate Change Policies, World Markets and Finland - Simulation Results

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We quantify the costs of global climate change policies to Finland using a modified GTAP-E model. We calculate resource abundance profiles proposed by Leamer assuming emission rights to be new factor endowments to characterize the impact of the Kyoto agreement on the distribution of the comparative advantage and to interpret the results. We estimate economy-level and detailed sector-specific effects of climate change policies without isolating Finland from world markets: changes in trade linkages are endogenously determined by global climate change policies. We produce a range of estimates by varying the regional coverage and the way of implementation of the climate treaty. When trade linkages are explicit, standard growth scenarios imply considerably higher emissions reductions than previous estimates.

1. Introduction

Kyoto Protocol is a possible step toward global climate change policies. Such policies must be global by the nature of the climate change problem, and because they are global they will have an effect not only on the climate but also on world markets. Climate policies are implemented in an open world economy where markets will adjust to costly emissions reductions. Individual countries will experience changes in their linkages to world markets irrespective of whether a country is planning to participate in the climate treaty or not. A typical individual country affected by changes in trade linkages is a small open economy, meaning that domestic economic costs cannot be quantified in isolation of effects from world markets. We focus on the small open economy case[2] In this paper the term means an economy

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[2] Our usage of the term "small open economy" is somewhat unconventional since the prices of traded goods are not given. In this paper the term means an economy whose impact on the rest of the world is marginally small.

whose impact on the rest of the world is marginally small: we quantify the economic cost of climate change policies in Finland when linkages to world markets are explicitly dependent on global climate change policies.

One way to interpret the impact of the Kyoto protocol is to understand that it creates a new factor of production, emission right, that firms have to buy to be able to produce. We follow this intuition and calculate (see section 5) resource abundance profiles for all countries/regions analyzed by a method proposed in Leamer (1984) section 4.3.2.. These profiles are then used to ex ante characterize the changes in comparative advantage of each of the countries and interpret some of the results obtained.

Changes in linkages to world markets depend both on domestic and global emissions reductions. There is a variety of such changes and their joint effect can be a major determinant of domestic costs. An example is a deterioration of export prices relative to import prices (a negative terms-of-trade effect) which implies a domestic welfare loss. Which sectors are most sensitive to such changes? Or in general: what is the economy-level and sectoral cost of climate policies in Finland when all changes in trade linkages are included. We quantify these costs and decompose them into sectoral effects using a large-scale computable general equilibrium model where cross-border trade linkages and carbon emissions are explicitly incorporated.

The model allows global analysis of climate change policies and world markets while producing detailed sector-specific effects of those policies. We can therefore analyze the case of Finland with a detail needed in domestic policy making without isolating Finland from the rest of the world. The modeling framework is based on GTAP (Global Trade Analysis Project) model and its extension called GTAP-E which has a special focus on energy sector and carbon emissions (see [4],[20]). The model used in this paper is referred to as GTAP-E-FIN model to distinguish it from the original GTAP-E model, due to Truong [20].The GTAP-E-FIN model is using the same GTAP4E database as the original version, but is more disaggregated, which reflects our focus on analyzing of the environmental policy effects on a small open economy (e.g., Finland, Sweden, Denmark). Also, a new "business-as- usual" scenario was formed, using target GDP growth scenarios that were based on [2] and [3].

Our simulation experiments are designed to target the GDP growth scenario to the official estimates and to produce emissions reductions endogenously. With a growth scenario close to the one used in the National Climate Change Strategy and in previous studies, we find that emissions reductions consistent with the Kyoto commitments are about 37 \% of the "business-as-usual" emissions in 2010. This estimate is above the recent domestic estimates which are typically less than 30 % (see [15], [7], [11], [8]). The discrepancy is partly explained by fully specified trade linkages which tend to magnify the need for emissions reductions. For the same reason, our model predicts a relatively high marginal cost of emission reduction indicated by the carbon tax which is about 300 FIM in 2010.

The carbon tax can be seen as a direct indicator of the costs of domestic emissions reductions, although with trade linkages the tax is also dependent on foreign policies. In contrast, the terms-of-trade effect depends on changes in trade linkages. We find that climate change policies in the absence of emissions trading can imply a two-way loss for Finland: the carbon tax is relatively high and the terms-of-trade effect is negative. We analyze the two effects over various cases ranging from Finland alone to OECD-level implementation of the treaty. We find that emissions trading including the supply of emission permits from the Former Soviet Union can implies that the carbon tax is significantly reduced and the terms-of-trade effect becomes positive. According to our results, emissions trading across the OECD borders would reduce the GDP loss of the Kyoto protocol to a fraction of the potential loss.

2. The Experiments

We seek to quantify the direct effect of domestic emissions reductions and the effects caused by changes in trade linkages. To this end, we consider the following five cases.

Finland alone. The previous estimates of domestic emissions reductions apply to the case where Finland complies with an emissions reduction target alone, meaning that the rest of world faces no effective emissions reduction target. For the sake of comparison, we want to consider this case. We estimate emissions reductions, and decompose the economy wide and sectoral implications under the assumption that the target specified in the 1997 Kyoto Protocol is met in Finland but not elsewhere. Using the global nature of our framework, this case allows the quantification of the effects of Finnish measures on other countries: we construct leakage rates which give the increase in emissions in a particular region/country as a percentage of the quantity of emissions reduced in Finland. If the total leakage rate is 100 %, the Finnish policies lead effectively to no global emissions reductions. In this way, we obtain a rough estimate of the leakage sensitivity of the Finnish economy.

Annex 1 no trading. In this case Annex 1 countries comply unilaterally with country-specific Kyoto targets without cross-border changes in emission quotas. The targets for EU countries are adjusted according to the EU burden-sharing agreement. Within each country the implementation of the target is cost effective, meaning that domestic carbon taxes or tradable emission permits are used. The comparison between this case and the Finland alone case will reveal the effects caused by changes in trade linkages on the Finnish economy: in both cases the domestic emissions-reduction target is the same, meaning that all discrepancies between the two cases are induced by trade.

Annex 1 trading. As opposed to the previous case, Annex 1\ emissions trading minimizes the total economic cost of the treaty. Since the need for emissions reductions is altered by emission trading (country-specific targets are reallocated without altering the total target), the effects caused by changes in trade linkages are altered too. For example, if the Annex1 implementation without trading severely damages some particular sector of the Finnish economy, one might expect that Annex 1 trading alleviates these damages, as it minimizes the economic costs of the treaty. We decompose the effects of emissions trading on the Finnish economy into the economy level and sectoral effects.

EU bubble. Given the uncertainties related to the ratification of the climate treaty and Europe-dependence of Finland, it seems reasonable to consider the case where the Kyoto targets are implemented only in EU. EU bubble means that emissions are reduced in individual EU countries according to the EU burden sharing agreement. Country-level emissions reductions are cost-effectively undertaken.

EU bubble trading. EU level emissions trading minimizes the costs of the emission target for the EU bubble. Using the results from the EU bubble experiment (without and with trading) together with the results from the Annex 1 experiment (without and with trading), we can quantify the trade-induced effects caused by the changes in the coverage of the treaty.

3. The GTAP-E-FIN Model and database

The Global Trade Analysis Project (GTAP) model and database has become a common tool for analysing multilateral trade agreements.[3] GTAP offers a variety of products, including: data, models, and software for multi-region, applied general equilibrium analysis. In recent meetings of Intergovernmental Panel on Climate Change (IPCC) several research groups were using the database for conducting their analysis of the economic implications of carbon taxes. The standard GTAP model is documented in [4].In this work we rely on GTAP data base version 4[4] [14] which contains information on 45 regions and 50 commodities.

In a joint project funded by the United States Department of Energy, a goal was set to produce a publicly available data base which contains the necessary combination of (a) comprehensive input-output data by region, (b)bilateral trade and protection data, and (c) energy price, quantity and tax data. As a result the data base, known as GTAP 4-E, formed a consistent data on energy quantity flows and prices incorporated into the GTAP\ database. The principal source of the energy data was the International Energy Agency (IEA).[5]. For calculation of emissions, Truong [20] documents also the CO2 emission coefficients used.

The model used in this paper is based on a GTAP model extension (called GTAP-E), developed by Truong [20]. The GTAP-E model includes explicit energy-economy and energy-environment trade linkages. These linkages reflect the adjustment that may take place by substituting different fuel types in production and energy content in consumption, in face of cost shocks. These linkages were missing in the original model. Reduction in CO2 emission levels is achieved by imposing CO2taxes ($/tonCO2). $These CO2 taxes can be converted into carbon taxes by multiplying CO2 taxes by 3.7 (there is approximately a ton of carbon in every 3.7 tons of CO2).

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[3] The project webpage is http://www.agecon.purdue.edu/gtap

[4] version 5 is soon due, see http://www.agecon.purdue.edu/gtap/database/index.htm

[5] A complete description of the required data can be found in http://www.agecon.purdue.edu/gtap/database/energy/ep_doco.pdf

In this work, the countries have been aggregated to 12 regions and 14 industries (Table 1). Finland and Sweden represent small open economies on which the results are focused. We call the model GTAP-E-FIN to distinguish it from the more aggregated GTAP-E model.

Table 1 *Regional and Commodity Coverage*

Identifier	*Countries in Region*	*Sectors in region*	**Identifier**
FIN	Finland	coal	COL
SWE	Sweden	oil	OIL
DNK	Denmark	gas	GAS
REU	Rest of EU	wood/paper products, publishing	WOOD
EFT	EFTA	electronic equipment	ELEC
FSU	Former Soviet Union	petroleum, coal products	P_C
EEA	Central European Associates	electricity	ELY
USA	United States	machinery	OMET
CAN	Canada	trade, transport	T_T
ANR 1)	Rest of Annex 1	ferrous metals	I_S
NEX 2)	Energy exporting countries	chemical, rubber, plastic products	CRP
NEM 3)	Energy importing countries	manufactured products	OMN
		agricultural products	AGR
		commercial, public services	SER

1) Australia, New Zealand, Japan

2) Indonesia,Malaysia,Vietnam,Mexico Venezuela,Colombia,Rest of Andean Pact, Argentina,Rest of South America,Rest of Middle East, Rest of North Africa, South African Customs Union, Rest of Southern Africa, Rest of Sub Saharan Africa,Rest of World

3) Republic of Korea,Philippines, Singapore,Thailand,China,Hong Kong, Taiwan,India,Sri Lanka,Rest of South Asia, Central America and Caribbean,Brazil,Chile Uruguay,Turkey,Morocco

When building the aggregation, the main focus was to analyze national vs. international CO2 emission reduction policies from the perspective of a small open economy. Although we focus reporting results to Finland these were also available for Sweden and Denmark. This paper is, in fact, the first analysis of the Kyoto protocols' implementation in global setting where small open economies are also included as their own regions.

The wood/paper products and publishing (wood) and the electronic equipment (elec) sectors were chosen as their own sectors due to their importance to the Finnish (and Swedish) economy and exports.

On the input side the model was fairly aggregated, i.e. three inputs in the model were: labour (aggregate of skilled and semi-skilled), capital (aggregate of capital and natural resources) and land. Of these land is assumed to be immobile input.

Additional adjustments were needed to GTAP-E-FIN model to incorporate the analysis of different kind of implementations of the model (EU-bubble).

4. The Reference Case

Estimates of future emissions will play a crucial role in determining the necessary cut to reach the target level as agreed in Kyoto. Evaluating the economic costs are based on the need for reductions in emissions that have been predicted to prevail in 2010. In the original agreement the Annex 1 parties have committed to reducing their emissions in 2008-2012 to the level agreed in Kyoto. In this work, we forecast the CO2 levels in fuel combustion activities in 2010. The necessary cuts are based on those projected levels.

Into the projected database predicted to prevail in 2010 we have implemented as exogenous the growth in GDP, labor force, population and the total factor productivity growth in different industries. As endogenous variables we get the level of energy consumption determining the level of emissions implying the necessary cuts needed to fulfill the agreement of Kyoto. We have also assumed a productivity growth between sectors (Industry, Services and Resources Agriculture) to vary. In the table 2 we present our estimates of the growth for GDP, population, labor force and the sectoral productivity levels. The figures used are based on [2] and [3].

Table 2 ***Annual increase in gdp divided to labour force growth, capital stock growth and productivity growth***

Region	**annual % increase in**		**annual % growth in**		**Productivity increase in**		
	gdp	population	labour force	capital stock	service sector	agricultural sector	industrial sector
Finland	2.4	0.2	-0.4	1.28	1.0	1.4	0.5
Sweden	2.4	0.2	0	1.25	1.0	1.4	0.5
Denmark	2.4	0.1	-0.4	1.31	1.0	1.4	0.5
Rest of EU 1)	2.5	0.1	0.1	1.27	1.0	1.4	0.5
Efta 1)	2.4	0.4	0.4	1.31	0.8	1.1	0.4
Former Soviet Union	0.9	0.1	0.5	1.15	0.3	0.4	0.1
Eastern Europe 1)	4	-0.1	0.1	1.33	1.3	1.8	0.6
USA	2.6	0.8	0.9	1.26	1.0	1.4	0.5
Canada	2.8	0.8	0.8	1.27	1.0	1.4	0.5
Rest of Annex1 4)	2	0.2	0.1	1.29	0.5	0.7	0.3
Net Energy Exporters 5)	5.6	0.9	2.4	1.36	1.2	1.7	0.6
Net Energy Importers 6)	3.9	2.1	2.5	1.30	0.8	1.1	0.4

1) United Kingdom, Germany, Rest of E
2) European Free Trade Area
3) Central European Associates
4) Australia,New Zealand,Japan
5) Indonesia,Malaysia,Vietnam,Mexico Venezuela,Colombia,Rest of Andean Pact Argentina,Rest of South America,Rest of Middle East, Rest of North Africa, South African Customs Union, Rest of Southern Africa, Rest of Sub Saharan Africa,Rest of World
6) Republic of Korea,Philippines, Singapore,Thailand,China,Hong Kong, Taiwan,India,Sri Lanka,Rest of South Asia Central America and Caribbean,Brazil,Chil Uruguay,Turkey,Morocco

Another approach to the predictions is presented by Rutherford et al. [17]. They set as exogenous variables the limits of energy usage and emissions as reported by energy authorities (e.g.,[1]). and let the energy efficiency adjusts. Rutherford et al. point out that differences in the baseline projections may explain some of the differences between the US and EU estimates of costs of achieving specific CO2 reduction targets.

More than emphasizing the absolute costs due to the technological restraints or the actual abatement procedures we look at the relative burden of countries and industries due to the Kyoto Agreement especially when the focus is in competitiveness and world markets. The table 3 reports the GTAP-E emissions compared to UN source data and the projected emission levels that define the necessary cut to reach the target level set in Kyoto.

Table 3 ***CO2-emissions from Total Fuel Combustion in GTAP-E-FIN Regions***

Region	1990 UN	1995 UNFCCC	1995 GTAP	1990 TARGET	% of 2010 Projection	2010 PROJECTION
Finland	54	56	57	54	*63*	86
Sweden	51	53	61	53	*56*	94
Denmark	52	59	64	41	*38*	107
Rest of EU 1)	2974	2912	2993	2857	*64*	4461
Efta 2)	68	70	80	65	*50*	130
Former Soviet Union	3070	1963	2263	3062	*126*	2427
Eastern Europe 3)	912	740	710	848	*72*	1176
USA	4840	5104	5111	4502	*63*	7121
Canada	416	441	459	391	*58*	676
Rest of Annex1 4)	1341	1451	1454	1299	*64*	2034
Net Energy Exporters 5)			2519			5583
Net Energy Importers 6)			5330			8383
Total world emissions			21100			32278

1) United Kingdom, Germany, Rest of E
2) European Free Trade Area
3) Central European Associates
4) Australia,New Zealand,Japan
5) Indonesia,Malaysia,Vietnam,Mexico Venezuela,Colombia,Rest of Andean Pact Argentina,Rest of South America,Rest of Middle East, Rest of North Africa, South African Customs Union, Rest of Southern Africa, Rest of Sub Saharan Africa,Rest of World
6) Republic of Korea,Philippines, Singapore,Thailand,China,Hong Kong, Taiwan,India,Sri Lanka,Rest of South Asia Central America and Caribbean,Brazil,Chil Uruguay,Turkey,Morocco

5. The Kyoto protocol and the distribution of comparative advantage

The Kyoto protocol allocates to Annex I countries a right to emit agreed amounts of GHG's. Because firms emitting GHG's have to buy rights (or pay taxes) to emit the emission rights can be seen a new factor of production, the endowment of which is distributed across countries by the Kyoto protocol. Since relative factor endowments are a crucial determinant of comparative advantage in neoclassical models of international trade and in CGE models like GTAP based on the neoclassical trade theory, the emergence of a new factor of production can in principle change fundamentally the distribution of comparative advantage in the world. The Kyoto protocol does this definitely since non-Annex I countries do not face any limits on emissions having thus an infinite supply of the new factor.

We have calculated relative resource abundance profiles for each of the regions in the model using the approach in Leamer (1984), section 4.3.2.. The idea is that a resource is relatively abundant (scarce) in a region relative to the other regions if its endowment of the resource relative to the global endowment exceeds (falls short of) the share of its GDP in total world GDP (Leamer shows that this is implied by the neoclassical trade theory). More formally, if the endowment of country i of a resource is V_i and the world endowment is V, the basic Leamer index is $x \equiv (V_i /V)/(Y_i/Y)$ where Y_i = country i GDP and Y = world GDP. Leamer transforms this finally to $l \equiv (5x-5)/x+5)$. If the country does not have the resource at all l = -1, if its endowment share equals its income share l = 0, and if country's endowment is infinite l approaches 5.

To calculate the Leamer indices ideally one would like to use quantity data on the regional availability of various endowments. We wanted to use as recent data as possible (instead of using, e.g., data in Trefler 1995) and decided to use the factor income data from the GTAP4 database. Thus, e.g., capital abundance is calculated as $(R_i/R)/(Y_i/Y)$. This would produce exactly the same result as one would get with quantity data were the factor prices equalized globally. The same holds if the factor price differentials are due to national productivity differentials which may in fact be the case (Leamer and Levinsohn 1995). For the relative abundance of the emission rights we naturally use the limits imposed by the Kyoto protocol on Annex I countries. As the basis for the calculations we have used our basic projection for the year 2010 without the Kyoto protocol to get the implied changes in comparative advantage at the most relevant point of time when the adjustment to the protocol must finally begin.

The next problem we face is that Kyoto protocol does not cover all the countries. This means that their emission right is infinite. Using the formulas above this implies that $x_i = 0$ for all the Annex I countries while $x_i=(1/nA)/(Y_i/Y)$ for all the non-Annex I countries where nA = the number of non Annex countries/regions. This implies a uniform loss of comparative advantage in emission intensive industries for all the Annex I countries while in the non Annex countries the relatively poorest countries would gain comparative advantage in these industries. Instead of using these figures we have followed the following procedure: First we have concentrated on Annex countries only and calculated Leamer indices among them. After that we have given somewhat arbitrarily the value l = 5 to all the non Annex countries. Our reasons for this choice of procedure is that the Kyoto protocol does not (as will be seen) divide the emission rights in proportion to GDP. This implies that among Annex I countries there may be large shifts in comparative advantage. Given that the share of trade between Annex I countries in world trade is large this is a point worth remembering. Also, the relative abundance profiles calculated in this way has implications for the emission permit trade among Annex I countries (or within EU). The other choice is more arbitrary but given that in our aggregation the non Annex countries are represented by two almost equal sized (in terms of GDP) regions it is best to think them having both gained the maximal comparative advantage in emission intensive industries.

Table 4 Leamer Indices

	labor	capital	land+natural resource	emission permits
FIN	-0.041	0.233	-0.478	-0.002
SWE	-0.043	-0.01	-0.728	-0.421
DNK	-0.031	0.161	-0.447	-0.433
REU	0.004	0.107	-0.722	-0.126
EFT	0.24	0.329	-0.362	-0.626
FSU	0.274	-0.103	0.139	3.673
EEA	-0.141	0.316	1.097	2.094
USA	0.177	-0.215	-0.623	0.328
CAN	-0.008	-0.159	-0.614	0.374
ANR	0.043	0.247	-0.441	-0.376
NEX	-0.339	-0.019	0.678	5
NEM	-0.146	-0.204	1.431	5

Our calculations are presented in Table 4. Several observations can be made. The first is the obvious one: Among the Annex I regions Former Soviet Union and Eastern Europe gain comparative advantage in GHG emission intensive industries. Secondly, and may be more surprisingly, both Canada and USA also have comparative advantage in these industries. Kyoto protocol puts these industries in comparative disadvantage in Europe and Japan. One way to understand these results is that the adjustment to the protocol could be easiest in terms of welfare and GDP losses in both Canada and the USA. For the potential of structural change what matters is naturally the whole resource abundance profile. If it is the case that the most emission intensive industries are also relatively capital intensive it is seen that Europe being relatively well endowed with capital may experience a shift of resources away from these industries. These are general equilibrium phenomena, however, and can be analyzed only with the whole model. Thirdly, the resource abundance profiles have implications for emission permit trade also. In Annex I trading FSU and Eastern Europe definitely seem to be candidates for net permit sellers while Western Europe is net buyer. More interestingly in EU trading Finland is the prime candidate for being a net permit seller.

6. Results for Finland

6.1 Economy-Level

Table 5 shows economy-level results for Finland for each experiment. The columns of the table are labeled by the type of the experiment (Finland alone, Annex 1 trading, Annex 1 no trading, EU bubble trading, and EU bubble). The rows of the table show the key economic-level indicators.

Emissions Reductions. The second row gives the required domestic emissions reduction as a percentage of the reference emissions (business-as-usual emissions) for each experiment. In the Finland alone case and in cases where emissions trading is not allowed, the Kyoto commitment implies that emissions are reduced below the reference path by about 37 percent. We note that the emissions cutback implied by our model is considerably higher than in previous estimates (22 \% in Pohjola (1998), 22\% in KTM (1999) and VTT (1999)). The discrepancy is in part explained by the differences in the scenarios about GDP growth and energy efficiency.

Emissions trading can considerably decrease the need for domestic emissions reductions: the after-trade reduction is about 17 percent in Annex 1 trading. The difference between these two numbers is explained by the supply of permits from the Former Soviet Union (FSU) which is included in the Annex 1 case. The FSU supply is generated by the nonbinding emission quota in this region. Trading with this quota is often called "hot air" trading which, according to our results, could significantly reduce domestic emissions reductions in Finland. In the EU level trading the FSU supply is excluded as well as the US participation. Perhaps surprisingly, the EU level market price exceeds the domestic tax in the Finland alone case, meaning that Finland becomes a net supplier of emissions reductions. Thus, according to this simulation, abatement costs in Finland are below the EU average.

CO_2 Tax. The first row of the table reports the calculated CO_2 tax (per ton of carbon dioxide), which indicates the domestic marginal cost of emissions reduction in 2010. In the Finland alone case, the tax is about $44, i.e., about 300 FIM. The corresponding tax is lower in previous simulations (275 FIM in Pohjola (1998), 230 FIM in VTT (1999)). One reason is that in our simulation a greater tax is needed because of the greater need for emissions reductions. Another reason may be that in our simulation Finland is a "small open economy" with endogenously changing trade linkages, whereas in previous studies trade linkages are not explicit.

Note that Annex 1 implementation without emissions trading increases the domestic marginal cost of emissions reductions. The result may be explained by an increase in the cost of fuel-switching due to the increased world-market demand for less carbon-intensive fuels. Note next that in Annex 1 trading the domestic tax equals the world-market price for a CO_2 emission unit. Annex 1 trading reduces the tax by about 70 percent compared to the tax needed in the absence of trading, meaning that the cost-saving potential of emissions trading is huge for Finland. The price under the EU bubble trading is significantly higher which can be explained by the exclusion the FSU supply (the major source of hot air).

Terms of Trade. As expected, the terms-of-trade effect is negative and most severe in the Finland alone case where there are no changes in the world market that could alleviate the domestic cost of the climate change policy. Going from one experiment to another introduces the following changes in the terms-of-trade effect. First, when the set of participating countries is increased, the deterioration of export prices is less dramatic. The reason is that the wider the coverage of the treaty is, the greater is the upward shift in world-market prices of carbon-intensive products, which increases the export prices for Finland and thereby alleviates the domestic cost of the climate change policy. In fact, for this reason the terms-of-trade effect is positive when the regional coverage and the aggregate abatement costs are maximized (Annex 1, no trading). Second, for a given set of participating countries, emissions trading should further alleviate the terms-of-trade effect, because trading minimizes the cost of emissions reductions. In the case of Annex 1 trading, the effect is almost entirely eliminated. However, the EU-level trading causes a deterioration of export prices. In the former case Finland is a net buyer and in the latter a net buyer, which may explain the difference.

The explicit inclusion of trade linkages show that there is possibly a two-way gain from the possibility to purchase emission permits for Finland: (i) the domestic marginal cost of emissions reductions (the CO_2 tax) is reduced, and (ii) the terms-of-trade effect is positive (Annex 1 trading).

GDP Loss. The Kyoto commitments can imply a considerable GDP loss in 2010. The loss is relatively insensitive across the experiments, excluding the case of Annex 1 trading which achieves significant cost savings because of the FSU supply of CO_2 emission permits.

Table 5 Economy wide results for Finland

	Experiment 1	Experiment 2	Experiment 3	Experiment 4	Experiment 5
Results for Finland					
Tax ($ / ton)	44.23	13.7	46.35	50.72	45.33
CO2 (%)	-37.66	-17	-38.00	-40.00	-38.00
CO2 (toe)	-32.55	*-15.00*	*-33.00*	*-34.00*	*-33.00*
Terms of Trade (%)	-0.32	0.02	0.23	-0.18	-0.15
EV (mill. $)	-1670.33	-385	-1377	-1413	-1547
gdp (%)	-1.2	-0.31	-1.14	-1.32	-1.18

Experiment 1: Finland alone reduces emissions
Experiment 2: Annex 1 countries reduce emissions (emission permit market exists)
Experiment 3: Annex 1 countries reduce emissions (no emission permit market)
Experiment 4: EU alone reduces emissions (internal emission permit market exists)
Experiment 5: EU alone reduces emissions (no internal emission permit market)

Leakage in experiment 1

Leakage	12.88
Leakage rate	40

Compared to the previous estimates of the GDP losses due to Kyoto commitments, our GDP losses are relatively high (.8 percent in Pohjola (1998), about .3 percent in VTT (1999)). The discrepancy is partly driven by exogenous factors, such as the assumptions about the GDP growth, but also by the changes in trade linkages which are not considered in previous studies. The GDP\ results can be decomposed into changes in its demand components; private and public consumption, investments, exports and imports, in value and real terms.

EV. A money-metric measure for changes in utility for the regional household is the variable EV, equivalent variation. It gives an approximation of the costs accruing to the economy as expressed in monetary terms. The equivalent variation can further be decomposed into factors behind it. These changes are due to changes in terms of trade and changes in allocative efficiency, i.e. the increase in deadweight losses. By comparing the results from the Finland alone and Annex 1-no-trading cases, it can be seen that almost 90 percent of the welfare losses accruing to Finland are due to the domestic measures, only 10 percent of the effects can be claimed to be trade-induced. Significant improvements in welfare losses can only be reached by emission trading throughout Annex-countries; the welfare decline is 16 \% of the worst case, where Finland would reduce emissions alone.

6. 2 Industry-Level

Table 6 shows industry level results for Finland for each experiment. The columns of the table are again labeled by the type of the experiment (Finland alone, Annex 1 trading, Annex 1 no trading, EU bubble trading, and EU bubble). The rows of the table show changes in output for each of the 11 industries of the model.

At industry level, the driving force in results is naturally the distortionary tax that treats goods differently depending on the coal-intensity used in production. Whereas different growth scenarios have only marginal effect on the results, the more varying effects are due to the way of implementation of the restrictions. To separate the effects of domestic and international impacts we have studied the effects of Kyoto agreement when Finland would do it individually compared to the multilateral implementation. A more robust way of analyzing the impact of several exogenous effects has been suggested by Harrison et al (1999) and applied e.g. in Böhringer and Rutherford (2000)

Output of most of industries declines in every experiment. Production of electronic equipment is a clear and perhaps surprising exception of this trend. The Kyoto commitments seem to imply a considerable gain for this industry if the case of Annex 1 with trading is excluded. On the other hand, the production of petroleum and coal products is most severely hurt by the Kyoto commitments. This is due to the high carbon intensity both of products and factors of production for this industry. Production of iron and steel and electricity are also quite sensitive to emission reductions. As coal, oil and processed oil were taxed based on their emissions, the respective change in electricity production reflects the usage of these fuels in production. As the electricity production in Finland rests largely on coal, its production contracts in every experiment. The electricity level can be seen to increase only in countries that use largely hydro or nuclear power (non-coal intensive fuels) in electricity production namely Sweden, Efta-countries, Former Soviet Union and Canada. The basic reason why some industries are more severely hurt by the commitments than others is always the same. Contracting industries are all carbon-intensive industries relative to other sectors of the economy, which means that they are bound to bare a larger proportion of the need to reduce emissions in a general equilibrium framework. A perhaps striking result is that the production of paper and wood products declines in all cases, but the decline is smallest in the Finland alone case.

Why does the production of electronic equipment gain and productions of petroleum, electricity and iron and steel lose so much in terms of output in the Finland alone experiment? This can be explained by the general equilibrium nature of the model. If Finland alone complies with an emission target, there will be no significant world market effects. This means that the relative prices of Finish carbon-intensive products must rise in both domestic and export markets. The production of these industries declines. In general equilibrium framework factors of production no longer needed in these industries have to move to other industries in the economy, thereby increasing production in less carbon-intensive industries.

Comparing the industry-level results of the Finland alone case to Annex 1 with no trading reveals the importance of trade-induced effects. As in economy-wide results, the differences in output changes for Finish industries between these two experiments are solely due to these effects. In the annex1 case the loss of iron and steel production in Finland is marginal compared to that in Finland alone experiment. In the same manner, the gain of electronic equipment production is three times as large when Finland alone complies than when all Annex1 countries reduce emissions. Reason for these findings are movements in world-market prices. When the set of complying countries is increased, there will be an upward shift of world-market prices of carbon-intensive products. Compared to Finland alone case, carbon-intensive products produced in Finland no longer lose their competitiveness as much compared to foreign products of equal carbon intensity in domestic and export markets. Trade-induced effects are also likely to be behind the surprising results for forest sector.

The importance of emission trading is clear also at the industry level. As expected, Annex 1 trading alleviates damages to those particularly damaged by the Annex 1 implementation. The need to cut back productions in carbon-intensive industries is greatly reduced when emission targets are met at the Annex 1 level with emission trading. Productions of petroleum and coal products as well as iron and steel are clear examples of this. Of course at the same time this means that industries which gain in relative terms in the annex 1 without trading case lose their advantage when emission trading is introduced. The reason for this is the fact that marginal cost of emission reductions is much lower if the emission market exists. Alternatively put, the economic costs of the treaty is minimized with emission trading which can be seen at industry level as well as at economy-wide level. Comparing Annex 1 trading experiment to EU bubble trading, the role of the hot air can be seen. In fact, the results are quite insensitive to whether internal EU-wide emission permit market exists or not. The real difference in results between experiments, excluding trade-induced effects between Finland alone experiment compared to others, arises from the inclusion of FSU in emission trading market.

Table 6 Sectoral results for Finland

	Experiment 1	Experiment 2	Experiment 3	Experiment 4	Experiment 5
Sectoral results (percentage change in sectoral output in Finland)					
Wood	-1.1	-1.75	-3.97	-3.10	-3.04
Elec	6.43	0.26	1.90	4.59	3.91
P_c	-22.27	-10.26	-20.02	-24.30	-22.27
Ely	-8.39	-3.28	-9.08	-9.41	-8.79
Omet	3.6	-0.68	0.08	2.66	2.12
t_t	-0.82	-0.26	-0.95	-1.04	-0.93
I_s	-10.75	0.02	-1.33	-2.88	-1.54
crp	-4.93	-1.12	-3.24	-3.94	-3.39
Omn	0.63	-0.55	-0.92	-0.03	-0.10
Agr	0.29	-0.35	-0.85	-0.40	-0.44
Ser	-2.2	-0.1	-0.62	-1.69	-1.47

Legend:

wood	wood/paper products, publishing
elec	electronic equipment
p_c	Petroleum, coal products
ely	Electricity
omet	machinery production
t_t	trade, transport
I_s	iron and steel
crp	chemical, rubber, plastic products
omn	manufactured products
agr	agricultural products
ser	commercial, public services

Experiment 1: Finland alone reduces emissions
Experiment 2: Annex 1 countries reduce emissions (emission permit market exists)
Experiment 3: Annex 1 countries reduce emissions (no emission permit market)
Experiment 4: EU alone reduces emissions (internal emission permit market exists)
Experiment 5: EU alone reduces emissions (no internal emission permit market)

7. International Impacts

Though this paper focuses mainly on Finland it worthwhile to look at the international implications of the Kyoto protocol as well. This helps in understanding the basic mechanisms working through the world markets emphasized in the previous section. A comparison with countries like Sweden and Denmark may be especially revealing. It is also a necessary input in understanding the political economy of the Kyoto agreement and its implications. The international results are all collected in tables collected in the appendix. Among the most important questions in the international setting are the following: 1) Given that Annex 1 countries do not cover all countries how much of the emission reduction leaks to non Annex 1 countries? 2) If emission trading is not allowed among Annex 1 countries is there any carbon leakage to FSU? 3) How are the costs of emission reduction distributed among Annex 1 countries and how does the distribution depend on the organization of emission reduction? 4) Are there significant differences between Sweden and Finland?

Carbon leakage. The most interesting comparison is between the case where emission reduction among Annex 1 is achieved through a common carbon tax (implemented through emission permit trading) and the case where only national implementation of the Kyoto protocol is achieved. In the former case the leakage rate is .7%, i.e. non-Annex 1 countries increase their emissions by an amount equaling .7 % of the emission reduction achieved in

Annex 1. With national implementation the leakage rate is more than three times larger, 2.2 %. Interestingly, more than half of the leakage takes place in the FSU, emissions in non-Annex 1 account for less than 50 \% of the leakage. Emissions in the FSU increase by 3.2 % while with emission permit trading it would reduce its emissions dramatically, by almost 60 %. Annex 1 emission permit trading would thus reduce global emissions significantly more than would be achieved through national implementation alone. The explanation is clear: Emission permit trading reduces the costs of emission reduction thereby minimizing the impacts on the allocation of production between Annex and non-Annex countries. It is also interesting to note the crucial role of growth in the FSU. Were it to grow fast the hot air disappears completely. It would have to reduce its emissions even without emission trading, i.e. there would be no leakage to FSU. With permit trading FSU would reduce its emissions further implying that other Annex 1 countries reduce their emissions less.

If EU countries alone reduce emissions the leakage rate is the same whether EU wide emission permit market exists or not. The aggregate leakage rate is 7 \%. Most of the leakage takes now place in the FSU and in Eastern Europe though all non-EU-countries increase their emissions. This indicates that firms in FSU and Eastern Europe are the principal competitors to the EU firms in the emission intensive industries. These results could provide one rationale to speed up the accession of Eastern European countries in the EU because these shifts in competitiveness would then be minimized. Otherwise EU wide emission permit market just reallocates emission reduction among EU countries with Nordic countries except Finland increasing and the rest of EU reducing their emissions. The reduction in the marginal cost of emission reduction for Nordic countries is significant, for Sweden alone the cost is reduced by 46 %.

Costs of emission reduction. In terms of GDP the costs of emission reduction are smallest among the Annex 1 countries when emission permit trading is allowed and significantly below the costs incurred with national implementation. The costs are also quite uniformly distributed with permit trading while the distribution is highly uneven with national implementation. Interestingly the costs to USA are the lowest without permit trading with .48 reduction in the GDP but even for it the permit trading halves the costs. The costs are highest for Denmark (3.4 % GDP reduction) and EFTA (Norway and Switzerland) with 2.5 % GDP reduction. Permit trading reduces these costs to .46 (Denmark) and .35 % (EFTA) of the GDP. The FSU appears to loose (GDP declines by 1.2 %, the biggest loss among Annex 1 countries) from permit trading even though it would be the major seller.[6] The Annex 1 countries outside Europe and North America (Australia and Japan among them) would experience the smallest loss under permit trading but its loss without trading is also small. The equal distribution of the costs of emission reduction with permit trading should not come as a surprise since that is exactly what the permit trading is supposed to do. The impacts on non-Annex countries are minor. Their GDP increases marginally regardless of the mode of implementation in Annex 1. Proper treatment of non Annex countries would require, however, a less aggregated version of the model. A priori one could e.g. expect that Sub-Saharan countries and Latin American countries could be differently affected by the Annex 1 climate change policies even though in terms of energy exports they are in the same group as most of Latin America.

[6] This result may be anomalous since in its current version the GTAP-E does not take into account the income generated by the international permit trade.

In terms of allocation of resources within Annex 1 countries the changes are much less steep if emission permit trading is allowed than if it is not allowed. This means that permit trading minimizes the need for sectoral reallocation. Significantly the sectoral changes are also smaller in non-Annex countries if Annex countries allow permit trading among themselves. This is due to the fact that permit trading reduces carbon leakage, the other of which is international reallocation of production.

The same overall conclusions apply when EU alone reduces emissions. The only exception is that with EU wide permit trading the costs to Nordic countries are reduced significantly (especially for Denmark) while the costs (in terms of GDP) to the rest of EU remain practically unchanged. Anyway the distribution of costs among EU countries are more equal with permit trading than without it. Likewise the permit trading reduces sectoral reallocation effects.

Comparison to Sweden. Most of what was said of Finland above applies to Sweden also. Some of the effects appear to somewhat stronger, though. This holds especially for the terms of trade changes induced by Annex 1 implementation of the Kyoto protocol. Sweden gains from improvements in her terms of trade. Sweden gains from this more if Annex 1 permit trading is not allowed. This is what one would expect (and would have expected for Finland also) since Sweden exports energy intensive products. The difference in terms of terms of trade behavior may be due to the assumptions made in the projections above. The Finnish terms of trade appear to be very sensitive to the assumptions on the Finnish growth rate. In the high Finnish GDP growth rate the supplies of Finnish export goods to the world market grow by a higher rate than the supplies of Swedish export goods making terms of trade decline. Even at growth rate equal to the Swedish rate the terms of trade improvement due to implementation of the Kyoto protocol the Finnish terms of trade improve only modestly.

References

[1] Böhringer C., J. Jensen and T. F. Rutherford (2000) Energy Market Projections and Differentiated Carbon Abatement in the European Union in Carraro Carlo (ed.) Efficiency and Equity of Climate Change Policy.

[2] Frandsen Soren.E. and H.G. Jensen (2000) Den globale udvikling og konsekvenser for dansk produktion og eksport af f\o devarer, mimeo,available at http://www.sjfi.dk/analyser/rap1.pdf

[3] Frandsen Soren.E.., Hans G. Jensen and David M. Vanzetti (2000) 'Expanding Fortress 'Europe' Agricultural Trade and Welfare Implications for European Enlargement for Non-Member Regions'. The World Economy, Vol 23 No3, March 2000.

[4] Hertel, Thomas W. ed. (1997). Global Trade Analysis: Modeling and Applications. (Cambridge: Cambridge University Press).

[5] Honkatukia J. (1999) Kioton mekanismien k\U{e4}yt\U{f6}n rajoittamisen vaikutukset Suomeen, ETLA\ Discussion papers No. 677.

[6] Honkatukia J. (1999) Ilmastosopimuksen toteuttamisen vaikutuksista Suomessa, Kansantaloudellinen aikakauskirja 4/1999.

[7] Honkatukia J. (1999), Kotimaisen päästökaupan kokonaistaloudelliset vaikutukset Suomessa, ETLA discussion paper No. 718

[8] Kioton mekanismit ja Suomi, Kauppa- ja teollisuusministeriön työryhmä ja toimikuntaraportteja 4/1999.

[9] Leamer E. (1984) Sources of International Comparative Advantage, MIT Press.

[10] Leamer E. and J. Levinsohn (1995) International Trade Theory: The Evidence, ch. 26 in Grossman G. and K. Rogoff (eds) handbook of International Economics, vol. 3, Elsevier.

[11] Lehtilä A. and S. Tuhkanen (1999) Integrated cost-effectiveness analysis of greenhouse gas emission abatement, The case of Finland, VTT Publications No. 374.

[12] Manne, A.S. and R.G. Richels (1995). "The Greenhouse Debate: Economic Efficiency, Burden Sharing and Hedging Strategies," The Energy Journal, 16(4), 1-37.

[13] Malcolm Gerald and T.P. Truong (1999)The Process of Incorporating Energy Data into GTAP, DRAFT GTAP Technical Paper

[14] McDougall R., A. Elbehri and T.P.Truong (1998) Global Trade, Assistance and Protection, The GTAP 4 Data Base

[15] Pohjola, J. (1997) CO2 -päästöjen vähentämisen kansantaloudelliset vaikutukset: Tuloksia polttoainerakenteen muutokset huomioonottavasta CGE-mallista, ETLA Discussion Papers 624.

[16] Rutherford T., Babiker M.H., and Maskus K.E. (1997), Carbon Taxes and the Global Trading System. presented at the International Energy Workshop at IIASA, June 1997.

[17] Jensen J., Bohringer C., Ruherford T., (2001), The costs of carbon abatement in six EU countries: implications of alternative baseline energy projections, http://www.feem.it/gnee/paplists/papa8.html.

[18] Shackelton R, McKibbin W.J. and Wilcoxen P.J. (1998) The potential effects of international carbon emmission permit trading under the Kyoto Protocol. Discussion paperpresented at the OECD, Paris.

[19] Trefler D. (1995) The Case of Missing Trade and Other Mysteries, American Economic Review, December, 1029-1046.

[20] T. Truong (1999) GTAP-E: Incorporating Energy Substitution into the GTAP Model, Technical Paper No. 16 in http://www.agecon.purdue.edu/gtap/techpapr/index.htm.

[21] Tulpule, V., S. Brown, J. Lim, C. Polidano, H. Pant, and B.S. Fisher (1998),An economic assessment of the Kyoto Protocol using the Global Trade and Environment Model, ABARE\ conference paper 98.27

8. Appendix 1

Annex 1 countries reduce emissions
(emission permit market exists)

	Finland	Sweden	Denmark	Rest of EU 1)	Efta 2)	Former Soviet Unlon	Eastern Europe 3)	USA	Canada	Rest of Annex 1 4)	Net energy exporters 5)	Net energy importers 6)
Economywide results												
Tax ($ / ton)	13.62	13.62	13.62	13.62	13.62	13.62	13.62	13.62	13.62	13.62	0.00	0.00
CO2 (%)	-17.70	-12.22	-21.17	-20.04	-14.70	-58.55	-33.74	-25.11	-21.46	-20.38	0.51	0.11
CO2 (toe)	*-17.51*	*-11.49*	*-22.67*	*-892.09*	*-19.11*	*-1419.45*	*-395.34*	*-1781.71*	*-144.53*	*-414.67*	*28.61*	*8.90*
Terms of Trade (%)	-0.05	0.30	-0.18	0.17	-0.60	-2.70	-0.53	0.08	-0.09	0.30	-0.39	0.12
EV (mill. $)	-414	-350	-970	-27038	-2443	-7291	-4108	-18806	-2918	-7687	-2935	2110
gdp (%)	-0.35	-0.22	-0.46	-0.30	-0.35	-1.23	-0.84	-0.22	-0.42	-0.19	0.00	0.01
Leakage												
					Leakage	37.51						
					Leakage rate	0.007						
Sectoral results (percentage change in sectoral output)												
Wood	-1.73	-0.79	0.31	-0.39	-0.10	0.13	1.20	-0.36	-0.15	-0.29	0.40	-0.15
Elec	0.58	-0.50	0.15	-0.06	-0.09	-3.88	-1.88	0.29	1.14	-0.09	0.73	-0.92
P_c	-10.21	-8.85	-7.91	-1.83	-12.09	-6.96	-7.39	-14.96	-13.92	-5.89	-1.23	-0.05
Ely	-3.46	3.59	-21.68	-3.6	15.39	-30.62	-22.1	-2.88	2.83	-0.67	1.26	0
Omet	-0.52	-1.13	0.35	-0.36	0.78	-2.34	1.07	0.31	0.71	-0.39	0.82	-0.53
t_t	-0.28	-0.44	-0.08	-0.44	-0.32	-1.04	0.53	-0.61	-0.63	-0.3	0.18	-0.12
I_s	0	0.23	2.46	-1.13	4.17	-4.72	-6.5	-1.13	0.14	-0.68	2.62	1
crp	-1.15	-0.67	1.81	-0.98	1.35	-1.85	-1.29	-1.17	-2.79	-0.52	0.96	0.31
Omn	-0.45	-0.64	-0.06	-0.46	0.18	0.67	1.59	-0.36	0.11	-0.57	0.62	-0.32
Agr	-0.32	-0.44	0.41	0	0.36	-0.73	0.59	-1.32	0.8	-0.11	0.31	0.05
Ser	-0.28	0.17	-0.37	-0.1	-0.67	-1.9	-3.21	-0.06	-0.38	0	0.38	0.28

1) United Kingd
2) European Fr
3) Central Europ
4) Australia,New
5) Indonesia,Ma Venezuela,Colom Argentina,Rest of Middle East, Rest African Customs U Africa, Rest of Sul of World
6) Republic of K Singapore,Thailar Taiwan,India,Sri L Central America a Uruguay,Turkey,M

Legend:

wood wood/pap
elec electronic
p_c Petroleum
ely Electricity
omet machinery
t_t trade, tran
I_s iron and st
crp chemical, r
omn manufactu
agr agricultural
ser commercia

Finland alone reduces emissions

	Finland	Sweden	Denmark	Rest of EU 1)	Efta 2)	Former Soviet Unlon	Eastern Europe 3)	USA	Canada	Rest of Annex 1 4)	Net energy exporters 5)	Net energy importers 6)
Economywide results												
Tax ($ / ton)	64.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO2 (%)	-46.00	0.01	0.05	0.02	0.01	0.69	0.03	0.00	0.00	0.00	0.00	0.00
CO2 (toe)	*-45.50*	*0.01*	*0.06*	*0.87*	*0.01*	*16.71*	*0.40*	*0.00*	*0.03*	*0.03*	*0.22*	*0.33*
Terms of Trade (%)	-0.65	0.04	-0.04	0.01	-0.03	-0.05	0.02	0.01	0.01	0.01	0.01	0.00
EV (mill. $)	-2596	16	-27	219	-83	-69	31	-27	3	-80	52	-83
gdp (%)	-1.90	-0.01	-0.00	0.00	-0.01	-0.00	0.00	0.00	0.00	0.00	0.00	0.00
Leakage												
Leakage						18.67						
Leakage rate						0.41						
Sectoral results (percentage change in sectoral output)												
Wood	-1.2	0.01	0.09	0.01	0.05	0.05	0.01	0	0	0	0	0.01
Elec	10.69	-0.16	-0.36	-0.12	-0.13	-0.11	-0.1	-0.03	-0.03	-0.02	-0.04	-0.07
P_c	-30.06	-0.14	0.47	0.02	-0.49	0.14	0.12	0	0.02	0	0	0
Ely	-11.18	1.28	0.11	0.01	0.24	1.32	0.02	0	0	0	0.01	0
Omet	5.65	-0.21	-0.05	-0.06	0.05	-0.08	-0.05	-0.02	-0.03	-0.04	-0.02	-0.01
t_t	-1.4	-0.01	0.01	-0.01	0.01	0.02	0	0	0	0	0	0
I_s	-13.79	0.63	1.32	0.28	0.6	0.36	0.23	0.01	0.03	-0.01	0.04	0.03
crp	-6.92	-0.01	0.18	0.02	0.13	0.09	0.03	0	0	0	0	0.01
Omn	1.52	-0.14	0.06	-0.01	0.04	0.04	-0.02	-0.01	-0.02	-0.01	-0.01	0
Agr	0.73	-0.08	0.03	-0.02	0.02	-0.01	-0.01	-0.01	-0.02	-0.01	0	0
Ser	-4.35	0	-0.01	0.01	-0.02	0	0.03	0.01	0.01	0.01	0.01	0.01

1) United Kingd
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Legend:

wood wood/pap
elec electronic
p_c Petroleum
ely Electricity
omet machinery
t_t trade, tran
I_s iron and st
crp chemical, r
omn manufactu
agr agricultural
ser commercia

EU alone reduces emissions

(internal EU-wide emission permit markets exist)

	Finland	Sweden	Denmark	Rest of EU 1)	Efta 2)	Former Soviet Unlon	Eastern Europe 3)	USA	Canada	Rest of Annex 1 4)	Net energy exporters 5)	Net energy importers 6)
Economywide results												
Tax ($ / ton)	51.63	51.63	51.63	51.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CO2 (%)	-41.13	-31.35	-45.96	-36.81	0.63	2.01	3.46	0.09	0.12	0.19	0.22	0.09
CO2 (toe)	*-40.68*	*-29.48*	*-49.22*	*-1639.02*	*0.82*	*48.68*	*40.60*	*6.08*	*0.78*	*3.94*	*12.42*	*7.47*
Terms of Trade (%)	-0.36	0.37	-0.88	-0.70	-0.02	-0.44	0.65	0.47	0.15	0.84	0.09	0.02
EV (mill. $)	-1923	-2343	-3856	-169202	-63	-367	-1205	6626	876	5589	2588	3736
gdp (%)	-1.50	-1.03	-1.80	-1.56	-0.06	-0.04	0.09	0.01	0.05	0.00	0.03	0.02

Leakage

Leakage	120.79
Leakage rate	0.07

Sectoral results (percentage change in sectoral output)

	Finland	Sweden	Denmark	Rest of EU 1)	Efta 2)	Former Soviet Unlon	Eastern Europe 3)	USA	Canada	Rest of Annex 1 4)	Net energy exporters 5)	Net energy importers 6)
Wood	-3.08	-1.4	0.8	-0.57	-0.99	0.44	-1.48	-0.03	-0.57	0.12	-0.01	-0.12
Elec	5.89	1.61	3.1	1.4	-1.57	1.08	0.04	-0.25	-0.35	0.11	0.48	-0.9
P_c	-24.96	-25.19	-26.85	-8.12	-6.94	-2.2	0.13	0.12	0.17	0.11	-0.73	0.03
Ely	-10.08	4.01	-47.85	-9.53	23.34	2.49	5.39	-0.1	-0.15	-0.15	0.39	0.01
Omet	3.27	-0.13	2.83	2.74	-1.89	0.81	-3.27	-0.88	-0.6	-1.51	0.17	-0.32
t_t	-1.21	-1.42	-0.16	-1.42	-0.21	0.41	-0.15	-0.04	-0.07	-0.1	0.03	-0.17
I_s	-3.03	-2.08	1.23	-4.27	7.91	6.68	5.11	0.12	0.5	-0.74	1.85	0.86
crp	-4.14	-2.67	4.42	-2.99	2.5	2.37	1.04	0.09	0.27	-0.25	0.68	0.41
Omn	0.43	-0.43	0.43	0.01	-0.68	0.94	-1.59	-0.32	-0.82	-0.99	-0.24	-0.44
Agr	-0.2	-0.58	0.85	0.49	-0.32	0.45	-0.54	-0.51	-0.75	-0.77	-0.07	-0.09
Ser	-2.61	-0.56	-2.08	-1.24	-0.07	0.19	1.29	0.18	0.47	0.62	0.58	0.32

1) United Kingd
2) European Fr
3) Central Europ
4) Australia,New
5) Indonesia,Ma
Venezuela,Colom
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6) Republic of K
Singapore,Thailan
Taiwan,India,Sri L
Central America a
Uruguay,Turkey,M

Legend:

wood wood/pap
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t_t trade, tran
I_s iron and st
crp chemical, r
omn manufactu
agr agricultural
ser commercia