Relocation of EU Industries from the Kyoto Protocol
New Insights from a New WorldScan Model

by

Johannes Bollen* and Ton Manders**

Abstract

The Kyoto Protocol (KP) has been saved by the Bonn agreement. One of the remaining concerns relate to the relocation of European energy industries within Europe, but also outside Europe, especially since the USA has decided not to ratify the Protocol. From a European perspective, there are three potential types of sectoral relocations: within Europe, within the so-called Annex-B region (also including non-EU countries that actually will limit their emissions), and outside the Annex-B region.

We use a new version of the WorldScan model to analyze and simulate the impacts of the Kyoto Protocol. This dynamic AGE model has been modified in two major ways. The model is now extended with more European regions. Second, more energy detail has been added to the model, which is also partly described in this paper.

This paper quantifies the impacts of the Kyoto Protocol. This paper also describes the sectoral relocations resulting from the implementation of the KP.

* RIVM National Institute of Public Health and the Environment

** CPB Netherlands Bureau for Economic Policy Analysis

1. Introduction

Implementation of the Kyoto Protocol (KP) may have negative impacts on countries, and especially small open economies such as the Netherlands. With the ratification process being finalized, the implementation of instruments comes to the fore. These instruments are emission trading in either local or an international setting, Joint Implementation (JI), and finally the Clean Development Mechanism (CDM). We will focus on international emission trading (ET) between the EU, Eastern Europe, the former Soviet Union and other OECD countries. But the climate policy influences the competitiveness of industries, and the central question to be answered in this paper is to quantify the potential impacts from this policy on the sectoral distribution. The analyses presented in this paper are based on the application of the Applied General equilibrium model called WorldScan (CPB, 1999).

What are the important mechanisms at work when thinking of implementing the KP?

One group of countries abates emissions and the other is not directly affected because of the lack of emission reduction strategies. This can be interpreted as the heterogeneity of the policy shock. There are indirect consequences of these asymmetric policy shocks because of trade linkages between countries. These are widely discussed in the literature and centers around the issue of carbon leakage (see OECD, 1999, Weyant, 1999, and Bollen et. al, 1999). There are two important channels for carbon leakage. First, global energy prices will fall as a result from the lower energy demand by the countries reducing emissions. Second, countries that implement an emission reduction strategy do so, by explicitly or implicitly distorting the price of energy. Then their demand price of energy will change, and will call for energy conservation in the production of energy-intensive goods, and this will in turn push the cost price of production and thus result to some extent in the or loss of market shares in international markets. There exist the danger of industrial activities being moved to regions where there is no climate policy.

But within the group of abating countries also the heterogeneity argument pops up. First, the European Union has been assigned strongly binding targets, as opposed to others (for example Eastern Europe and the former Soviet Union, and Germany that were assigned with less or no binding targets). This argument also extents to the countries within the EU. Some countries were given less binding targets than other countries (the issue of burden sharing). This will later on be more extensively explained and illustrated. Thus the burden of abatement is asymmetrically assigned to countries. Secondly, and equally important is the ability of countries to reduce emissions (costs versus abatement). This depends on the current energy and carbon intensity, and the existing energy prices, both at the macro-level and even more importantly at the sectoral level. But it also depends on future developments of these indices. These factors are country and sector-specific and all determine the countries' ability to cope with emission reductions. Other reasons - e.g. externalities from congestion - called for existing taxes on different energy carriers. These taxes are part of the energy price, and the higher energy prices, the higher the costs of abatement. Thirdly, some energy-intensive sectors are larger than others, and this coincides with large market shares by these companies in international markets. When strong and large companies are faced with higher energy prices and thus higher production costs, they can partly pass on these distortions to both domestic and foreign consumers. Countries that can pass on the policy to abroad will be faced with terms-of trade gains. Finally, some countries are energy-exporters, and some importers. The countries that export energy, are generally the ones that will also be faced with lower production of energy sectors, simply because of the imposed fall of energy demand.

The analysis in this paper will aim to quantify the importance of these different elements to countries/regions and thus hopefully provide useful information for the climate policy debate. The climate policy will restrict to consequences of the implementation of the Kyoto Protocol (KP), and its' amendments as agreed in Marrakech. The analysis will restrict to the potential economic impacts for countries/regions and sectors in a global setting up to the end of the so called first budget period (2008-2012). We will use multi-region-multi-sector AGE model called WorldScan model (CPB, 1999) to analyze the consequences of the KP.

There are some limitations to the analyses that need to be emphasized here. They mostly concern the model and are

- the exogenous role of the government

No specific behavior is modeled with respect to the government. All taxes are imposed on production and consumption, and fed back in the economy in a lump-sum way to the consumers. When analyzing energy taxes, the model cannot endogenously lower taxes of other inputs such as labor, and thus will not be able to simulate a double dividend.

- lack of rational expectations with longer time horizons

WorldScan is limited in the sense that it is not a fully forward looking intertemporal optimization model[1]. This implies that the agents in the model cannot anticipate on policy shocks. Still, the model mimics this rationality on the consumption (savings) and on the production side (investments), and thus realistically describes long-run impacts of policies, see CPB (1999) for more details.

- unemployment assumption or the lack of wage rigidities

Climate policies will lead to higher energy costs, and depress the real wage rate. Resistance to this in the economy can lead (temporarily) to unemployment. The OECD (1999) shows that the assumption of wage rigidity could amplify the cost of emission reduction. The impacts of these medium-term adjustments may be considerably higher and distort economies more than shown by the long-run effects. WorldScan assumes fixed unemployment rates (around 5 percent), and hence the model describes only long-term adjustments of policy shocks.

- focus on CO_2 emissions (and disregarding the other greenhouse gases)

Recent research on climate change policies show considerable relevance of reducing non-CO_2 emissions when aiming to mitigate climate change, see IEA's ETSAP network on MARKAL models (http://www.ecn.nl/unit_bs/etsap/). Moreover, options to increase the region's sink capacity are not included. Still, climate change is mostly determined by CO_2 emissions, and this will even become more

important in the course of this century. Thus, WorldScan covers the most important driving forces behind the main macro-economic impacts of climate change policies, especially in the long run.
The analysis also has several some strong points. They are

- as mentioned before the heterogeneity of countries/regions

The model simulations add realism to analyses. For example, region-specific energy intensities lead to asymmetric impacts from climate change policies.

- equilibrium focus of analysis, because all sectors are linked to each other

Sectors within a country are linked to each other. Hence, the direct impact of climate change policies to energy sectors, consumers and energy-intensive sectors will also be felt in the rest of the economy.

- long term consumption preferences converge

The model includes time-dependent consumption preferences, which converge to the USA preferences. And it can describe the economies' transition from being an energy-intensive to energy-extensive.

- trade dimension with long-term H-O specialization patterns

The trade dimension improves the realism of simulating sector specialization. But equally important is the following. Trade linkages between regions in the model help to understand the potential spillover effects of climate change policies. For example, WorldScan projects these spillovers from Annex B to the non-annex B in the case of the Kyoto Protocol. Reducing emissions in the Annex B region lowers the global energy price, and the production of energy-intensive goods moves to regions, which do not implement any carbon policy. Both mechanisms increase the CO_2 emissions of the non-Annex B region, and change their terms of trade and industry output.

The setup of this paper is as follows. The next section starts with an overview of the WorldScan model. Then, Section 3 presents some characteristics of the baseyear data that determine the outcomes of the policy experiments, concluded by a description of both assumptions and developments of the no-policy baseline scenario. Section 4 will then explain the assumptions of the policy experiments that addresses the research questions posed in the beginning of this introduction. Section 4 presents and discusses the results of the model simulations. Finally, Section 5 concludes.

[1] In other words, the model has adaptive instead of fully rational expectations.

2. WorldScan

This section presents an overview of the most important elements of WorldScan.

The energy version is derived from the core version of WorldScan, which is described in CPB (1999). WorldScan is a recursive, multi-region, multi-sector, and applied general equilibrium (AGE) model, which can simulate long-term growth and trade in the world economy. It builds on the neoclassical theories of growth and trade. Table 2 presents two important dimensions of the model: twelve regions, and eleven sectors. There are six sectors that concern the supply of energy: coal, oil, gas, modern biomass, other non-fossil fuels, and electricity.

Table 2 Regions and Sectors in WorldScan

Regions	Sectors
Annex B	
Western Europe	Materials
• Netherlands	• Agriculture and food processing
• Belgium and Luxembourg	• Energy-intensive goods
• France	• Consumption goods
• Italy	• Capital goods and consumer durables
• Spain	• Services (domestic)
• United Kingdom	• Trade and transport services
• Germany	• Other raw materials
• Rest of Europe	
United States	Energy
Rest OECD	• Coal
EEFSU	• Oil and petroleum products
• Eastern Europe	• Natural gas
• Former Soviet Union	• Electricity
Non-Annex B	• (Biomass)
• Middle-East and North Africa	• (other non-fossil fuels)
• Latin America	
• ROW	

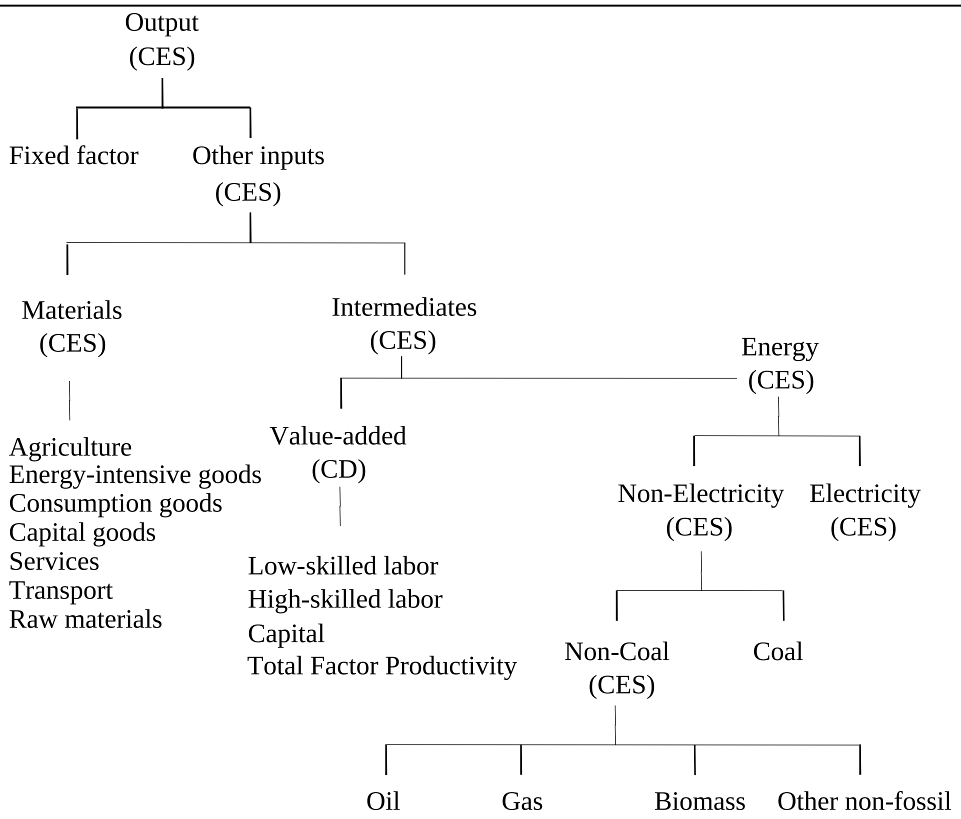
Two perspectives can illustrate the most important characteristics of WorldScan. First, there is the macro-economic perspective on production, consumption and investment. In this context, countries are allowed to run trade deficits or surpluses, so that investments do not have to equal savings. These deficits and surpluses affect the net-foreign debt position of countries. Second, the sectoral perspective centers on the allocation of inputs. Within a country sectors differ, and also across countries the same sectors differ from each other. As with the macro perspective, also on the sectoral level trade solves differences in demand and supply. From the macro-economic perspective, trade implies changes in the financial position of a country. However, from the sectoral perspective, trade means that a country is either a net-importer or net-exporter of a particular good. Trade patterns depend on regional differences in technology, endowments, demand, and transport costs.

Producers minimize the costs of required inputs and consumers maximize utility. Production functions are defined as a nested structure, see Figure 2 below. It can be seen that these functions are defined as nested Constant-Elasticity-Substitution (CES) functions. The nesting structure of the production functions is similar across regions and sectors.

For details on labor markets, see CPB (1999) and Bollen and Manders (2001). Investments are equal to the difference between the required minus depreciated capital stock. Capital owners invest in and allocate their wealth to countries based on the return on investments (region-specific) and preferences for certain regions. The supply of capital comes from all regions and matches demand on a market, which is cleared by the interest rate. Finally, the fixed factor is also input to production, which is to some extent exogenous in terms of land availability and partly endogenous because of changing energy reserves.

On the consumption side are agents, which - by a heuristic rule - aim to maximize utility by appropriate arbitrage between current consumption and savings (postponing consumption). This decision depends on financial and human[2] wealth, with the latter being the discounted value of future income flows. The arbitrage is heuristic in the sense that the applied rule estimates future income by looking one period ahead, and truncates the rest of the future - thus disregarding full forward-looking behavior.

Figure 2 Production structure of WorldScan sectors



If total production, investments, and consumption are given at the macro level, the next step is to allocate inputs to sectors. In the energy version of WorldScan the set of intermediate products includes 13 types of goods (sectors). The sectoral perspective in WorldScan can be characterized by production functions having a similar format across regions and sectors, but differing with respect to the cost

2 Besides labor income these flows include government transfers and surplus profits. The latter originate from monopoly power.

shares of inputs. Like in many other CGE models, demand originates from final consumption, the demand for intermediate goods, and investments. Consumers allocate their expenditures on various goods with preferences slowly moving to the USA lifestyle. The intermediate and investment demand is sector -and country-specific, and follows from producers' minimizing costs at given levels of technology. On the sectoral level, imports and exports solve for the tension between consumption and production. WorldScan assumes a dynamic Armington utility function, which reflects (changing) brand loyalty for a product. Domestic and foreign goods substitute with finite price elasticities, which are low for the short term and high in the long run. Current trade patterns can be explained by regional and sectoral differences in technologies, endowments, preferences for different varieties, and transportation costs. Therefore, on the longer term, WorldScan specialization patterns tend to follow the law of one price as predicted by the Heckscher-Ohlin theorem[3].

WorldScan has six energy sectors: electricity, coal, oil, gas, modern biomass, and other non-fossil fuels. The oil and gas sectors are subject to resource depletion. Total demand for energy within a country is the aggregate of consumption and intermediate demand. On the consumption side all energy products are included. The supply of energy increases by [1] more availability of energy resources and [2] higher efficiency of technologies that transform the primary products into secondary energy that is suitable for either consumption or intermediate demand. The calibration of the model uses the GTAP database (see Dimaranan *et al.*, 2002). However, the data don't include non-fossil fuels. However, expenditures on non-fossil fuels come from the IMAGE-team (2001). Prices of biomass and other non-fossil fuels follow the price path in the agriculture sector and domestic services sector, respectively. CO_2 emissions are calculated as the product of the demand for energy and an energy-specific emission coefficient, which does not vary over time. The non-fossil fuels (also biomass) have zero emissions (see also IMAGE-team, 2001). The model assumes a second-best world for all sectors, i.e. it includes in the price formation arguments such as subsidies, taxes, and tariffs on exports and imports that are based on GTAP. The energy price equations also includes the carbon tax. Government income from energy taxes is fed back into the economy by lumps-sum transfers to the consumers. The energy version of WorldScan thus enables the modeler to simulate policy shocks that reduce the CO_2 emissions.

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3 A country will export that commodity which intensively uses its abundant factor.

3. Baseyear data, assumptions, and characteristics of the baseline

This section will start with the major characteristics for different countries and regions in the perspective of the policy experiments that will be described in Sections 4 and 5. This section will be concluded by the assumptions of the future developments of the baseline scenario.

Table 2 presents some characteristics for a number of countries and regions in 1997. The Table presents the levels for population, GNP, energy demand, CO_2 emissions, and indices for energy and carbon intensity (relative to the USA). The energy intensity is measured as the ration between physical energy demand and real GNP (1997 US$). The carbon intensity is calculated as the ratio between total energy related CO_2 emission and total physical energy demand. Both intensities are measured as relative to the USA (indexed to 100). The data show considerable differences between countries and regions. It can be seen from Table 2 that especially European countries are relatively energy extensive in physical terms. Also there are large disparities in the carbon intensity, especially France has a low value because of their large nuclear power stations. Also it can be seen that EFS is still very energy-intensive, but has moderate carbon-intensity. The carbon intensity used to be higher in nineties, but declined rapidly because of breakdown of the EFS economies and closure of mines and removal of brown-coal as an energy source for production.

Table 2 Baseyear data (1997)

	Population (mn)	GNP (bn $)	Energy (toe)	Emissions (GtC)	Energy Intensity (USA=100)	Carbon intensity (USA=100)
WEU	376	7738	142	0.93	73	89
NLD	16	340	9	0.07	102	96
BLU	11	229	6	0.04	108	86
GER	82	2025	32	0.25	60	102
FRA	60	1338	24	0.10	69	55
GBR	59	1256	23	0.16	70	89
ITA	57	1091	17	0.12	58	94
ESP	40	506	11	0.08	86	89
USA	275	7693	201	1.53	100	100
ROE	190	5616	83	2.32	57	366
EFS	390	858	112	0.79	529	93
ROW	4585	6169	320	2.41	217	100

Table 3 then zooms in on the energy characteristics of the sectors and regions. It presents the ratios between values of the energy expenditures and production. These values also account for the existing taxes on the inputs for production. Thus the qualifications from the Table 2 do not have to coincide with those from Table 3. The sectors presented in Table 3 are: Agriculture and foodstuffs (including food processing industries), consumer goods, capital Goods, E-intensive industries (chemical, ferrous, and non- ferrous industries, paper factories), Services, and the Trade and Transport sector. First int can be seen that energy-intensive and trade and transport are much more energy-intensive as compared to the service sector. And there are of course large differences between countries, even within the EU.

Especially the Netherlands and France have large energy bills in the energy intensive sector compared to production, coming from relative large taxes on energy. Other striking number is the energy share of production of energy-intensive goods in Spain, and agricultural goods in Belgium. Overall energy intensities in EFS in physical terms were 500% higher than in the USA, and twice as high in energy-intensive goods, which points at small energy taxes – at the importance of the energy-intensive sector in the total economy.

Table 3 Energy Intensities per sector and region, 1997

	Agriculture	Consumer Goods	Capital	E-Intensive	Services	Trade and transport
WEU	3.2	2.0	0.8	8.1	1.1	6.2
NLD	4.3	1.4	0.5	9.9	1.3	8.1
BLU	11.1	1.7	0.7	9.3	1.3	11.0
GER	3.3	2.0	0.5	7.0	0.9	4.5
FRA	3.7	2.4	0.7	9.8	1.4	9.9
GBR	1.5	2.2	1.0	6.1	1.0	5.3
ITA	3.2	1.8	1.3	7.1	0.9	4.3
ESP	2.8	2.1	1.1	13.7	1.4	6.8
USA	6.9	2.5	0.8	6.3	1.1	2.7
ROE	4.9	3.5	1.4	9.3	1.7	3.2
EFS	11.3	2.2	2.3	14.8	2.8	5.6
ROW	2.7	1.9	1.2	8.8	2.2	5.4

The baseline path follows assumption as reported in RIVM (2001a) for European countries, and Bollen et al (2002) for the other non-EU world regions. The future developments of sectors and regions in the EU are based on pre-Kyoto Protocol scenario of EU DG-Energy, supplemented by prospects for transport and agriculture. For the other regions, the economic growth and the changes of energy demand and supply follow the IPCC-A1B scenario. The A1B scenario assumes globalization and rapid technological diffusion of new technologies. Catching-up and the breakdown of trade barriers characterize the global developments of the scenario. Further, the scenario lacks any climate policy, besides the ones that are already in pace. Moreover, it is assumed that existing taxes on demand and thus the tax structure remain the same for the coming ten years.

To summarize the major developments in the baseline scenario, Table 4 characterizes for some variables the growth rates between 1997 and 2010. This Table also presents the Assigned Amount (AA) as assumed and used for the policy analysis to be described in the next section. The first observation relates to the major driving forces of emissions; growth of population, economies. As can be seen these are region-specific. This argument also extents within Europe. Especially the Netherlands seems to rapidly expand their population. This holds also for economic growth and energy demand. Compared to the “average” EU country, the Netherlands in this scenario has median energy intensity changes between 1997 and 2010, but switch more to carbon –based fuels, which results with higher population growth rates, to higher emission levels than the other European countries. It can thus be expected that the costs of abatement will fall heavily on the Dutch.

Although the burden of abatement is more or less the same relative to other countries in 1990 emission levels, this will not be the case in 2010.

Table 4 Baseline, annual growth rates for different indicators in 1997-2010 period and AA's for different regions

	Population	GNI	Energy demand	Emissions	AA	AA
	(%)	(%)	(%)	(%)	% reduction compared to 1990*	% red. compared to 2010
WEU	0.3	2.5	1.0	0.9	-7	-14
NLD	0.5	2.7	1.4	1.3	-6	-26
BLU	0.2	2.4	1.0	0.8	-6	-20
GER	0.3	2.5	1.0	0.9	-7	-5
FRA	0.5	2.4	0.8	0.9	-7	-16
GBR	0.1	2.6	1.2	0.9	-6	-11
ITA	0.1	2.3	0.5	0.4	-6	-13
ESP	0.1	3.0	1.4	1.1	-5	-20
USA	0.8	3.3	2.1	1.4	*-3*	*-26*
ROE	0.7	2.7	1.8	0.5	7	-10
EFS	0.2	3.8	0.9	0.4	3	50
ROW	1.4	5.3	5.5	5.0	-	-

AA (in CO2 equivalents) taken from the reductions reported den Elzen and de Moor (2001)

One critical issue worth mentioning here before discussing the setup of the in the simulations, concerns the AA's of the countries in Eastern Europe and the former Soviet Union. Despite the fact that these countries are extremely energy-intensive, they also have come out the Kyoto negotiation process with very relaxing AA's. These are +3% of the 1990 emission level. And considering the fall of emissions between 1990 and 1997 and the moderate rise at 0.4 % growth between 1997 and 2010, this may yield emissions 50 % below their AA. The difference between the AA and the 2010 emission level in the policy debate is referred to as "hot-air". And this will in turn have major implications for the policy simulations, especially the cases that concern emission trading between Annex-B countries.

4. Policy cases

The setup of the policy experiments is straightforward. Table 5 below illustrates all the cases.

The central base-policy case is one in which all Annex-B countries (except the USA) act in line with the Kyoto protocol, under the assumption that the reductions take place solely in the segment of energy-related CO2 emissions[4]. Moreover, full emission trading is assumed.

[4] The AA's are taken from Den Elzen and de Moor (2002), and also account for the sink-corrections as agreed in the Marrakech-accord. This implies that it is implicitly assumed that the actual percentage reductions for Annex-B region will be equal to the percentage reductions of the non-energy related CO2 and non-CO2 gases. Moreover, we thus also assume that there are no costs involved with these non-energy CO2 and non-CO2 emission reductions.

Table 5 Policy cases

Case	*Abbreviation*	*Description*
Annex B Trading	*ET*	Kyoto targets, to be reached within Annex B with one emission price and transfers based on Kyoto targets, and without USA.
Annex B Trading With USA	*ETU*	as ET but with USA
No Annex B Trading	*NT*	as ET but without emission trading
Sensitivity	*ET_la*	ET, Armington elasticities halved
	ET_lsub	ET, energy substitution elasticities halved
	ET_lsup	ET, energy supply elasticities halved

The amount of hot-air that can be supplied by EFS will by 2010 be equal to 0.43 Gt C and the necessary emission reductions by the other Annex-B countries equal to 0.22 Gt C. Thus in principal, with emission trading, no actual emission reductions have to be occur by the Annex-B countries (without USA). But, it is assumed that EFS will opt to withhold the supply of permits up to the point that their revenues will be maximal in the middle of the first budget period (year 2010). Additional simulations have been performed that fix at different percentages of hot-air kept out of the permit market, and to maximize the revenues to the EFS region in the first budget period. It turns out that these revenues are maximal, when 75% of the total amount of hot-air is kept out of the market, and thus effectively reducing the number of permits of the emission market. The KP allows for this option, and this is called banking. The banking option allows countries to by lowering AA's of the first budget-period and move these to increase the AA's with an equal amount in the second budget period (2013-2017). The 75% maximizes the EFS' revenues in the ET case, and is used for all other cases reported in this paper.

Another policy case concerns the case of full emission trading within Annex-B, but now USA also is included in the abatement coalition. This simulation compared to the base policy case differs only with respect to the role of the USA, and thus can shed some light on the potential impacts from USA's refusal to ratify the KP.

The basic argument in favor of flexible instruments such as Emission Trading (ET) - their efficiency gains as compared to a situation in which each country has to achieve its own reduction target domestically - are well-known and widely accepted. The difference between the two cases is that in the former case one uniform price of emissions will exist, while in the latter for each country separate prices will be the outcome. The uniform price in case of ET will equal the marginal cost of reducing emissions in the Annex-B region. However, the existence of hot-air permits in the markets complicates the simulations, because there are in fact two prices. The first is the uniform marginal cost price of emission reduction across the importing countries, and the second is the zero-cost price to the EFS. This is because EFS does not actually have to reduce emissions, but only supplies permits a price equal to the uniform cost-price of emission reductions of importing countries.

But perhaps emission trading is a too optimistic option to implement the KP, and it is only possible for the Annex-B countries (excluding the USA) to each individually reduce emissions in line with KP. Thus country-specific prices will be the outcome of this way to implement the KP. This option is included in the analysis and is simulated with country-specific carbon taxes.

Also some sensitivity analyses have been conducted. Three simulations have been added, which have in common that they follow the assumptions of the base policy-case. But they differ with respect to parameter settings of the model. The first sensitivity case concerns a 50% reduction of the Armington elasticities included in the model. This means that the rate of substitution between foreign and domestically produced goods is halved. The second sensitivity case concerns a 50% reduction of the energy related substitution elasticities in the production function. This simulation may shed some lights on the uncertainty with respect to the substitution between the different fossil energy carriers used in the production of goods, but also between energy and non-energy inputs. Energy conservation is thus more expensive in this simulation. The last sensitivity aims to shed some light on the behavioral relationships of the energy producers. In this simulation, all the producers are faced with 50% lower supply elasticities, i.e. the supply curve of energy is verticalized. And thus it is more difficult to reduce energy.

[4] Results

The policy base-case simulation is the Annex-B trading case without the USA, and EFS keeping 75% of their hot-air out of the market. Table 6 shows for 2010 the regional AA's, the actual emissions (after ET), the permit price, the General National Income (GNI), Energy, and finally carbon intensity. All these indicators are reported as percentage changes compared to the baseline level, except for the carbon tax which is reported in US$ / tC and equals to permit price.

Table 6 Results in 2010, Emission Trading without the USA (change compared to base)

	AA relative to base	Actual emissions relative to base	Carbon tax	GNI	Energy Intensity	Carbon Intensity
	(%)	(%)	($/tC)	(%)	(%)	(%)
WEU	-14	-6	33	-0.2	-5	-1
NLD	-26	-5	33	-0.4	-5	0
BLU	-20	-6	33	-0.3	-4	-1
GER	-5	-7	33	-0.1	-6	-1
FRA	-16	-4	33	-0.1	-2	-2
GBR	-11	-8	33	-0.1	-7	-1
ITA	-13	-5	33	-0.2	-5	0
ESP	-20	-6	33	-0.3	-5	-1
USA	-	0	-	0	0	0
ROE	-10	-7	33	-0.1	-5	-2
EFS	50	0	0	0.2	0	0
ROW	-	0	-	0.0	0	0

Table 6 shows that all countries import permits, i.e. their actual emission reductions in the third column is less negative than the numbers in the AA column. The only exception is of course the EFS region, which will supply hot-air permits at 33US$/tC and at zero costs. The first observation is that the GNI losses are limited to 0.4% at the most[5]. Also it can be seen that these changes are country/regions specific. The main reason for these differences is the restrictiveness of the targets, and the sectoral composition of the economy, the energy shares of production, etc. etc. It can be seen from Table 6 that the GNI losses in the Netherlands are the largest. Thus the main reason comes from being the country/region with the strongest increase of emissions in the baseline, that results in sharpest reductions to comply with the KP. Another reason is the high energy bill shares compared to production, which indicates that marginal distortions will have a stronger GNI impact than in the other regions. Table 5 shows that countries outside Annex B region (including the USA) will - at the macro-level - hardly be impacted from the base-policy by the other Annex B countries. A last observation

[5] Previous analysis shows that different factors could either lower or increase these costs. Increasing factors are wage rigidities, specific sectoral adjustment elements not captured in the parameter settings of production functions, market power of permit sellers, and restrictions of emission trading. Decreasing factors are the use of CDM, non-CO2 emission reduction options to meet the AA's of the KP, and generate double dividends when setting out a tax reform. We refer to Bollen et. al (2000) for more details.

from Table 5 is that the restrictive carbon policy will lead to the import of permits and lower emissions. The emission reductions will mainly be brought about by lower energy intensities and to a lesser extent by emission reductions. Only in France, fuel switching is equally important as energy reductions in achieving the goals. The explanation is that France is already carbon-extensive (nuclear power), and can relatively easily absorb the switch away from the fossil fuels.

Table 7 Effects from ET without USA, sectoral impacts in 2010

	Carbon tax	GNI	Sectors					
			Agricultur e	Consume r Goods	Capital goods	E-Intensive	Sevices	Trade and Transport
	($/tC)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
WEU	33	-0.2	0.2	0.1	-0.2	-0.4	0.0	0.0
NLD	33	-0.4	0.1	0.1	0.3	-1.0	0.1	-0.1
BLU	33	-0.3	-1.0	0.0	0.1	-0.7	0.2	-0.3
GER	33	-0.1	0.1	0.1	0.0	-0.5	0.0	0.1
FRA	33	-0.1	0.1	0.0	-0.3	0.1	0.0	-0.1
GBR	33	-0.1	0.2	0.1	-0.2	0.0	0.1	0.1
ITA	33	-0.2	0.2	0.1	-0.5	-0.3	0.0	0.0
ESP	33	-0.3	0.4	0.2	-0.2	-1.5	0.0	0.1
USA	-	0.0	0.0	0.0	-0.1	0.4	0.0	0.0
ROE	33	-0.1	0.1	0.1	0.0	-0.3	0.0	0.1
EFS	0	0.2	-0.1	-0.1	-0.4	0.5	0.1	0.0
ROW	0	0.0	0.0	0.0	-0.1	0.3	0.0	0.0

Table 7 shows results for the same base-policy case as Table 6, but also zooms in on the sectoral changes. The sectors columns show for 2010, the sectoral VA-changes compared to the baseline scenario values. The changes in VA are sector-specific. Generally in abating countries, there's a switch from energy-intensive production towards energy-extensive production (services and consumer goods). From Table 7 it can be observed that the E-intensive sector in the USA will profit from the climate policies pursued by the other Annex B countries. Thus this seems to be at the expense of the competitiveness of Europe's E-intensive sector.

Within EU there are large also differences. The E-intensive sector in Spain and the Netherlands also will be faced with less production compared to the baseline scenario, and on the other end in France production will increase. Thus, although all countries are faced with the same carbon-tax, the competitiveness of the E-intensive sector differs across countries.

Within the EU there will be a switch from energy-intensive to energy-extensive production. And on the macro-level production the losses of the E-intensive sectors will be partly compensated by the gains of the E-extensive sectors.

Within Europe policy makers fear that USA's refusal to sign the KP will go hand in hand with a loss in the competitiveness of EUs' E-intensive sectors. To analyze the impacts from USA's refusal to sign the KP, a simulation is added to this paper that also assumes full emission trading, but now also includes the USA as a carbon mitigating country with targets equal to the ones agreed in Kyoto. The hot-air assumption in this simulation is the same as with the base policy case[6]. Table 8 has the same format as Table 7.

Table 8 Effects from ET without USA, sectoral impacts in 2010

	Carbon tax	GNI	Sectors					
			Agriculture	Consumer Goods	Capital goods	E-Intensive	Services	Trade and Transport
	($/tC)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
WEU	77	-0.4	0.5	0.2	-0.6	-0.5	0.0	-0.1
NLD	77	-0.8	0.5	0.1	0.4	-1.7	0.1	-0.3
BLU	77	-0.6	-1.9	-0.1	0.0	-1.2	0.4	-0.6
GER	77	-0.3	0.4	0.3	-0.1	-0.9	0.0	0.1
FRA	77	-0.3	0.3	0.0	-0.8	0.7	-0.1	-0.2
GBR	77	-0.3	0.6	0.2	-0.7	0.6	0.1	0.1
ITA	77	-0.5	0.5	0.2	-1.4	-0.6	-0.1	-0.2
ESP	77	-0.6	1.0	0.4	-0.6	-3.0	0.0	0.1
USA	77	-0.4	-0.4	-0.3	-0.5	-0.8	0.2	0.1
ROE	77	-0.3	0.8	0.3	-0.3	0.0	0.0	0.2
EFS	0	0.5	0.0	0.0	-1.0	1.5	0.1	0.1
ROW	0	0.0	0.2	0.2	-0.5	1.2	-0.1	0.0

The inclusion of the USA to the carbon abatement group will lead to a higher permit price, because they push the demand for permits. Hence the price of the permits will rise from 33 to 77 US$ / tC. The macro-economic losses will be higher, as can also be noted from the results reported in table 8. The E-intensive sector in the USA will now also be confronted higher energy prices, and thus production will reduce by 0.8 % compared to the baseline scenario (as opposed to the 0.4% increase in the policy base case). Europe's competitiveness of E-intensive sectors will increase compared to the USA, but they will now instead loose competitiveness to the non-annex B regions. And this will yield even higher production losses than in the case where USA will not pursue any carbon abatement. Thus the leakage of E-intensive activities will move from USA at a low level, and because of a more expensive permit trading system with the USA, at a higher rate to the non-Annex B region. In sum, the EU will be economically worse off when the USA does ratify the KP. This goes of course hand in hand with a "global" environmental gain that accrues to the global population.

The simulations above assume that emission trading will occur, but this is not an obvious assumption. Emission trading will imply large monetary transfers to the "hot-air" EFS region, and requires policy efforts to design institutions that can accommodate the working of the permit market. This will take time and go at the expense of financial resources that cannot be appropriately be represented with models such as WorldScan. Still the potential gains from permit trading can be considerable, and this conclusion comes from analyzing the results presented in Table 9 (with same format as the two

[6] Strictly speaking this may yield non-maximal permit revenues to the EFS region, but this will hardly impact the results of the simulation

previous tables). The policy case assumes no emission trading, including USA's decision not to ratify the KP.

Table 9 Effects from NET without USA, sectoral impacts in 2010

	Carbon tax	GNI	Sectors					
			Agriculture	Consumer Goods	Capital goods	E-Intensive	Services	Trade and Transport
	($/tC)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
WEU	230	-0.6	0.5	0.1	-0.5	-2.6	0.1	-0.2
NLD	230	-1.7	-0.6	0.0	2.6	-11.4	1.1	-1.0
BLU	149	-1.0	-4.4	-0.2	1.1	-5.1	1.3	-1.3
GER	27	-0.1	0.2	0.0	-0.8	1.9	-0.1	0.1
FRA	155	-0.7	0.3	-0.1	-0.6	-1.3	0.0	-0.4
GBR	55	-0.2	0.3	0.0	-1.0	1.2	0.0	0.1
ITA	98	-0.7	0.5	0.0	-1.8	-1.7	-0.1	-0.3
ESP	133	-0.9	1.4	0.6	-0.7	-7.2	0.3	0.2
USA	0	0.0	0.1	0.0	-0.3	0.8	-0.1	0.0
ROE	49	-0.2	0.2	0.1	-0.1	-0.2	0.0	0.1
EFS	0	0.0	0.1	0.0	-0.7	2.0	-0.2	0.0
ROW	0	0.0	0.0	0.0	-0.3	0.7	-0.1	0.0

Each country/region now has to reduce emissions separately. There is no emission market, and there will be different marginal costs of abatement. The countries will not be able buy the permits from abroad if they feel that their marginal costs of abatement lies above the price of the permit market. Hence, the sectoral impacts will now be more severe, and also the macro-economic costs to the Annex-B group (excluding the USA) will increase. Some countries, such as the Netherlands will be confronted with higher income losses if they individually have to account for the rules of the KP compared to policy base case (1.7% loss versus 0.4%). It can also be seen that the costs of abatement now will diverge much stronger than compared to the previous cases. Countries with the highest macro-economic losses will have the strongest incentive to work on institutionalizing and operating the permit market. Finally, the USA will even be confronted with more heavily distorted competitors, and thus the production gains by E-intensive companies will even be higher compared to the policy base case. This will argument also holds but to a lesser extent for the non-Annex B regions.

Currently, Europe has significant taxes on the demand for energy (especially on refined oil and oil-products). However taxes on coal are very low. Table 10 presents the current taxes on coal, oil, and gas. A negative entry means that - either explicitly or implicitly - the specific energy carrier is subsidized.

Thus the carbon tax distorts coal more than oil, and oil more than gas because of it's relation to CO2 emissions and impact on the climate. This may be very costly and could perhaps be replaced by less distorting carbon taxes. To analyze the impact from more efficient allocation of taxes on energy, we also included a simulation with the same assumptions as the base policy case, but now also accounting for the existing taxes on energy. For example, the Netherlands has a very high tax on oil, and thus we have the carbon tax hardly come on top of oil, and much heavier on coal than the “normal” carbon tax.

Table 10 Tax quote on energy in 1997

	Coal	Oil	Gas
WEU			
NLD	0.2	3.0	0.0
BLU	0.0	2.1	0.1
GER	0.2	2.9	0.4
FRA	0.1	4.3	0.2
GBR	0.2	3.2	0.0
ITA	0.0	2.8	0.6
ESP	0.0	2.4	0.1
USA	-0.1	0.2	-0.1
ROE	0.0	2.0	0.0
EFS	-0.2	0.1	-0.2

Table 11 presents the results of this policy simulation. The carbon tax will now be much lower and go do down from 33 to 13 US$ / tC. Income and sectoral production changes respond accordingly.

Table 11 Effects from FET without USA and alternative tax scheme, sectoral impacts in 2010

	Carbon tax	GNI	Sectors					
			Agriculture	Consumer Goods	Capital goods	E-Intensive	Services	Trade and Transport
	($/tC)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
WEU	13	-0.1	0.1	0.1	-0.2	-0.3	0.0	0.0
NLD	13	-0.2	-0.6	-0.2	0.3	-1.0	0.1	0.1
BLU	13	-0.1	-0.8	-0.1	-0.1	-0.4	0.1	-0.1
GER	13	-0.1	0.1	0.1	0.1	-0.5	0.0	0.1
FRA	13	-0.1	0.1	0.0	-0.3	0.0	0.0	0.0
GBR	13	-0.1	0.2	0.1	-0.2	-0.1	0.1	0.1
ITA	13	-0.1	0.1	0.0	-0.4	-0.1	0.0	0.0
ESP	13	-0.1	0.3	0.1	-0.2	-1.1	0.1	0.1
USA	-	0.0	0.0	0.0	-0.1	0.3	0.0	0.0
ROE	13	-0.1	0.1	0.1	0.0	-0.3	0.0	0.1
EFS	0	0.1	0.0	0.0	-0.2	0.5	0.0	0.0
ROW	-	0.0	0.0	0.0	-0.1	0.3	0.0	0.0

Table 12 summarizes the results. Thus the columns refer to ET without the USA, ET with USA, NTR without the USA, and finally ET without the USA, and the alternative tax scheme. The first two rows present the carbon leakage rate. The leakage rate is defined as the ratio between the sum of the emission increases resulting from countries that do not have to perform any carbon abatement and the sum of the emission reductions from countries that do so. It can thus be seen from Table 12 that the leakage rate will be equal to 16.6 percent. Thus 16.6 percent of the climate policy effort will leak away to the region that will not have to abate emissions. There are two reasons. First, consumption of E-intensive products will partly be reduced, but part of the production will shift from abating countries to the non-abating countries. Secondly, because energy demand will fall, the global energy price will fall, and consequently E-intensive production costs of E-intensive sectors in non-abating countries will decline compared to the competitors of the emission abating countries. Thus production of E-intensive sectors in non-abating countries will be magnified compared to the impact of the first leakage channel.

Table 12 Different policy cases, income changes in 2010

	ET_NOUSA	ET	NTR_NOUSA	ET_NOUSA_TAX
	($/tC)	(%)	(%)	(%)
Carbon tax	33	77	Region specific	13
Leakage rate	16.6	12.1	20.8	13.3
WEU	-0.2	-0.4	-0.6	-0.1
NLD	-0.4	-0.8	-1.7	-0.2
BLU	-0.3	-0.6	-1.0	-1.0
GER	-0.1	-0.3	-0.1	-0.1
FRA	-0.1	-0.3	-0.7	-0.7
GBR	-0.1	-0.3	-0.2	-0.2
ITA	-0.2	-0.5	-0.7	-0.7
ESP	-0.3	-0.6	-0.9	-0.9
USA	0.0	-0.4	0.0	0.0
ROE	-0.1	-0.3	-0.2	-0.2
EFS	0.2	0.5	0.0	0.1
ROW	0.0	0.0	0.0	0.0

Also be aware that in all cases there is leakage to EFS, because they often remain below their AA, but above the no-policy baseline. It is thus also straightforward that the leakage will decline if one compared the leakage rate from ET with NTR, because the second leakage channel is enhanced in the latter case. Therefor leakage can rise up to 20 percent. However, if the USA joins the abatement group, then leakage will decline, because market power of the remaining countries that do not have to reduce any emissions is less strong than USA's competitors, which will also have to reduce emissions. Hence leakage rate drops to 12 percent. Finally the alternative tax scheme will show the opposite effect of NTR compared to the policy base case. The carbon tax declines, and so the second channel is shut off.

The cost abatement depends on the values of the model parameters. Sensitivity analysis on critical parameter values will point also at the uncertainty of the model outcomes. In AGE models such as WorldScan, it's a tedious task to perform a thorough sensitivity analysis. However we choose to characterize the parameters into three clusters: Armington trade elasticities, the energy-related substitution elasticities of production functions, and finally the supply elasticities of energy sectors. Then we reduced consecutively reduced the values of these parameters by 50 percent. The results are shown in Table 13 below, and the table has the same format as Table 12.

The Armington elasticities relate price the willingness to substitute foreign goods for domestic goods. The sensitivity case reduces the Armington elasticities of all sectors by 50 percent. Thus any climate policy will now be more difficult, because the distorted can less easily adapt to changing international circumstances, and shift the production of E-intensive goods to abroad. Thus marginal costs increase, and the leakage rate will fall at the same time. This can also be seen in the Armington column compared to the base case. Also some countries now have the possibility to pass on the price increases of e-intensive goods to outside the region that pursues the carbon abatement. They will get a terms-of-trade gain (export price of import price). However some will also loose because of relative no market power. The GNI losses are the aggregate of all the sectoral movements.

Table 13 Sensitivity analysis, income changes in 2010

	Base	Armington	Substitution	Supply
	($/tC)	(%)	(%)	(%)
Carbon tax	33	36	56	33
Leakage rate	16.6	14.7	16.4	16.6
WEU	-0.2	-0.2	-0.3	-0.2
NLD	-0.35	-0.31	-0.50	-0.35
BLU	-0.27	-0.25	-0.37	-0.27
GER	-0.13	-0.12	-0.18	-0.13
FRA	-0.15	-0.14	-0.21	-0.15
GBR	-0.13	-0.12	-0.18	-0.13
ITA	-0.21	-0.19	-0.30	-0.21
ESP	-0.26	-0.24	-0.36	-0.26
USA	0.00	-0.01	-0.01	0.00
ROE	-0.13	-0.12	-0.16	-0.13
EFS	0.2	0.2	0.4	0.2
ROW	0.0	0.0	0.0	0.0

The next column is again the policy base case, but now with substitution parameters of the production function set at 50 percent of the original configuration. Thus fuel switching is less likely to occur, and also the possibility to switch from energy to non-energy is more difficult. The costs of abatement will rise, and so will the leakage rate. The G NI changes are thus also going to rise, which is also illustrated in the Substitution column in Table 13.

The last column is the 50 percent reduction of the supply elasticity of energy producers. This parameter indicates the response of demand changes on the supply price. The lower the supply elasticity, the more inelastic supply curve, the larger the response on the price of energy. Thus higher energy prices are needed to achieve the same emission target. And the non-Annex B region may profit even stronger from sharper price reductions of energy. The expectation is that leakage will be higher. But this clearly is not the case. The reason is the existence of hot-air permits and hardly binding KP at the global level. Total energy demand will only decline by 2 percent as a result from the KP. World energy prices thus will also likely hardly change.

5. Main findings and conclusions

1] The implementation of the KP with ET, and without the USA has little impact on countries on the macro-level. The large amount of hot-air and the decision of the USA not to ratify the KP leads to a drop in the demand of demand for permits, thus leading to a low price in the permit markets. Thus the impacts on GNI are limited, and even on the sectoral level the impacts are only moderate.

2] Within participating countries, energy-intensive sectors loose mostly, and energy-extensive sectors gain. Energy-intensive sectors in non-participating will benefit from the climate policy.

3] Within EU, countries with high abatement costs will loose compared to low-cost-countries. For example, the energy-intensive sector in the United Kingdom and France gain at the expense of similar sectors in the Netherlands and Spain.

4] However, like most AGE models, WorldScan does not take account of adjustment costs. Wage rigidities and sectoral adjustments can significantly increase the costs of climate policies in the short to medium term.

5] The growth of baseline emissions in the 1997-2010 period is important in assessing the impacts of the KP. The baseline emissions determine the amount of hot-air, and the reduction effort of participating countries. With respect to ET, it is assumed that Eastern Europe and the former Soviet Union maximize the revenues from permit exports by withholding hot-air from the market (75 percent of the total amount of hot-air)

6] ET lowers the costs of the implementation of the KP considerably. The USA's decision not to ratify the KP makes it even less expensive, but the other side of the coin is that the environment is worse off.

7] Especially the Netherlands and Spain within the EU have agreed to targets that are more stringent compared to the targets of the other EU countries. This is somewhat surprising, considering the fact that their abatement curve (marginal costs versus %emission reduction) is also higher than for other EU countries. High cost' countries such as the Netherlands and Spain are also the countries within the EU that will benefit the most from ET.

8] The carbon leakage rate can increase up to 20 percent (No ET, and without the USA). The USA will increase its' production of E-intensive goods by 1.6% (cumulated impacts in 2010) in the case of no ET, and no binding targets to the USA.

9] The existing taxes on energy are rather inefficient in terms of the climate change problem. Oil is being heavily taxed, whereas from the climate perspective coal should be more heavily taxed. If energy taxes are banned, and replaced by a carbon tax, then the impacts of the KP will be decrease.

10] Sensitivity analysis shows that lowering neither the substitution elasticities of the production function, nor the Armington trade elasticities or the supply elasticities of energy sectors has little additional impacts on countries compared to the central estimate of the costs of implementing the KP.

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