Competitiveness Effects of Trading Emissions and Fostering Technologies to Meet the EU Kyoto Targets: A Quantitative Economic Assessment

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Enterprise and Industry Directorate-General European Commission

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Contents

E	xecu	tive summaryii
1]	Background and motivation
2	(Competitiveness effects of the EU Emissions Trading Scheme9
	2.1	Modelling approach and prerequisites
	2.2	Policy scenarios
	2.3	Economic impacts of the EU Emissions Trading Scheme15
	2.4	Economic impacts of linking the EU ETS internationally
	2.5	Economic impacts of EU emissions regulation in 2020
	2.6	Conclusions
3	r	The potential for biofuels alongside the EU ETS
	3.1	Introduction
	3.2	The climate policy baseline
	3.3	Promoting the use of biofuels
	3.4	Conclusions
4	(General conclusions
5]	References
A	nnex	1: Competitiveness effects of the EU ETS
	Anr	nex 1a: Nontechnical description of the core PACE model
	Anr	nex 1b: Model regions and sectors
	Anr	nex 1c: Benchmark data sources
	Anr	nex 1d: Competitiveness indicators
	Anr	nex 1e: Quantitative simulation results
A	nnex	2: Empirical policy analysis – data and approach
A	nnex	3: The potential for biofuels alongside the EU ETS
	Anr	nex 3a: The WorldScan model62
	Anr	nex 3b: Details of convential biofuel implementation
	Anr	nex 3c: Sensitivity analysis with respect to land allocation

Executive summary

Under the Lisbon process, the European Union aims at becoming the most competitive and dynamic knowledge-driven economy in the world. At the same time, the EU pursues ambitious climate policies in order to fulfil its emissions reduction targets under the Kyoto Protocol. Two policy actions that have been proposed in order to achieve the environmental goals are a strengthening of the EU Emissions Trading Scheme (ETS) and accelerating the development of renewable energy sources such as biofuels. Reflecting the parallel EU priorities concerning the Lisbon strategy and international climate policy, this study addresses the competitiveness effects of trading emissions and fostering technologies in order to meet the EU's emissions reduction targets under the Kyoto Protocol. Moroever, we assess future EU climate policy strategies in 2020. In order to analyze these issues, we develop a comprehensive quantitative economic assessment framework.

Our analysis is based on the development and application of suitable methodologies: We apply two complementary economy-wide general equilibrium models featuring the EU ETS and alternative biofuels production technologies, respectively. Furthermore, we carry out an ex-post empirical policy analysis to detect the competitiveness effects of the EU ETS using firm-level data. As the first assessment of the EU ETS we integrate data on allowance allocation for the first trading period (2005 to 2007) from the EU Community Independent Transaction Log into the model-based approach. We analyse the effects of a further tightening of the national emission caps under the second trading period (2008 to 2012) as imposed by the European Commission, as well as linking the EU ETS emerging domestic ETS outside Europe. Finally, we assess future EU climate policy strategies in 2020.

Trading Emissions: Competitiveness effects of the EU ETS

Our quantitative assessment of the competitiveness effects of the EU ETS is based on the PACE model, a computable general equilibrium model of international trade and global energy use. Assessing the emissions-market and macroeconomic impacts of strengthening the EU trading scheme, we find that while under the current National Allocation Plans (NAP I) the CO₂ value within the EU ETS lies below one US\$ per ton of CO₂, the permit price is substantially increased under a more stringent NAP II emissions allocation in the year 2010 (please see Table 1 for all EU ETS results). The lower level of emissions allocation in the second phase of the trading scheme induces relative welfare gains for EU economies, as in this case a larger part of the national abatement efforts is undertaken by sectors covered by the EU ETS. These sectors exhibit relatively low-cost abatement options and benefit from larger efficiency gains through international emissions trading under NAP II. At the same time the non-covered industries have to be regulated by less stringent complementary domestic abatement policies, i.e. carbon taxes, in order to fulfil the national targets under the Kyoto Protocol. The access to project-based emissions reductions in developing countries via the Clean Development Mechanism (CDM) for companies covered by the EU ETS has no significant impact on central macroeconomic indicators and social welfare, as CDM credits may only flow into parts of the EU economies which already face low emissions constraints. However, government CDM as facilitated under the Kyoto Protocol may substantially decrease the permit price and the environmental-regulation induced macroeconomic burden for European economies, as in this case the entire economy is granted access to low-cost abatement options in developing countries.

Regarding the economy-wide competitiveness effects of the emissions regulation under the EU ETS, we find that the terms of trade of EU-15 Member States are decreased by 1.5% under NAP I and 1.2% under NAP II. While for the new Member States these negative effects are much less pronounced under NAP I, they are comparable to those of the old Member States under NAP II. In general, the losses in economy-wide competitiveness for the EU can be largely neutralized by means of government CDM access for the European economies. In order to decompose the national competitiveness effects on the sectoral level, we assess three explicit indicators: Revealed Comparative Advantage (RCA), Relative World Trade Shares (RWS) and Relative Trade Balance (RTB). Our simulation results with respect to the RCA indicator show that the environmental regulation under NAP I induces large competitiveness gains for the covered EU ETS sectors vis-à-vis the remaining (non-covered) industries of EU economies who face losses in competitiveness: Given a relatively high allowance allocation, it is the non-covered sectors that - in the absence of the CDM - account for the major emissions reductions and economic burden. A stricter allowance allocation under NAP II increases the burden on ETS sectors, thereby eliminating the competitiveness gains of the covered sectors and reducing the competitiveness losses of the non-covered sectors. Regarding the RWS indicator, we find that decreasing the allocation may turn a low competitiveness gain for the covered EU ETS sectors vis-à-vis comparable sectors outside Europe under NAP I into a competitiveness loss under NAP II. While CDM access for covered industries leaves these results unchanged, government CDM can largely balance these opposed effects of covered and non-covered EU industries, compensating the latter by importing low-cost emissions abatement from developing countries. In this case, all sectoral competitiveness impacts are relatively low.

In order to complement the model-based analysis of EU emissions trading, we assess the competitiveness implications of the European ETS with an empirical policy analysis. By means of a statistical ex-post assessment for selected European companies covered by the EU ETS as well as a statistical and econometric case study for a large sample of German ETS firms, we assess the stringency of environmental regulation of the EU trading scheme as well as the employment and competitiveness impacts of EU ETS emissions allocation in the year 2005. The European dataset implies that the total EU emissions trading scheme was generally long in 2005. The long position is very large in Lithuania, while other countries were short in emissions allowances. Our empirical results suggest that, on the one hand, sectoral affiliation of European firms had an important impact on their relative allocation. In this respect, the energy firms of our EU sample exhibit an amount of EU emissions allowances that exceed their actual emissions level in 2005, while in particular electricity companies were in a short position due to stricter environmental regulation. Furthermore, we find a positive relationship between financial firm performance (as measured by cash flows in the year 2004) and their relative allowance allocation. Our empirical results thus suggest that for regulated companies the competitiveness impacts of the emissions allocation within the first phase of the EU ETS were not pronounced. This empirical conclusion is consistent with the general results of our model-based assessment.

Assessing a future international linkage of the EU ETS, we find that linking to emerging schemes in Japan, Canada and Russia in each case decreases the allowance price in 2010. It shows that while the overall economic effects of linking the EU ETS internationally are considerably small, a permit-price decreasing linkage to emerging domestic ETS in Japan and Canada results in an unchanged welfare situation for the EU-27 (as compared to a purely EU

scheme). Due to a lower allowance price, permit-importing EU-15 Member States slightly benefit in terms of lower welfare losses and the permit-exporting EU-12 aggregate faces lower absolute welfare gains. A further linkage to Russia leaves the welfare situation of the EU-27 and EU-15 Member States unchanged, whereas the welfare gain of the EU-12 aggregate shrinks further in this policy setting. Accounting for government access to low-cost reduction options in developing countries via the CDM decreases the level of welfare losses, while the qualitative effects across scenarios reflect the allowance-price implications discussed above.

We find that linking the EU ETS internationally does not significantly affect the economywide competitiveness effects for EU Member States. However, the covered European ETS sectors may face slight decreases in their competitiveness gains through linking to emerging schemes in Japan and Canada – both vis-à-vis the remaining industries of EU economies (RCA) and comparable sectors in non-EU regions (RWS). For the non-covered sectors we observe the opposite (and less pronounced) effects. Further regional flexibility in emissions trading – due to a permit-price decreasing linkage to Russia – may however alleviate the losses of the covered sectors. Also under a linking strategy the CDM serves as an efficiency mechanism that is not only able to reduce economy-wide comparative losses, but also balance heterogeneous sectoral competitiveness effects within EU economies, especially for the old Member States.

As a future policy scenario, we analyse the EU climate policy strategy proposed by the European Council in March 2007 to achieve a unilateral 20% reduction of greenhouse gas emissions by 2020 versus 1990 levels. In this context, we assume a stricter allowance allocation in a potential third trading period (NAP III) of the EU ETS, which we approximate by a 20% decrease of relative allowance allocation compared to NAP II. Table 1 shows that the stricter reduction targets and tighter allowance allocation in 2020 result in a substantially higher allowance price and induce larger levels of production and aggregate welfare losses than under NAP II emissions regulation and the national Kyoto targets in 2010. However, it shows that facilitating government CDM under a (post) Kyoto Protocol leads to comparable price and macroeconomic effects in 2010 and 2020. The extensive economic flexibility in emissions abatement by means of CDM access for all sectors of the economy thus enables EU Member States to implement far stricter climate policy measures at comparable macroeconomic adjustment costs. Our simulated competitiveness implications of EU climate policy in 2020 confirm these findings at the economy-wide level. Moreover, it shows that the stricter climate policy in 2020 induces competitiveness gains for the covered EU ETS sectors vis-à-vis the remaining industries of EU economies, while it may generate losses vis-à-vis comparable sectors outside Europe.

NA	P I	NA) CDM	P I_ I_dir	NA) CDM	P I_ 1_all	NA	P II	NAI CDN	P II_ 1_all	NAI	P III	NAP CDM	[•] III_ 1_all
		20	05				20	10			20	20	
				CO ₂ value	e in DIR s	ectors (in	constant 3	\$US per to	on of CO ₂)				
	0.20		0.21		0.00		9.53		4.19		49.64		5.26
					Produc	tion impa	ct (in % vs	. BAU)					
	-0.86		-0.86		-0.04		-0.54		-0.05		-2.06		-0.07
					Welfa	ire impact	(in % of .	HEV)					
	-0.37		-0.37		-0.02		-0.10		-0.02		-1.34		-0.05
					Terms-of	Trade im	pact (in %	vs. BAU)					
	-1.40		-1.40		-0.10		-1.20		-0.10		-2.80		-0.10
				Revealed	d Compar	ative Adva	ntage – R	CA (in %	vs BAU)				
DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR
3.40	-0.39	3.42	-0.40	0.22	-0.03	0.84	-0.10	-0.38	0.05	1.84	-0.22	-0.31	0.04
				Relati	ive World	Trade Sha	res – RWS	S (in % vs	BAU)				
DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR
0.24	0.01	0.23	0.01	-0.06	0.00	-0.50	0.10	-0.29	0.03	-0.95	0.23	-0.39	0.03
				Rel	lative Trad	le Balance	e – RTB (i	in % vs BA	1 <i>U</i>)				
DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR
92.62	-59.51	93.63	-59.55	7.57	-2.87	-13.09	-35.57	-18.32	-1.43	-28.69	-77.58	-10.74	-0.73

Table 1: Competitiveness effects of the EU ETS: Central results by policy scenario for the aggregate EU-27 region and respective sectors

Note: In the table, scenario NAP I_CDM_dir represents NAP I allowance allocation combined with CDM access only for sectors covered by the EU ETS directive, while NAP I_CDM_all represents government CDM under the Kyoto Protocol enabling CDM access for all sectors of the economy. Moreover, those sectors covered by the EU ETS directive are denoted DIR sectors, while the remaining industries are denoted NDIR sectors. The simulation results presented in the table are measured relative to the benchmark situation – termed business-as-usual (BAU) – where no emissions regulation is imposed.

Fostering technologies: The potential for biofuels alongside the EU ETS

Parallel to strengthening the EU ETS, the comprehensive EU climate policy strategy aims at ensuring that 20% of total energy use originates from renewable sources. One important measure for this objective is to increase the share of biofuels up to at least 10% of total fuel use in transportation. We therefore assess the impacts of raising the share of conventional (first generation) biofuels to at least 10% within the policy environment of the EU ETS, making use of simulation outcomes from the global general equilibrium model WorldScan.

Within this specific policy environment our analysis shows that the emissions price of the EU ETS is hardly affected when various targets for the share of biofuels in transport fuels are met. Hence, promoting biofuel use in road transport is a form of enhancing the use of renewables that will not - by lowering the emissions price - hinder the commercial advent of cleaner technologies in EU ETS sectors. Increasing biofuel shares in transport fuel use does have a mitigating effect on the policy efforts needed to curb emissions in the other sectors. This is reflected by a drop in the carbon taxes at the Member State level. Hence, the negative impacts of these distortionary taxes on economic welfare will decline. The introduction of biofuels may, depending on the biofuel excise regime and the impact on the carbon tax, raise the user price of transport fuels. This affects economic welfare negatively. On balance the net effect on economic welfare turns out to be very small, being either slightly positive or negative. When carbon taxes are very small the benefits of reducing them fall short of the extra burden of raising biofuel usage. Hence, overall economic welfare is declining in the new Member States. When biofuel targets are increased above 10% the negative impacts on welfare tend to dominate: the additional benefits of reducing distortionary carbon taxes tend to fall short of the extra costs of raising biofuel usage. The impacts on food prices of conventional biofuel promotion up to the 10% target turn out to be negligible. Here one should bear in mind however, that the WorldScan model does not focus on the peculiarities of agricultural production and food production. Meeting the 10% target would require an increase of the biofuel feedstock share in current global arable acreage from 1% to approximately 3%. Hence, large impacts on food prices are hardly to be expected. Full liberalisation of biofuel trade will make biofuels cheaper (enhancing welfare) but leave carbon taxes in non-ETS sectors at a higher level (reducing welfare). On balance economic welfare does increase when biofuels are imported rather than produced domestically, but the change is rather small. For ethanol-exporting Brazil the welfare increase will be most noticeable.

These results are quantified with various counterfactual WorldScan simulations and are summarized in Table 2 with some selected indicators in percentage deviations from the policy baseline: the EU ETS emissions price, the carbon taxes and arable land rents averaged at EU-level, and economic welfare. In the summary table three different ways of taxing biofuels are distinguished: no excise, a competitive biofuel excise equating the user costs of biofuels and fossil fuels in transportation, and a full excise equal to existing transport fuel taxes. Moreover three targets for the share of biofuel use in transport fuel use are represented: 10%, 15% and 20%. For each of the scenarios either existing biofuel import tariffs are maintained (no trade liberalization) or put to zero (full trade liberalization). Finally, we report scenarios with a fuel tax that achieves the same emission reduction within the transport sector as would be accomplished with a 10% biofuel target. Table 2 illustrates (at the level of EU-27) our main findings: biofuel promotion does hardly affect the emissions price, has large impacts on carbon taxes, raises arable land rents to some extent and has limited impacts on economic welfare. The latter are raised almost negligibly by the liberalization of biofuel trade.

Achieving transport specific emission targets by a fuel tax instead of biofuel targets drives average carbon related taxes up and is detrimental to economic welfare.

	Emissions price	Carbon tax (EU average)	Arable land rents (EU average)	Economic welfare
	No trade	liberalisation		
No excise, target 10%	0.2	-10.9	2.2	0.03
Competitive excise, target 10%	0.2	-14.7	2.3	0.02
Full excise, target 10%	0.1	-21.6	2.2	-0.00
Full excise, target 15%	0.2	-31.8	3.4	-0.01
Full excise, target 20%	0.2	-41.2	4.6	-0.03
Raising fossil fuel excises	-0.3	10.1	0.3	-0.06
	Biofuel tra	ude liberalised		
No excise, target 10%	0.2	-10.6	1.5	0.03
Competitive excise, target 10%	0.2	-14.8	1.6	0.02
Full excise, target 10%	0.2	-20.8	1.6	-0.00
Full excise, target 15%	0.2	-30.8	2.4	-0.01
Full excise, target 20%	0.3	-40.0	3.3	-0.02
Raising fossil fuel excises	-0.3	9.7	0.3	-0.06

Table 2: Biofuel scenarios – Selected indicators in % deviation from baseline in 2020

General insights

Our analyses suggest that the overall competitiveness effects of strengthening the EU Emissions Trading Scheme and accelerating the development of sustainable biofuels are limited. Moreover, we find that the interactions between these two environmental policies are not pronounced. A central insight of our analysis is that the scope of economic impacts and competitiveness effects crucially depends on the design of the respective policy instrument – such as the target share of biofuels in total transportation fuel use or the stringency of allowance allocation within the EU ETS. Moreover, the national and EU-wide economic impacts are determined by complementary environmental policy measures applying to the same or other segments of European economies, such as unilateral energy taxation of EU Member States. Our methodology-based analysis suggests that while assessing the national competitiveness effects of environmental regulation is of great importance, the respective (heterogeneous) sectoral impacts may provide extensive insights as they are able to decompose the economy-wide effects.

1 Background and motivation

In March 2000, the European Council agreed at the Lisbon summit to make the European Union (EU) the most competitive and dynamic knowledge-driven economy in the world by the year 2010. At the same time, the EU pursues ambitious climate policies in order to fulfil its emissions reduction targets under the Kyoto Protocol (UNFCCC, 1997) and limit global climate change to two degrees Celsius in the long run. Two policy actions that could help achieve these goals are a strengthening of the EU Emissions Trading Scheme (ETS) and a reduction of transport fuel emissions by accelerating the development of sustainable biofuels (European Commission, 2007). Reflecting the parallel EU priorities concerning the Lisbon strategy and international climate policy, this study addresses the competitiveness effects of trading emissions and fostering technologies in order to meet the EU's emissions reduction targets under the Kyoto Protocol. Moroever, we assess future EU climate policy strategies in 2020. In order to analyze these issues, we develop a comprehensive quantitative economic assessment framework.

Aiming at a cost-efficient achievement of the EU emissions reduction commitments under the Kyoto Protocol, the European Commission launched the EU Emissions Trading System (ETS) which is operating since January 2005 (European Commission, 2003). The envisaged trading scheme consists of several temporal stages: a first phase from 2005 until 2007, a second one from 2008 until 2012, coinciding with the first Kyoto commitment period, and subsequent five-year-periods covering potential post-2012 commitment periods. In its initial stage, the trading system only applies to energy-intensive (downstream) sectors that include all major CO₂ producing sites such as power, heat and steam generation, oil refineries, coke ovens in iron and steel production, mineral industries (e.g., glass, cement), as well as pulp and paper plants. Besides emissions trading the amending directive linking the European trading scheme with the Kyoto Protocol's project-based mechanisms (European Commission, 2004) enables European ETS companies to generate emissions reductions by means of the Clean Development Mechanism (CDM) and Joint Implementation (JI). While the former facilitates project-based investments in emissions reductions in developing countries, the latter enables project-based abatement in other Annex B regions. Imports of CDM and JI credits may serve as substitutes for ETS allowances.

As a policy option to strengthen the EU ETS the Commission proposes linking the EU trading system to emerging compatible schemes outside Europe (European Commission, 2007). This strategic issue of EU climate policy may become relevant in the near future. At present, non-European countries like Canada or Japan are contemplating the set up of domestic ETS with the intention of linking up to the European scheme – which would enable companies outside the EU to trade emissions with European firms. Employing explicit indicators, in this study we therefore aim at a first assessment of the competitiveness effects of trading emissions at the European level and beyond in order to meet the European Union's emissions reduction targets under the Kyoto Protocol. Moreover, the EU recently committed itself to "achieve at least a 20% reduction of greenhouse gas emissions by 2020 compared to 1990" (Council of the European Union (2007). In order to fulfil these stricter emissions reduction targets, it can be expected that the EU ETS – as the central instrument of current EU climate policy – will be designed more stringently, i.e. featuring a stricter allowance allocation.

On its March 2007 summit the European Council further agreed to embark on an ambitious energy policy that establishes several targets for the year 2020. Amongst others this policy

aims to reduce greenhouse gas emissions by at least 20% compared to 1990 and to ensure that 20% of total energy use comes from renewable sources, partly by increasing the share of biofuels up to at least 10% of total fuel use in transportation. In meeting the 20% reduction ceiling for greenhouse gas emissions the EU ETS will play a central role as the 'pricing engine' for CO_2 emissions. The higher the emissions price will be the sooner technological emissions reduction options will tend to be commercially adopted. The 20% target for renewable energy may undermine this role of the EU ETS. The fostering – by costly subsidization or prescription – of renewables has the danger to depress the emissions price and to prevent (or postpone) the commercial advent of cleaner technologies. However, the promotion of the use of biofuels in road transport will not directly affect the functioning of the EU ETS as long as the scheme will not cover fuel use for transportation itself. In this study we assess the impacts of raising the share of conventional biofuels to at least 10% within this specific policy environment, making use of simulation outcomes from the global general equilibrium model WorldScan.

This report is structured as follows. Section 2 presents a model-based and empirical analysis of the competitiveness effects of trading emissions under the EU ETS. Section 3 analyses the efficiency implications of fostering technologies and exploiting the biofuel potential. In Section 4, we conclude.

2 <u>Competitiveness effects of the EU Emissions Trading Scheme</u>

In 2005, the European Union Greenhouse Gas Emissions Trading Scheme (EU ETS) was launched. The scheme represents a cornerstone of the efforts by EU Member States to fulfil the emissions reduction targets under the Kyoto Protocol, which requires European countries to reduce their greenhouse gas emissions on average by eight per cent until 2012 compared to 1990 emissions levels. Subject to the EU ETS are European producers in four sectors, namely energy (e.g. electric power, direct emissions from oil refineries), production and processing of ferrous metals, minerals (e.g. cement, glass), as well as pulp and paper. Furthermore, the amending directive linking the EU ETS with the Kyoto Protocol's project-based mechanisms enables EU companies to generate emissions reductions by means of CDM or JI. As a strategic issue of EU climate policy, linkage of the EU ETS to emerging schemes outside Europe may become relevant in the near future. At present, non-European countries like Canada or Japan are contemplating the set up of domestic ETS with the intention of linking up to the European scheme - which would enable companies outside the EU to trade emissions with European firms. In March 2007 the EU committed itself to "achieve at least a 20% reduction of greenhouse gas emissions by 2020 compared to 1990" (Council of the European Union (2007). In order to fulfil these stricter emissions reduction targets, it can be expected that the EU ETS – as the central instrument of current EU climate policy – will be designed more stringently, i.e. featuring a stricter allowance allocation.

Since its implementation, the EU ETS has been accompanied by discussions on potential losses in competitiveness in international markets of companies that are covered by the EU ETS legislation. Against this background, this section evaluates the competitiveness effects of the EU ETS at the sectoral and economy-wide level employing a computable general equilibrium modelling framework. The model covers the central energy inputs for production

as well as recent projections for regional CO_2 emissions, features a detailed specification of international emissions trading and accounts for complementary environmental regulation through domestic carbon taxation.

2.1 <u>Modelling approach and prerequisites</u>

We conduct a static counterfactual scenario analysis, which is suitable to provide insights into the relative impacts of alternative designs of the EU ETS on macroeconomic and competitiveness indicators. For our quantitative analysis of competitiveness implications of the EU ETS, we employ the *PACE* model (*Policy Assessment based on Computable Equilibrium*; see Böhringer and Vogt, 2003), a large-scale computable general equilibrium model of international trade and global energy use. The core model framework is described in detail in Annex 1a.¹ The main activities aiming at the adaptation of the core PACE model included

- § the regional disaggregation of the PACE model to cover EU-27 Member States as well as central non-EU regions (see Annex 1b for all model regions and sectors);
- § the explicit modelling of export and import flows at the sectoral and economywide level; and
- § the implementation of sectoral and economy-wide competitiveness indicators.

Besides our benchmark data sources (which are presented in Annex 1c), the set of relevant inputs for our numerical analysis includes allocation of emissions allowances, CDM transaction costs and investment risk indicators. In order to incorporate the emissions allocation of the first trading period (2005-2007) into our model framework we employ empirical data from the Community Independent Transaction Log (European Commission, 2007a) containing information on allowances allocated in accordance with the final National Allocation Plans, as well as verified emissions for about 12,000 installations of EU Member States. Regional "allocation factors" are then calculated as the ratio between allocated permits and verified emissions and implemented into our model framework - thus implying the required emissions reductions of the covered ETS sectors versus business-as-usual levels. To our knowledge, this incorporation renders the first model-based analysis of the EU ETS based on empirical emissions allocation. In order to derive NAP II allocation factors we rely on allocation data for the second trading period (2008 to 2012) as well as emissions projections for 2010. Due to lacking information for Finland, Sweden, Bulgaria and Romania we assume a neutral allocation factor equal to one. Our data shows that for most EU regions the (overall heterogeneous) NAP I allocation factors are larger than one - especially for new Member States - implying that the respective allocated allowances exceed the business-as-usual emissions levels. In contrast, the far lower NAP II allocation factors reflect a substantially decreased allowance allocation in the second trading period.

¹ An earlier version of this model was employed within the research project "Technology Transfer and Investment Risk in International Emissions Trading" (TETRIS) funded by the European Commission under the 6th Framework Programme.

The potential economic benefits of CDM access for industrialized countries in order to achieve their Kyoto targets may be substantially reduced by *transaction costs* associated with abatement projects in developing countries. Transaction costs in emissions trading may arise from a variety of activities associated with market exchange, e.g. search and information acquisition, bargaining over prices, as well as negotiation, monitoring and enforcement of contracts. In our quantitative model framework, constant transaction costs are represented by an absolute premium on marginal abatement costs of CDM host countries, amounting to 1 US\$/tCO₂.²

As a second barrier to CDM investments we account for *investment risk* involved in financing carbon-abatement projects. Following Böhringer and Löschel (2002) host-country-specific investment risk for CDM projects, e.g. resulting from country and project risks, is derived by region-specific bond-yield spreads between long-term government bonds of the respective developing country and the United States (as a risk-free reference region). It is assumed that investors are risk-neutral and discount emissions reduction credits generated by CDM projects with the mean risk value of the respective host country.

2.2 Policy scenarios

In order to assess the competitiveness effects of trading emissions to meet the European Union's emissions reduction targets under the Kyoto Protocol, we implement alternative policy scenarios into the model framework. These scenarios reflect the sectoral coverage of the EU ETS as well as National Allocation Plans of EU Member States. The policy scenarios presented in Table 3 are compared to the benchmark situation – usually termed business-as-usual (BAU) – where no emissions regulation is imposed.

First we introduce the *Notrade* scenario, which represents a cost-efficient domestic emissions regulation (in order to meet the national reduction targets under the Kyoto Protocol) by means of a uniform carbon tax on the entire economy, i.e. reflecting the absence of any flexible mechanism of the Protocol. In the following we denote those sectors covered by the EU ETS directive as *DIR* sectors, while the sectors not covered by the directive are denoted *NDIR* sectors.

² The magnitude of transaction costs is in line with recent estimates (see Michaelowa and Jotzo, 2005).

Policy scenario	Reference year	EU CO ₂ r	regulation	CDM	access
		DIR	NDIR	DIR	NDIR
Notrade		Tax		No	No
NAP I	2005	Pormits		No	No
NAP I_CDM_dir	2005	(NAP I		Yes	No
NAP I_CDM_all		allocation)		Yes	Yes
NAP II				No	No
NAP II_CDM_dir		Permits	T	Yes	No
NAP II_CDM_all	2010	(NAP II	Tax	Yes	Yes
Linking		allocation)		No	No
Linking_CDM				Yes	Yes
NAP III		Parmits		No	No
NAP III_CDM_dir	2020	(NAP III		Yes	No
NAP III_CDM_all		allocation)		Yes	Yes

Table 3: Policy scenarios for 2005, 2010 and 2020

Note: For policy scenarios involving *Notrade* and *NAP I* (reference year 2005) we assess EU-25 Member States, for scenarios involving *NAP II* and *Linking* (reference year 2010) as well as *NAP III* (reference year 2020) we assess EU-27 Member States. Moreover, the *Linking* scenarios will be further specified with respect to regional linking constellations in Table 4.

EU Emissions Trading and the CDM

Accounting for the current EU emissions regulation, scenarios *NAP I* and *NAP II* stand for the first (2005-2007) and second trading period (2008-2012) allocation of the EU ETS. We apply 2005 and 2010 as the respective reference years – 2005 as the reference year of the empirical NAP I allocation data and 2010 as the central year of the second trading period. While the *DIR* sectors are regulated by allocating tradable emissions permits, in the absence of the CDM the remaining *NDIR* sectors have to be regulated via domestic abatement measures (here: unilateral carbon taxation) in order to meet the national emissions reduction targets under the Kyoto Protocol.

Furthermore, we provide a representation of the CDM that distinguishes private and public CDM investments. Firstly, the amending directive linking the EU ETS with the Kyoto Protocol's project-based mechanisms enables European *companies* (here: the *DIR* sectors) to generate emissions reductions by means of CDM or JI and using the respective credits as a substitute for EU ETS allowances. We capture this regulation through scenarios *NAPI_CDM_dir* and *NAPII_CDM_dir*, respectively. Secondly, the Kyoto Protocol enables

Annex B *governments* to undertake CDM and JI in order to fulfil their national commitments under the agreement, implying CDM access for all (*DIR* and *NDIR*) sectors.³ This regulation is captured through scenarios *NAPI_CDM_all* and *NAPII_CDM_all*, respectively. As described in the previous section, our CDM representation considers transaction costs and investment risk as central barriers to CDM investments.

Linking the EU ETS

In the future, carbon trading may not be limited to Europe. The EU ETS directive proposes that "agreements should be concluded with third countries listed in Annex B to the Kyoto Protocol which have ratified the Protocol to provide for the mutual recognition of allowances between the Community scheme and other greenhouse gas emissions trading schemes" (European Commission, 2003). At the same time, non-EU countries are indeed contemplating the set up of domestic ETS with the intention of linking up to the European scheme. This would enable European firms to trade emissions with companies outside the EU.

Canada is promoting the Large Final Emitter System to cover energy-intensive companies which account for almost 50 percent of total Canadian greenhouse gas emissions (CEPA Environmental Registry, 2005). Japan has started the Pilot Project of Domestic Emissions Trading Scheme on a voluntary basis, with about 30 private companies participating in the program (Japanese Ministry of the Environment, 2004). Russia could have incentives to develop a domestic emissions trading system in order to be linked to the European scheme and exploit a larger market for the sale of excess emissions permits – so-called "Hot Air" – due to lower business-as-usual (BAU) emissions than the committed target emissions. Hence, there are strong signs for future ETS to be established in non-EU countries and potentially linked with the European scheme by 2020.⁴

Table 4 presents the set of regional scenarios of our analysis, showing the corresponding constellations of linking the EU ETS internationally. As a reference case, scenario EU represents the current EU ETS. In this case, all non-EU linking candidates fulfill their Kyoto commitment by imposing a cost-efficient carbon tax on their economies. Scenario EU^+ analyses the potential linkage of the current EU ETS to emerging ETS in Japan and Canada, two countries that ratified the Kyoto Protocol. Scenario EU^{++} assumes that also the Kyoto-ratifier Russia is joining the linked ETS. Furthermore, Table 4 presents the set of CDM host countries of our analysis.

³ Note that in our model framework JI corresponds to international emissions trading, as it exclusively involves Annex B parties.

⁴ For an economic impact assessment of linking the EU ETS to Australia and the United States in the context of a Post-Kyoto agreement see Anger (2006).

Regional scenario	Regions participating in emissions trading	CDM regions
EU	EU-27	
EU^+	EU-27 Japan Canada	China India Rest of East South Asia
EU^{++}	EU-27 Japan Canada <i>Russian Federation</i>	Brazil Central + South America South Africa

Table 4: Regional scenarios of linking the EU ETS and CDM host countries

For the case of a future linkage between the EU ETS and emerging non-EU schemes (the three linking scenarios) we apply the reference year 2010 and assume the NAP II allowance allocation for EU-27 Member States. Regarding the allocation for the non-EU regions Japan and Canada in 2010, we start from a neutral current allocation factor equal to one which is then downscaled along with EU regions by 6%, yielding an allocation factor of 0.94 in 2010. For Russia we assume an allocation factor equal to one in 2010, implying no allocation of excess permits ("Hot Air") to installations covered by a Russian ETS.⁵ Regarding national emissions constraints, unlike in our scenarios of EU emissions trading, here we assume the respective emissions reduction targets for all signatory countries under the Kyoto Protocol. In this setting, for transparency the CDM is covered as *government* CDM only, represented by the three scenarios $EU_CDM_all, EU^+_CDM_all, EU^{++}_CDM_all$.⁶

EU Emissions Regulation in 2020

In March 2007, the EU committed itself to "achieve at least a 20% reduction of greenhouse gas emissions by 2020 compared to 1990" (Council of the European Union (2007). In order to fulfil these stricter emissions reduction targets, it can be expected that the EU ETS – as the central instrument of current EU climate policy – will be designed more stringently, i.e. featuring a stricter allowance allocation to the covered sectors. In our set of scenarios *NAP III* we therefore assume a *unilateral* future EU climate policy target of 20% emissions reduction versus 1990 levels and a stricter relative allowance allocation in a potential third trading period which is reflected by a 20% decrease of *NAP II* allocation factors in 2020. All other scenario characteristics (such as the sectoral scope of the EU ETS, carbon taxation of *NDIR* sectors and CDM specifications) are comparable with scenario *NAP II*.

⁵ The reason is that a grandfathered allowance allocation of "Hot Air" would imply an indirect subsidy for Russian installations, as the allocated permits could be exported to other ETS regions. It is not unambiguous if such an ETS design may prevail or even be linked to an EU scheme.

⁶ Note again that all simulation results of the economic effects of our policy scenarios are measured against the benchmark (BAU) situation, where no policy changes apply.

2.3 <u>Economic impacts of the EU Emissions Trading Scheme</u>

This section presents the simulation results of our model-based policy assessment regarding the macroeconomic and competitiveness effects of the emissions regulation under the EU ETS. A detailed description of the employed competitiveness indicators is given in Annex 1d. The whole set of corresponding quantitative simulation results is presented in Table 16 to Table 18 in Annex 1e.

Emissions-market and macroeconomic effects

As a prerequisite for our assessment of competitiveness effects of EU emissions trading, we start our analysis with the corresponding effects on the market for emissions permits and the macro economy. We first focus on the European market for emissions allowances. Figure 1 shows the EU ETS permit price resulting from our alternative policy scenarios. We find that the CO_2 value results in less than 0.5 US\$ per ton CO_2 of for all NAP I scenarios: Due to a high allocation of emissions allowance to covered installations in the first trading period in total, demand and price for emissions permits is very low. Our empirical result corresponds to the actual price development for allowances at the European Energy Exchange (EEX) during the period April to May 2007, when this study was conducted (EEX, 2007).

Considering CDM access for sectors covered by the EU ETS (DIR sectors) only by means of the EU linking directive (scenario NAP I_CDM_dir) does not change the permit price as due to the already low CO₂ value of NAP I there is no additional demand for CDM credits – the permit price within the EU ETS is even lower than the CDM transaction costs of one US\$ per ton of CO₂. If we allow for government CDM under the Kyoto Protocol (scenario NAP I CDM all), implying CDM access for all sectors of EU economies, the ETS permit price falls to zero. This result can be explained from a terms-of-trade perspective: Compared to the case of NAP I_CDM_dir in which the non-covered NDIR sectors had to be regulated by domestic carbon taxation, marginal abatement costs for NDIR sectors are now substantially lower due to their access to low-cost emissions abatement options in developing countries through government CDM. As a consequence, the demand of these EU sectors for emissionproducing fossil fuels is higher than under NAP I_CDM_dir, and so is the associated international price for fossil fuels. In turn, due to the higher international price, the fossil-fuel demand of European DIR sectors will be lower under NAP I_CDM_all - implying a lower demand for emissions permits and a lower corresponding EU permit price. The formerly small excess demand of DIR sectors for emissions permits under NAP I CDM dir thus vanishes in the case of NAP I_CDM_all, yielding a permit price of zero. Since the CO₂ value is lower than the CDM transaction costs, no CDM projects are undertaken by DIR sectors in this policy setting.



Figure 1: CO₂ permit price within EU ETS by scenario

Under the *NAP II* trading scenario we observe a permit price of 9.53 US\$ per ton CO_2 (Figure 1). This price increase in the second trading period is due to a much stricter allowance allocation and the corresponding increase (decrease) in demand (supply) for emissions permits. Allowing for CDM access for *DIR* sectors causes the EU allowance price to fall to 3.70 US\$, implying that less costly emissions reduction projects are undertaken via the CDM by *DIR* sectors under this policy scenario. If we account for government CDM under the Kyoto Protocol, enabling CDM access to the entire economy, the CO_2 value rises slightly to 4.19 US\$ due to the additional demand for CDM credits originating from the non-covered *NDIR* sectors.

From a general equilibrium perspective, economic effects of climate change policies surpass the emissions market. First, the domestic emissions market and the goods market are interlinked. For potential emissions permit importers, carbon abatement policies may decrease production levels by the associated decreased energy use due to increased domestic abatement or a policy-induced increased permit price. Second, carbon abatement in large open economies may not only cause adjustment of domestic production and consumption patterns, but also influence international prices via changes in exports and imports. These *terms-of trade*-changes, i.e. changes in the ratio between export and import prices, imply a secondary benefit or burden that can significantly alter the economic implications of the domestic emission policy. The most important terms-of-trade effects are changes on international fuel markets: The cutback in global demand for fossil fuels due to carbon emission constraints implies a significant drop of the respective prices, providing economic gains to fossil fuel importers and losses to fossil fuel exporters. In order to analyze these general equilibrium impacts from climate policy in greater detail, we assess aggregate macroeconomic indicators such as production and social welfare.⁷

⁷ Note that we pursue a cost-effectiveness analysis that quantifies adjustment costs of environmental regulation as compared to an unconstrained business-as-usual situation. The deliberate neglect of economic benefits from controlling global warming implies that the macroeconomic effects resulting from the imposition of emissions constraints on the respective economies will necessarily be negative.

In the following, we concentrate our discussion about macroeconomic impacts on social welfare impacts. Social welfare – conceptually measuring aggregate utility – serves as an overarching economic indicator that quantifies the overall economic impacts resulting from policy interferences. Welfare changes are expressed by the Hicksian Equivalent Variation (HEV), which measures the income change that is equivalent to the induced change in utility, i.e. expresses welfare change in terms of income change. The welfare indicator thereby summarizes both economic impacts on the emissions market as well as macroeconomic impacts. Figure 2 presents welfare impacts for aggregate EU regions across policy scenarios.



Figure 2: Welfare impacts for EU aggregates by scenario

According to Figure 2, the overall level of EU welfare losses from environmental regulation for EU aggregates is relatively low across all scenarios (below 0.4%). Comparing the alternative policy settings, we find that welfare losses under *NAP I* regulation substantially exceed those under *NOTRADE*. On pure efficiency grounds the current ETS design is economically inferior to a fictitious cost-efficient, economy-wide carbon tax. The central reason is that – in the absence of the CDM – the high level of allowance allocation to the covered *DIR* sectors within the first trading period imposes high reduction efforts for the non-covered *NDIR* sectors by means of complementary domestic carbon taxation in order to achieve the national emissions reduction targets under the Kyoto Protocol. Considering the relatively costly abatement options in the non-covered sectors (such as households or transport), these sectors face a major share of the economic burden resulting from the national reduction commitment. While CDM access for *DIR* sectors leaves welfare impacts unchanged, government CDM induces a substantial decrease in welfare losses due to the access of all sectors to low-cost abatement options in developing countries (and the associated alleviation of the formerly burdened non-covered sectors).

Regarding the design of the EU ETS in the second trading period, we find that a stricter allowance allocation under *NAP II* lowers welfare losses by a considerable amount as compared to *NAP I*. In this case a larger part of the national abatement efforts is undertaken by *DIR* sectors, which have lower-cost abatement options and additionally benefit from

efficiency gains through international emissions-trading. The corresponding relative welfare changes of the CDM scenarios are comparable to those under *NAP I*.

Effects on international competitiveness

In the following, we focus on the competitiveness effects of the EUETS at the national and sectoral level. Figure 3 reports relative changes in the national terms of trade for aggregate EU regions across alternative policy scenarios.



Figure 3: Terms-of-Trade impacts for EU aggregates by scenario

Figure 3 shows that – consistent with our findings on welfare effects of the EU ETS – the economy-wide competitiveness of EU economies is deteriorated through the sectoral coverage and the relatively high allowance allocation of the EU ETS as compared to efficient domestic action. Moreover, compared to the BAU situation the terms of trade of EU-15 Member States are decreased by 1.5% under *NAP I* and 1.2% under *NAP II*. While for the new EU-10 Member States these negative effects are much less pronounced under *NAP I*, for the EU-12 they are comparable to those of the old Member States under *NAP II*. In general, the losses in economy-wide competitiveness for the EU can be largely neutralized by means of government CDM imports. Corresponding to our findings regarding social welfare, only the access of all sectors to low-cost abatement options in developing countries may substantially reduce the costs of compliance with the Kyoto targets, thereby alleviating the negative competitiveness for EU economies.

In order to decompose the national competitiveness effect at the sectoral level, we assess wellknown indicators such as Revealed Comparative Advantage (RCA), Relative World Trade Shares (RWS) and Relative Trade Balance (RTB). For an appropriate interpretation of the results on sectoral competitiveness, it is important to note that alternative indicators measure competitiveness implications using a different reference point. The RCA indicator compares the performance of a *DIR* (*NDIR*) sector with an average performance of all sectors within the respective EU aggregate. The RWS indicator shows how the relative performance of a *DIR* (*NDIR*) sector in the European Union changes compared to the relative performance of *DIR* (*NDIR*) sectors across the world. Finally, changes in the RTB index indicate how the exportimport performance of a *DIR* (*NDIR*) sector varies through the environmental regulation relative to the performance of the same sector in the BAU situation.

Figure 4 outlines sectoral competitiveness effects as measured by the RCA and the RWS indicator. The RCA indicator shows that the environmental regulation under *NAP I* induces large competitiveness gains for the covered EU ETS sectors vis-à-vis the remaining (non-covered) industries of EU economies, which face losses in competitiveness. The main reason is that given a relatively high allowance allocation, it is the non-covered sectors that – in the absence of the CDM – account for the major emissions reductions and economic burden. A stricter allowance allocation under *NAP II* increases the burden on ETS sectors, thereby eliminating the competitiveness gains of the covered sectors and reducing the competitiveness losses of the non-covered sectors. The RTB indicator confirms these findings at an even more pronounced level due to increased (decreased) exports and falling (rising) imports for *DIR* (*NDIR*) sectors. Regarding the RWS indicator, we find that decreasing the allocation may turn low competitiveness gains for the covered EU ETS sectors vis-à-vis comparable sectors outside Europe under *NAP I* into competitiveness losses under *NAP II*.

While CDM access for covered industries leaves these results unchanged, government CDM can largely balance competitiveness effects between covered and non-covered EU industries, compensating the latter by importing low-cost emissions abatement from developing countries. In this case, all sectoral competitiveness impacts are relatively low for all three indicators.

Regarding the competitiveness for non-EU countries we find that the United States, China and India obtain gains in their terms of trade due to the unilateral European environmental regulation under the EU ETS. If we, however, consider government access to CDM projects for the EU, the gains in national competitiveness of the USA are much less pronounced, while the gains for China and India even turn into competitiveness losses. The sectoral competitiveness effects for individual non-EU countries are heterogeneous. According to the RCA and RTB indicators, we find that the EU ETS may induce a structural change also in the respective non-EU countries.



Figure 4: Sectoral competitiveness effects w.r.t. RCA and RWS indicators for EU aggregates by sector and scenario

Box 1: Empirical Policy Analysis: Emissions Allocation in Europe

In order to complement the model-based analysis of economic impacts of the EU ETS, we assess its competitiveness effects with an empirical policy analysis. We employ a statistical assessment for selected European companies as well as a statistical and econometric case study for Germany, which to our knowledge represent the first empirical assessments of their kind. Thereby, we assess the factors of regulation stringency of the EU ETS as well as the associated employment and competitiveness impacts. Details on our database as well as on the empirical approach are given in Annex 2.

EU-wide Assessment

In our analysis, relative allowance allocation is measured by the so-called *allocation factor*. The allocation factor gives the allocation of EU emissions allowances relative to the actual emissions of the respective entity and is calculated as the ratio between allocated allowances and verified emissions. Thereby, it also represents the stringency of EU ETS regulation. The following figure presents the allocation factor – based on installation level data from the *Community Independent Transaction Log* (European Commission, 2007) aggregated at the national level – for all EU ETS countries. It indicates that on average companies in most EU countries have received more allowances than their respective verified emissions. Consequently and in line with previous findings of Kettner et al. (2007) at the European level, the allowances and emissions data suggest that in 2005, the trading scheme as a whole was in a long position.



Figure: Allocation factors at the national level for EU ETS countries in 2005

By means of a statistical analysis for selected EU ETS companies, we aim to assess the relationship between regulation stringency of the EU ETS and economic factors of those firms. Our selection of firms at the European level is based on their importance within the EU ETS as measured by the amount of allowances allocated. From each EU ETS country the "Top 20" of companies within the EU ETS was selected. We compute the (Pearson's) correlation coefficient between economic variables and the allocation factor at

the firm level, which gives information about the (linear) relationship between regulation stringency for the most important firms within the EU ETS and their economic and sectoral characteristics (the latter being covered by sectoral variables, see Table 1).

Overall, the results from our EU-wide assessment suggest that:

- § There is no strong relationship between the level of employment in 2004 and the relative allowance allocation for the respective firms.
- § In contrast, 2004 cash flows and the allocation factor are positively linked, i.e. firms with higher cash flows received relatively more allowances.
- § Sectoral affiliation plays a substantial role for the relative allowance allocation.

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	Allocation Factor	Cash Flow 2004	No. Employees 2004	Mining	Electricity	Energy	Business	Pulp & Paper	Coke & Petrol.	Other Manuf.
Allocation Factor	1.00	0.31	0.01	0.26	-0.26	0.25	0.05	0.06	-0.11	-0.07

Note: 106 observations. Pearson's correlation coefficients for the respective variable pairs are given.

Given their baseline emissions in our EU-wide sample, firms belonging to the coke and petroleum sector and in particular to the electricity sector seem to have received relatively few allowances. A relative shortage in allowances especially of the electricity sector indicates a stricter regulation of these sectors within the trading scheme. Buchner et al. (2006) attribute this phenomenon to the quasi absence of international (i.e. non-EU) competition and to the general conjecture that power plants are able to abate emissions at relatively low cost. In contrast to the case of the electricity sector, we observe a positive relationship between the affiliation to (other) energy as well as the mining sector and the relative firm allocation.

Case Study for Germany

Using a large German firm sample, we firstly conduct a statistical (correlation) analysis analogously to the EU sample. Secondly, within the framework of an econometric analysis, we aim to assess the impact of regulation stringency in terms of relative allowance allocation on competitiveness and employment at the firm level. This econometric analysis may offer important insights into the economic effects of the EU ETS in Europe as a whole, as German companies represent about 24 per cent of all allocated allowances. As in the statistical analysis for selected EU ETS companies, the correlations of our interest are those between economic variables and the allocation factor. For our German sample, the values of the correlation coefficients remain however low in most cases. These results suggest that:

- § Economic and sectoral characteristics of the respective firms are less related to the allocation of EU emissions allowances at a firm level in Germany.
- § However, electricity companies in Germany were relatively highly allocated, both given their level of emissions and compared to other German sectors.

The higher burden of the German electricity sector, indicated by the positive and relatively high correlation coefficient between the sectoral indicator variable and the allocation factor, is differing to our results at the EU level. Therefore, the correlation analysis shows that there are major differences between allowance allocation at the EU level and in Germany, underpinning the findings of Buchner et al. (2006). The authors attribute this phenomenon to the fact that in the German National Allocation Plan (NAP), process emissions – in contrast to combustion emissions – were assigned their historic baseline amounts without involving projections. As electricity generation is principally combustion, the German electricity sector received a relatively small regulatory burden.

Within the econometric analysis of the EU ETS, we employ an ordinary least squares (OLS) regression estimation in order to test whether the relative allocation had an impact on competitiveness. Following the competitiveness concept "ability to sell", as an empirical indicator for competitiveness we employ firm revenues. As a second economic indicator we use employment changes of the respective firms. The central results of our regression analysis for Germany suggest that:

- § There is no significant competitiveness ("ability to sell") impact of the relative allocation of EU emissions allowances at the firm level in Germany.
- § *Regulation stringency of the EU ETS did not affect employment of the respective German firms in 2005.*

From a theoretical point of view, a positive effect of regulation stringency on the development of firm revenues and employment in 2005 could have been expected, i.e. a high relative burden due to EU ETS regulation could have had negative impacts on the ability to sell of a firm and, consequently, on its revenues and number of employees. However, the estimated coefficient of the allocation factor does not significantly differ from zero. This result suggests that EU ETS companies that received a relatively high amount of allowances could not, consequently, increase their revenues as compared to other German companies within the trading scheme, which may be due to the modest overall burden in the first ETS phase and the low allowance prices. Correspondingly, we do not find a significant impact of the relative allowance allocation on employment in 2005 either, suggesting that firms with a higher regulatory burden within the trading scheme did not react with respective worker layoffs.

2.4 <u>Economic impacts of linking the EU ETS internationally</u>

This section presents the simulation results of our model-based policy assessment regarding the competitiveness effects of linking the EU ETS internationally. Unlike in the previous section on the EU ETS, in order to provide a consistent reference scenario we have to assume compliance with the Kyoto Protocol for the regions that are not (yet) involved in international emissions trading, which yields a different reference situation than in the previous section. We will discuss the economic implications of this new setting below. The whole set of corresponding quantitative simulation results is presented in Table 19 to Table 22 in Annex 1e.

Emissions-market and macroeconomic effects

As a prerequisite for our competitiveness assessment of linking the EU ETS internationally we start our analysis with the corresponding effects on the market for emissions permits and the macro economy. Figure 5 presents the international permit price resulting from our alternative policy scenarios.



Figure 5: CO₂ permit price within linked ETS by scenario

We observe a CO₂ value for the reference case of the European ETS (scenario EU) of 11.37 US\$ per ton CO₂, which is almost two dollars higher than the corresponding permit price under NAP II in the previous section – a result that is due to a differing reference situation of regional compliance to the Kyoto Protocol. The reason is that in all linking scenarios we assume compliance with the Kyoto Protocol and domestic abatement policies (i.e. cost-efficient taxation) for the regions that are not (yet) involved in international emissions trading. As a consequence, the demand for emissions and energy of these regions is lower than in the previous section assessing pure EU climate policies. This implies a lower international fossil fuel price, a corresponding higher energy and emissions demand of EU ETS sectors and thus a higher price for CO₂ emissions permits.

Linking the EU ETS to emerging domestic ETS in Japan and Canada (scenario EU^+) decreases the permit price to 9.68 US\$ due to lower marginal abatement costs within the newly linked schemes. Through an additional linkage to Russia (scenario EU^{++}) the CO₂ value decreases further to 7 US\$, as Russia features lower-cost abatement options than the EU regions – and consequently exports emissions permits to Europe. This result holds although we abstract from the allocation of Russian excess emissions permits ("Hot Air") to the covered installations. Given a Russian allocation factor of one, the lower permit price in scenario EU^{++} therefore only originates from low-cost Russian abatement options.

For transparency in our linking scenarios we concentrate on *government* CDM, i.e. access to abatement options in developing countries for all sectors of the linked economies. We find that the CO_2 values within those sectors covered by the respective ETS are only slightly decreased, which is due to the price-driving high demand for CDM of governments in order to compensate the non-covered sectors of the respective economies. Here, this effect is stronger than the terms-of-trade effects on fossil-fuel markets discussed in the previous section. Moreover, we observe that accounting for government CDM, linking the EU ETS to Canada and Japan does not change the permit price, while a further linkage to Russia leads to a substantial price decrease also in a CDM setting.

In the following, we concentrate our discussion about macroeconomic impacts on the social welfare indicator. Figure 6 presents the corresponding welfare effects for aggregate EU regions across alternative policy scenarios.



Figure 6: Welfare impacts for EU aggregates by scenario

The figure shows that while the overall economic effects of linking the EU ETS internationally are generally small, the welfare impacts differ considerably between alternative Member State aggregates and depend on the policy setting regarding the CDM. A permit-price decreasing linkage to emerging domestic ETS in Japan and Canada (scenario EU^+) results in an unchanged welfare situation for the EU-27 (as compared to a pure EU scheme). Due to a lower allowance price, permit-importing EU-15 Member States slightly benefit in terms of lower welfare losses and the permit-exporting EU-12 aggregate faces slightly lower welfare gains.

A further linkage to Russia leaves the welfare situation of the EU-27 and EU-15 Member States unchanged, while the welfare gain of the EU-12 aggregate shrinks further. For these regions, competing with permit-exporting Russia, the falling CO_2 value diminishes the potential benefits from exporting emissions rights. Accounting for government access to low-cost reduction options in developing countries via the CDM decreases the level of welfare losses towards zero, while the qualitative effects across scenarios still reflect the allowance-price implications discussed above.

Effects on international competitiveness

In the following, we assess the effects of linking the EU ETS with emerging schemes outside Europe on national and sectoral competitiveness of EU and non-EU countries. Starting with the impacts on the European Union, Figure 7 shows that linking the EU ETS internationally does not significantly affect the economy-wide competitiveness effects for EU Member States. Further, we find that also under a linking strategy the CDM serves as an efficiency mechanism that is able to largely reduce economy-wide competitiveness losses.



Figure 7: Terms-of-Trade impacts for EU aggregates by scenario

While the economy-wide impacts of linking the EU ETS internationally are limited, the simulated sectoral competitiveness implications show a differentiated picture. We find that the covered European *DIR* sectors may face slight decreases in their competitiveness gains through linking to emerging schemes in Japan and Canada – both vis-à-vis the remaining industries of EU economies (RCA) and comparable sectors in non-EU regions (RWS). For the non-covered *NDIR* sectors we observe the opposite (but less pronounced) effects. Further regional flexibility in emissions trading – due to a permit-price decreasing linkage to Russia – may however alleviate the losses of *DIR* sectors. Moreover, it shows that also under a linking strategy the CDM serves as a flexible instrument that balances heterogeneous sectoral competitiveness effects within EU economies, especially for the old Member States.

Figure 8 presents the prospects for the non-EU linking candidates of joining the European system with respect to national competitiveness impacts. The economy-wide terms-of-trade impacts show to be relatively heterogeneous. While a linkage to Japan and Canada (scenario EU^+) induces an increase of the original competitiveness gains for Canada, Japan is facing a further decrease in its terms of trade. For Russia joining the trading scheme (scenario EU^{++}) results in a decrease of its competitiveness gains under BAU.

These heterogeneous results can be explained as follows: A linkage to Japan and Canada implies the introduction of an inefficient domestic emissions regulation in these two countries which is due to a relatively high allowance allocation and the associated abatement-burden shifting to non-covered sectors. As for the EU, for these countries with effective emissions reduction targets such a policy design implies competitiveness gains for covered (energy-intensive) sectors and competitiveness losses for non-covered (energy-extensive) sectors. This burden-shifting effect is more pronounced in Japan than in Canada. As a consequence of its inefficient domestic regulation, the original terms-of-trade loss of Japan is further increased by linking to the European ETS. In contrast, Canada is benefiting from linking to the EU in overall competitiveness terms. This linking candidate may compensate its inefficient domestic regulation by competitiveness gains in sectors covered by the domestic ETS.

A further linkage to Russia (scenario EU^{++}) leaves the terms-of-trade situation of Canada unchanged, slightly alleviates the losses of Japan and substantially decreases the competitiveness gains of Russia. In this policy setting Russia has an incentive to reduce emissions at relatively low marginal cost in order to export permits to the emissions-trading partners. Although this reaction generates welfare benefits for Russia, by inducing a decreased international fossil-fuel demand and price it decreases the terms of trade of this energy-exporting region.



Figure 8: Terms-of-Trade impacts for linking candidates by scenario

2.5 <u>Economic impacts of EU emissions regulation in 2020</u>

In this section we analyse future EU climate policy strategies in the year 2020 as proposed by the European Council in March 2007, implying more ambitious national emissions reduction targets of EU Member States. Given the ambitious unilateral EU emissions reduction target of 20% versus 1990 levels, we also assume a stricter relative allowance allocation to energyintensive sectors which we approximate by a 20% decrease of *NAP II* allocation factors. Note again that regional "allocation factors" reflect the ratio between allocated permits and BAU emissions levels, implying the required emissions reductions of the covered ETS sectors versus BAU levels (as opposed to committed national target emissions). In our case, the approximated allocation factors in 2020 induce an average emissions reduction of about 30% versus BAU levels of EU Member States. In order to compare our results with our findings in section 2.3, also in this section all non-EU regions are assumed to not having committed to binding emissions reduction targets in 2020.⁸ Table 5 presents the corresponding simulation results for the EU-27.

The table below shows that the stricter relative allowance allocation in 2020 results in a substantially higher allowance price of 50 US\$ per ton of CO₂, amounting to more than five times the CO₂ value under the *NAP II* allocation in 2010 (compare section 2.3). This large price difference is due to the strong increase (decrease) in demand (supply) for emissions permits under the stricter allocation regime in 2020. However, the results in Table 5 suggest that allowing for CDM access in the covered *DIR* sectors (scenario *NAP III_CDM_dir*) may substantially lower the CO₂ value to a comparable level as under *NAP II* allocation. In this case, the allowance prices under *NAP II* and *NAP III* almost align as permit demand is largely diverted to CDM credits in both policy settings. When accounting for government CDM under a post-Kyoto Protocol (scenario *NAP III_CDM_all*), the CO₂ value rises only moderately due to the additional demand for CDM credits originating from the non-covered *NDIR* sectors – who are represented on the emissions market by their national governments.

⁸ Note that *NAP II* (2010) and *NAP III* allowance allocation (2020) apply to a different reference year.

NOTI	RADE	NAF	? III	NAP CDM	TII_ [_dir	NAP CDM	III_ 1_all
			20	20			
	CO_2 value	e in DIR s	ectors (in	constant S	\$US per to	n of CO ₂)	
	_		49.64		4.18		5.26
		Produc	tion impa	ct (in % vs	. BAU)		
	-0.65		-2.06		-1.95		-0.07
		Welfa	re impact	(in % of .	HEV)		
	-0.28		-1.34		-1.27		-0.05
		Terms of	Trade imp	oact (in %	vs. BAU)		
	-1.40		-2.80		-2.50		-0.10
	Revealed	d Compare	ative Adva	ntage – R	CA (in %	vs BAU)	
DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR
-4.61	0.57	1.84	-0.22	7.04	-0.80	-0.31	0.04
	Relati	ve World	Trade Sha	res – RWS	S (in % vs	BAU)	
DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR
-3.08	0.52	-0.95	0.23	0.86	-0.06	-0.39	0.03
	Rel	ative Trad	le Balance	e – RTB (i	in % vs BA	A <i>U</i>)	
DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR
-173.28	-20.85	-28.69	-77.58	120.94	-84.91	-10.74	-0.73

Table 5: Simulation results by policy scenario for the aggregate EU-27 region in 2020

Regarding the macroeconomic impacts for the EU-27 economies in 2020, Table 5 shows that – in the absence of the CDM – the negative impact on both production and aggregate welfare is much more pronounced than under *NAP II* emissions regulation and the national Kyoto targets in 2010. Although the allowance allocation to the covered ETS sectors is stricter in 2020 – and thus represents a more cost-efficient EU emissions regulation than in 2010 – the more ambitious national emissions reduction targets for 2020 which lead to larger aggregate, i.e. economy-wide, adjustment costs. The reason is that the higher abatement efforts of the covered sectors induced by the stricter allocation in 2020 are not sufficient to reach the ambitious future EU reduction targets. In order to fulfil the national emissions targets in 2020 the non-covered industries therefore have to be regulated by far higher levels of domestic carbon taxation than in 2010. This is illustrated in Table 6 which presents the level of carbon taxes in the non-covered sectors for central EU economies. It shows that the carbon tax levels for *NAP III* regulation and the more ambitious national emissions targets in 2020 are substantially higher than for the *NAP II* scenario in 2010, inducing more pronounced macroeconomic adjustment costs for the EU-27 economies.

Scenario Region	NAP II (2010)	NAP III (2020)	NAP II_ CDM_all (2010)	NAP III_ CDM_all (2020)
France	85.46	604.84	4.17	5.67
Germany	39.01	231.11	4.17	5.67
United Kingdom	22.17	18.65	4.17	5.67
Italy	140.56	304.09	4.17	5.67
Spain	130.53	549.11	4.17	5.67

Table 6: Simulated carbon taxes in non-covered sectors by scenario (\$US per ton of CO₂)

Table 6 further shows a pronounced heterogeneity across regional carbon taxes for the noncovered sectors. This heterogeneity can be explained by regionally diverse stringencies of allowance allocation to the covered sectors – a stricter allocation (such as in the case of the United Kingdom) inducing higher abatement efforts of the covered sectors, thereby implying a lower carbon tax for the non-covered sectors (and vice versa). Furthermore, heterogeneous tax levels may originate from different stringencies of national emissions targets in 2020 as well as from the availability of emissions abatement options: The observed high carbon taxes for the non-covered sectors of the French economy can thus also be explained by high marginal abatement cost levels of this region (generating the major fraction of electricity supply by carbon-neutral nuclear power plants).

Table 5 suggests that CDM access which is restricted to the covered sectors is not able to substantially reduce these negative macroeconomic impacts. However, we find that facilitating government CDM under a post-Kyoto Protocol leads to comparable welfare and production effects as *NAP II* emissions regulation given the EU's Kyoto targets in 2010. Thus, the extensive economic flexibility in emissions abatement by means of CDM access for all sectors of the economy enables EU Member States to implement far stricter climate policy measures at comparable macroeconomic adjustment costs. This finding is underpinned by the results in Table 6, showing that the carbon taxes in non-covered sectors of EU economies may be drastically decreased (and regionally harmonised) by government CDM access, and that the CO₂ value falls to a comparable level in 2010 and 2020.

The simulated economy-wide competitiveness implications of EU climate policy in 2020 confirm our findings on macroeconomic impacts (see Table 5). The terms-of-trade losses of EU-27 Member States in scenarios *NAP III* and *NAP III_CDM_dir* amount to more than twice their losses under *NAP II* emissions regulation and the Kyoto targets. Allowing for government CDM may, however, equalize the terms-of-trade effects between climate policies in 2010 and 2020. Decomposing these economy-wide impacts at the sectoral level shows that – in the absence of the CDM – the environmental regulation in 2020 induces far larger competitiveness gains for the covered EU ETS sectors vis-à-vis the remaining industries of EU economies (RCA indicator): The non-covered sectors face stronger relative losses in competitiveness, as the stricter national emissions targets in 2020 induce higher economic

burdens for these industries. Moreover, these sectors are not able to participate in international emissions trading in order to improve their relative competitiveness position.

By contrast, Table 5 illustrates that the more ambitious climate policy measures in 2020 may augment the competitiveness losses for the covered EU ETS sectors in 2010 vis-à-vis comparable sectors outside Europe (RWS indicator) in 2020, whereas the non-covered industries may further increase their former competitiveness gains under *NAP II* regulation and the Kyoto targets. Finally, as for the economy-wide impacts we find that allowing for government CDM roughly equalizes sectoral competitiveness effects between the two climate policy strategies in 2010 and 2020.

2.6 <u>Conclusions</u>

Assessing the economy-wide competitiveness effects of the emissions regulation under the EU ETS, we find that the terms of trade of EU-15 Member States are decreased by 1.5% under NAP I and 1.2% under NAP II. While for the new Member States these negative effects are much less pronounced under NAP I, they are comparable to those of the new Member States under NAP II. In general, the losses in economy-wide competitiveness for the EU can be largely neutralized by means of government CDM access for the European economies. In order to decompose the national competitiveness effect on the sectoral level, we assess three explicit indicators: Revealed Comparative Advantage (RCA), Relative World Trade Shares (RWS) and Relative Trade Balance (RTB). Our simulation results with respect to the RCA indicator show that the environmental regulation under NAP I induces large competitiveness gains for the covered EU ETS sectors vis-à-vis the remaining (non-covered) industries of EU economies who face losses in competitiveness. Given a relatively high allowance allocation, it is the non-covered sectors that - in the absence of the CDM - account for the major emissions reductions and economic burden. A stricter allowance allocation under NAP II shifts a part of the burden towards ETS sectors, thereby eliminating their competitiveness gains and reducing the competitiveness losses of the non-covered sectors. Regarding the RWS indicator, we find that decreasing the allocation may turn a low competitiveness gain for the covered EU ETS sectors vis-à-vis comparable sectors outside Europe under NAP I into a competitiveness loss under NAP II. While CDM access for covered industries leaves these results unchanged, government CDM can largely balance these opposed effects of covered and non-covered EU industries, compensating the latter by importing low-cost emissions abatement from developing countries. In this case, all sectoral competitiveness impacts are relatively low.

In order to complement the model-based analysis of EU emissions trading, we assess the competitiveness implications of the European ETS with an empirical policy analysis. All in all, our empirical assessment shows that the EU ETS was in an overall long position of allowances in 2005. Moreover, sectoral affiliation was a decisive factor of relative allocation to the covered installations, revealing a particularly high burden for the electricity sector at the EU level, However, industry affiliation played a different and less pronounced role in Germany. Moreover, our econometric analysis suggests that in 2005 relative allowance allocation did not have a significant impact on competitiveness and employment at the firm level in Germany, a result that might also be due to the modest overall burden.

We further find that linking the EU ETS internationally does not significantly affect the economy-wide competitiveness effects for EU Member States. However, the covered European ETS sectors may face slight decreases in their competitiveness gains through

linking to emerging schemes in Japan and Canada – both vis-à-vis the remaining industries of EU economies (RCA) and comparable sectors in non-EU regions (RWS). For the non-covered sectors we observe the opposite (but less pronounced) effects. Further linkage to Russia may however alleviate the losses of the covered sectors. Also under a linking strategy the CDM serves as an efficiency mechanism that is not only able to reduce economy-wide comparative losses, but also balance heterogeneous sectoral competitiveness effects within EU economies, especially for the old Member States.

Finally we assess the proposed EU climate policy strategy to achieve a 20% reduction of greenhouse gas emissions by 2020 versus 1990 levels combined with a stricter allowance allocation in a potential third trading period of the EU ETS (which we approximate by a 20% decrease of NAP II allocation factors). We find that the stricter reduction targets and tighter allowance allocation in 2020 results in a substantially higher allowance price and induces larger levels of production and aggregate welfare losses than under NAP II emissions regulation and the national Kyoto targets in 2010. However, it shows that facilitating government CDM under a (post) Kyoto Protocol leads to comparable price and macroeconomic effects in 2010 and 2020. The extensive economic flexibility in emissions abatement by means of CDM access for all sectors of the economy thus enables EU Member States to implement far stricter climate policy measures at comparable macroeconomic adjustment costs. Our simulated competitiveness implications of EU climate policy in 2020 confirm these findings at the economy-wide level. Moreover, it shows that the stricter climate policy in 2020 induces competitiveness gains for the covered EU ETS sectors vis-à-vis the remaining industries of EU economies, while it may generate losses vis-à-vis comparable sectors outside Europe.

3 The potential for biofuels alongside the EU ETS

3.1 Introduction

On its March 2007 summit the European Council agreed to embark on an ambitious policy for energy and climate change. The aims of this policy which may be called the three times 20 targets for 2020, are the following: the EU will reduce greenhouse gas emissions by at least 20% compared to 1990, will ensure that 20% of total energy use comes from renewable sources and will accomplish a 20% decrease in energy intensity over and above business as usual developments. Part of the target for renewable energy will be covered by increasing the share of biofuels up to 10% of total transport fuel use in 2020.

With the target to reduce greenhouse gas emissions by at least 20% in 2020, if need be unilaterally, the EU demonstrates that it takes its ambition seriously to limit global warming to 2° Celsius above pre-industrial levels. According to current knowledge this temperature target can only be met if emissions are reduced by this order of magnitude in all industrialized countries and if large and fast-growing emitters as China, India and Brazil are starting soon to curb emissions as well (Boeters et al., 2007). The EU initiative may not only bring afloat the international negotiations about post-2012 climate policies, but also conveys a significant signal to EU energy users and producers that greenhouse gas emissions will become

increasingly costly in the medium term. This signal is instrumental to the long-term decision making process on transitions to cleaner technologies, in particular in power generation.

The EU Emissions Trading Scheme (EU ETS) can be considered as the 'pricing engine' for CO_2 -emissions. Though its current coverage is confined to large combustion installations that together emit about halve of EU fossil CO_2 emissions, other greenhouse gases and emitters are scheduled to be brought into the scheme as well. The higher the emissions price will be the sooner technological emission reduction options will tend to be adopted commercially.

The 20% target for renewable energy may potentially undermine this role of the EU ETS. Subsidization of renewable electricity generation will reduce the demand for permits, and lower the permit price, unless the cap is tightened simultaneously. Hence, the fostering – by costly subsidization or prescription – of renewables has the danger to depress the emissions price and to prevent (or postpone) the commercial advent of cleaner technologies. The promotion of biofuels for transport will, however, not directly affect the functioning of the EU ETS as long as the scheme will not cover fuel use for transportation. Yet, without further investigation, it is not clear whether a policy that fosters the use of biofuels is more or less costly than alternatives, such as a further rise in fuel excises.

In this section the impacts of alternative policy measures are assessed that aim to exploit the biofuel potential, using a climate change version of the global general equilibrium model WorldScan (Lejour et al., 2006)⁹. The outcomes of WorldScan are of a long-term nature as the model does not reflect the temporary costs of structural adjustments, which has to be borne in mind when interpreting the simulation outcomes.

The policy options are assessed for the year 2020 against a policy baseline with modest economic growth in which all Annex I countries impose ceilings on fossil CO_2 emissions. It is assumed that within the EU an ETS is operational that does not cover CO_2 emissions from road transport. This policy baseline is briefly described in Section 3.2 and compared to a business as usual scenario. The impacts of alternative biofuel promotion policy measures are assessed in Section 3.3 against the policy baseline. Raising transport fuel excises to curb emissions from road traffic is also analysed here as an alternative. Conclusions are drawn in Section 3.4.

3.2 <u>The climate policy baseline</u>

We consider a climate policy baseline scenario that has both the EU ETS in place and emission reduction targets in the other countries of Annex I of the Kyoto Protocol. As the EU ETS covers only part of the economy (hereinafter: the regulated sector), other policy measures must ensure that the part that is not covered (henceforth: the non-regulated sector) reduces emissions as well to meet the overall reduction targets. Through the EU Burden

⁹ The WorldScan version used in this chapter distinguishes twenty markets for goods and services and factor markets for labour, capital and agricultural land in each of the twenty model countries and regions. Six different energy carriers are distinguished: coal, oil refinery products, natural gas, biodiesel, ethanol, and other renewable energy. Only the first three of these contribute to the CO_2 emissions generated by the model. See Annex 3a for more details on the WorldScan version used for this study.
Sharing Arrangement each Member State has taken on a reduction target for total emissions. Hence, permit allocation to the regulated sectors implicitly puts a complementary, national cap on emissions from the non-regulated sectors. Reduction of emissions from the nonregulated sectors is to be addressed by a large variety of policies at EU and national levels. We represent these policy efforts with separate carbon taxes for the non-regulated sector at the Member State level.

We implement the EU ETS in a rather coarse way and assume that the scheme covers the following sectors: electricity, energy intensive and chemical products and capital goods and durables. These sectors emit somewhat less than half of EU-27 fossil CO_2 emissions. Households and the remaining production sectors belong to the non-regulated sector.

In the policy baseline it is assumed that the EU puts a cap on greenhouse gas emissions in 2020 that is 20% below the level of 1990. In addition, post-2012 cap-and-trade systems are also assumed to operate in the other Annex I countries, though here the caps are assumed to be more modest. Permits are assumed to be internationally tradable within the EU ETS only. Moreover, *no use* is made of CDM or JI. Though one may question the likelihood of the mere reliance on domestic reductions in the Annex I parties in this policy baseline, this assumption was deliberately made in order to enable a focus on internal EU impacts, without having the need to account for the influences of international permit trade.

The policy baseline has been constructed against a business as usual (BaU) scenario with moderate economic growth that describes how the economies would develop in the absence of such policies. The BaU scenario does not include climate change policies or carbon taxation, but it does include actual biodiesel and ethanol production over the period 2001-2004, keeping the share of biofuel use fixed from 2004 onwards until 2020. The impacts of the policy baseline in 2020 vis-à-vis the policy-free BaU scenario are as follows (see Table 7). First, within Annex I, the distribution of emission abatement efforts is rather skew. In particular, the USA profits from its withdrawal from the Kyoto Protocol. The USA target in terms of 1990 emissions is 17% up, while the targets of EU-27 and the rest of the OECD are 20% and 22% down respectively. Emission prices are especially high for the rest of the OECD which has to reduce emissions by almost 50% compared to the BaU scenario and meets abatement costs of 125 \in per ton CO₂.

	Percer	ntage CO ₂ reduc	ction	Emission price or carbon tax a)	Economic welfare
	Target compared to 1990 emissions	Target compared to BaU emissions	Emissions compared to BaU emissions		Change compared to BaU scenario
	(%)	(%)	(%)	€/ tCO ₂	(%)
Annex I EU-27	-7 -20	-24 -33	-24 -33	41 54	-0.63 -0.62
Germany France United Kingdom Italy Spain Other EU-15 Poland Bulgaria and Romania Other EU-12 USA	-31 -13 -23 -18 0 -14 -18 -20 -19 17	-35 -36 -30 -42 -41 -40 -1 0 -32 -9	-33 -33 -30 -34 -36 -33 -34 -25 -39 -9	66 68 83 116 80 90 6 4 46 6	-0.63 -0.47 -0.56 -1.06 -0.72 -0.77 1.00 1.19 -0.64 -0.07
Rest of OECD Former Soviet Union	-22 -8	-48 14	-48 2	125 0	-1.56 -1.07
Non-Annex I Brazil China India World			2 4 2 3 -12		-0.14 -0.04 -0.09 0.03 -0.51

Table 7: Policy baseline impacts vis-á-vis BaU scenario, 2020

a) The emissions price for EU-27 is the price of the EU ETS; at Member State level the carbon tax is shown of the non-regulated sectors

The EU-reduction with respect to the BaU scenario is more than 30% and the EU ETS emission price is above 50 Euro per ton CO_2 . In the USA emissions prices are, at 6 Euro per ton, about ten times smaller than in the EU. In Annex I countries, economic welfare is on average 0.6% less than in the BaU scenario. Welfare losses are higher than average for the rest of the OECD (1.6%) while some of the new EU economies experience welfare gains of 1 to 1.2% because of permit exports. The welfare level in the USA remains almost unchanged reflecting their assumed limited effort in emissions reduction.

Because permits are tradable within the EU ETS, Member States need not reduce their emissions in the regulated sectors by the full amount indicated by their emission targets. The Member States of EU-15 tend to reduce their emissions less than targeted, importing the permits from the new Member States. Hence, in some countries, notably Poland and Bulgaria and Romania, sizable reductions are induced by the high emissions price of the EU ETS. In the non-regulated sectors trade in reduction obligations is not possible. Hence, the carbon taxes for these sectors vary by Member State and are in general higher in EU-15 than in the new Member States. In EU-15 the carbon tax generally reaches levels that are above the emissions price of the EU ETS, whereas in the new Member States the tax is relatively small.

In non-Annex I countries emissions increase, mainly because of the relative decrease in prices of energy carriers in comparison to the BaU scenario. With the exception of India, these countries experience minor welfare losses due to the increased prices of non-energy imports. Globally, emissions are 12% lower than in the BaU scenario. According to Boeters et al. (2007) – which use the same baseline – such a reduction tends to fall short of meeting the 2°C temperature target.

3.3 <u>Promoting the use of biofuels</u>

Our assessments focus on conventional biofuels that are produced from food or feed crops. Biodiesel is produced from vegetable oils and ethanol from cereals or sugar crops. Thus, raising biofuel production puts extra claims on arable land. As in all scenarios the availability of arable land is kept constant at 2001 base-year levels, land rents will increase when biofuel feedstocks are expanding. We do not assess the prospects of the so-called 'second-generation' biofuels that are produced from cellulosic and ligno-cellulosic material and from biowaste. Though these fuels would reduce the biofuel claim on arable land, they are still too costly to be competitive with conventional biofuels.

Though the direct use of conventional biofuels does not add to greenhouse gas emissions, using conventional biofuels is not climate-neutral as fossil CO_2 is emitted in biofuel crop production and in the extraction of biofuels from these crops. Moreover, the strain on arable land use may induce farmers to raise the use of nitrogen fertilizers, which would increase the emissions of the greenhouse gas nitrous oxide (N₂O). The latter emissions, however, are not reflected in WorldScan. The use of biofuels has some advantages. Large investments need not be required in distribution infrastructure nor in car engine adjustments. Promoting the use of biofuels will increase energy security as it reduces oil demand. Biofuels have some air quality benefits as well. Finally, the production of biofuels may bring economic benefits to rural communities. Yet, large scale production may raise food prices and have negative impacts on the long-term sustainability of biofuel crop production and on biodiversity.

In establishing a breakdown of production costs we assumed that those biofuel technologies are applied that operate at lowest cost, neglecting greenhouse gas emissions. In our scenarios biofuels are promoted to various degrees and with various supporting policy measures. In addition to the EU, we also account for biofuel targets in some other countries, where explicit biofuel promotion policies exist (cf. UNCTAD, 2006).

In general our scenarios follow one of three ways of fostering the increase of biofuel use:

- § full exemption of transport fuel excises (this assumption is also made in the policy baseline);
- § competitive excise on biofuels to establish equality of the biofuel user price with the user price of fossil transport fuels (this tax is determined endogenously in the model);
- § full taxation of biofuels with existing fossil transport fuel excises.

	Emission price a)	Arable land price	Agricultural producer price	Food consumer price	Economic welfare
Annex I		0.9	0.2	0.1	0.01
EU-27	0.2	2.2	0.5	0.1	0.03
Germany	-8.1	2.4	0.6	0.1	0.03
France	-9.3	2.4	0.5	0.0	0.03
United Kingdom	-17.7	6.1	1.0	0.1	0.07
Italy	-9.1	2.5	0.5	0.1	0.04
Spain	-14.3	2.6	0.4	0.0	0.01
Other EU-15	-8.8	2.1	0.2	0.1	0.02
Poland	-36.1	1.8	0.7	0.2	-0.05
Bulgaria and		0.7	0.3	0.2	
Romania	-100.0				-0.15
Other EU-12	-11.0	2.1	0.6	0.1	-0.02
USA	-0.1	0.5	0.2	0.0	0.00
Rest of OECD	0.0	0.5	0.1	0.1	0.00
Former Soviet Union		0.2	0.1	0.1	-0.01
Non-Annex I		0.3	0.1	0.1	0.00
Brazil		0.6	0.2	0.1	0.01
China		0.2	0.1	0.1	-0.01
India		0.1	0.1	0.1	0.00
World		0.5	0.2	0.1	0.01

Table 8: Prices and economic welfare, in % difference with respect to the policy baseline, for a biofuel target of 10% with biofuels fully exempted from fuel excises, 2020

a) The deviation of the emissions price for EU-27 is with respect to the price of the EU ETS; at Member State level the deviation with respect to the carbon tax is shown for the non-regulated sectors

Imposing a biofuel share of 10% in 2020, *leaving biofuels fully exempted* from transport fuel excises, has rather limited impacts on economic welfare (see Table 8). The table shows the percentage deviations with respect to the policy baseline for emissions prices, the price of arable land, the agricultural producer price, the food consumer price and economic welfare. The impact of imposing targeted biofuel shares in transport fuel use on EU national carbon taxes is relatively large. These taxes decrease in all Member States (in Bulgaria and Romania they vanish altogether) because road transport belongs to the non-regulated sector. The biofuel target reduces emissions in road transport. Therefore a lower carbon tax suffices to meet the cap of the non-regulated sectors. The EU ETS emissions price rises slightly due to increased demands for fossil fuels in the regulated sectors.

In all countries the price of arable land increases because the biofuel feedstocks compete for arable land with other agricultural activities. The land rent increase is particularly high in the United Kingdom. Presumably this is due to the high base-year share of permanent pastures and meadows in total agricultural area of the United-Kingdom, leaving a relatively small acreage for crop production. In the wake of rising land prices agricultural producer prices and food consumer prices also rise, but to a much smaller extent. Overall economic welfare is affected positively to a minor extent in the Member States of EU-15 and negatively in the new Member States.



Figure 9: User costs of fossil transport fuels in Euro per Mtoe, policy baseline, 2020

By increasing the biofuel share to 10% transport fuel users can evade both the carbon tax and the fossil fuel tax, which improves welfare. In the new Member States these taxes are relatively small (see Figure 9). In these countries the benefits of tax evasion fall short of the extra costs of biofuel consumption. Hence, on balance welfare declines in the new Member States.

How do the impacts of imposing a 10% EU biofuel share differ under the three alternative ways of fostering the increase of biofuel use (no excise, competitive excise and full excise)? Unsurprisingly, as fuel blends become more expensive, less fuel will be consumed. Hence, emission taxes will fall if excises are imposed that make biofuels just competitive with fossil fuels and they fall even more when biofuels are taxed on just the same basis as fossil fuels (see Table 9). As the transport fuel bill in the Member States is heavily distorted by fossil fuel excise taxes, welfare losses are to be expected when the excise burden is raised. The latter tend to outweigh the gains from reduced carbon taxes as economic welfare decreases in all Member States when taxes on biofuels rise.

Alternative targets

The economic impacts of biofuel targets become the larger, the more ambitious biofuel targets are. In the next table we show the consequences of raising the targets to 15% and 20% compared to the 10% target in the scenarios discussed thus far. In all these counterfactual scenarios *full taxation* of biofuels is assumed.

Table 9: Emission prices in Euro per ton CO_2 and economic welfare with respect to the policy baseline, for a biofuel target of 10% in three excise variants, 2020

	No ex	cise	Competiti	ve excise	Full excise		
	Emissions price a)	Economic welfare	Emissions price a)	Economic welfare	Emissions price a)	Economic welfare	
EU-27 a)	54	0.03	54	0.02	54	-0.00	
Germany	60	0.03	58	0.02	54	-0.01	
France	62	0.03	60	0.02	55	-0.00	
United Kingdom	68	0.07	61	0.05	49	0.02	
Italy	105	0.04	100	0.04	95	0.03	
Spain	69	0.01	66	0.01	61	-0.01	
Other EU-15	83	0.02	80	0.01	76	-0.00	
Poland	4	-0.05	3	-0.06	2	-0.13	
Bulgaria and	0	-0.15	0	-0.15	0	-0.26	
Romania							
Other EU-12	42	-0.02	41	-0.04	38	-0.09	

a) The emissions price for EU-27 is the price of the EU ETS; at Member State level the carbon tax is shown of the non-regulated sectors

Higher biofuel targets lead to substantially lower carbon taxes in the non-regulated sector, the most striking example being the United Kingdom where the tax is more than halved when the target is doubled. However, the consequences for economic welfare are rather small.

Table 10: Emission prices in Euro per ton CO_2 and economic welfare with respect to the policy baseline, for biofuel targets of 10%, 15% and 20%, with full excises on biofuels, 2020

	109	%	159	%	209	%		
	Emissions price a)	Economic welfare	Emissions price a)	Economic welfare	Emissions price a)	Economic welfare		
EU-27	54	-0.00	54	-0.01	54	-0.03		
Germany	54	-0.01	48	-0.02	43	-0.03		
France	55	-0.00	49	-0.01	43	-0.01		
United Kingdom	49	0.02	34	0.01	20	-0.01		
Italy	95	0.03	85	0.05	74	0.06		
Spain	61	-0.01	51	-0.02	41	-0.03		
Other EU-15	76	-0.00	68	-0.01	61	-0.02		
Poland	2	-0.13	0	-0.20	0	-0.27		
Bulgaria and	0	-0.26						
Romania			0	-0.40	0	-0.54		
Other EU-12	38	-0.09	34	-0.14	30	-0.20		

a) The emissions price for EU-27 is the price of the EU ETS; at Member State level the carbon tax is shown of the non-regulated sectors

In general, increasing the targets leads to a deterioration of welfare. The welfare losses are again highest in the new Member States, especially in the countries where the carbon tax is very small or even absent.

Though a doubling of the biofuel target from 10% to 20% has substantial impacts on land rents our simulations fail to show the dramatic agricultural price increases that have been reported by studies making use of partial equilibrium agricultural models (OECD, 2006; European Commission, 2006). In WorldScan arable land allocation is not founded on a detailed representation of agricultural production possibilities. Hence, the increase of land rents may be understated. A sensitivity analysis with respect to the elasticity of transformation for arable land does, however, show no sizable impacts on land rents when land allocation is made less flexible.

Zero biofuel import tariffs

Thus far we kept the import tariffs on biofuels at their baseline levels of 2006. Biofuel trade is hindered by tarification. This is particularly relevant for ethanol, where the EU import tariff appears to be prohibitive. For biodiesel, the import tariffs seem less restrictive. A biofuel promotion policy aiming to obtain biofuels at minimal costs would leave the decision whether to produce the fuels domestically or to import them from elsewhere to the market. We simulate the situation of improved opportunities for sourcing from abroad in additional scenarios in which the EU tariffs on biofuels are put to zero. Biofuel trade liberalization tends to raise the carbon taxes of the non-regulated sectors because lower transport fuel costs will induce more fuel consumption. The impacts are very small however (compare Table 11 and Table 9).

	No ex	cise	Competiti	ve excise	Full excise		
	Emissions price a)	Economic welfare	Emissions price a)	Economic welfare	Emissions price a)	Economic welfare	
EU-27	54	0.03		0.02	54	-0.00	
Germany	60	0.03	58	0.02	54	-0.01	
France	62	0.03	60	0.02	55	-0.00	
United Kingdom	69	0.07	61	0.05	51	0.02	
Italy	106	0.05	100	0.04	96	0.04	
Spain	69	0.01	66	0.01	61	-0.00	
Other EU-15	81	0.02	78	0.01	75	-0.00	
Poland	4	-0.05	3	-0.06	2	-0.12	
Bulgaria and							
Romania	0	-0.14	0	-0.14	0	-0.24	
Other EU-12	41	-0.01	41	-0.03	38	-0.08	

Table 11: Emission prices in Euro per ton CO_2 and economic welfare with respect to the policy baseline, for a biofuel target of 10% in three excise variants, at zero biofuel import tariffs, 2020

a) The emissions price for EU-27 is the price of the EU ETS; at Member State level the carbon tax is shown of the non-regulated sectors

Economic welfare in general improves, but – again – the impacts are very small. Yet, the shift from domestic production to imports from abroad is substantial in the case of ethanol. The EU share of domestic production decreases from almost 100% to about 50%. For biodiesel the shift to imports is less pronounced as the tariffs on biodiesel imports are considerably lower than those on ethanol. Biofuel trade liberalization reduces the share of agricultural value

added somewhat in the EU, and raises the share elsewhere. The change is most pronounced for Brazil that benefits most from the abolition of the high tariff on ethanol. The welfare effects on exporters are negligible, with the exception of Brazil.

Increasing transport fuel taxes as an alternative

One of the purposes of the biofuel target is to reduce CO_2 emissions from road transport. It is therefore interesting to compare biofuel promotion with the impacts of alternative policies that would obtain emission reductions of the same magnitude.

Table 12: Emissions price in Euro per ton CO_2 and economic welfare with respect to the policy baseline, 10% target with full excise versus increased transport fuel taxation, 2020

	Biofuel targ	get 10%	Emission reduction equivalent transport fuel tax					
	Emissions price a)	Economic welfare.	Emissions price a)	Carbon tax in transport	Economic welfare			
EU-27 a)	54	0.00	54		-0.06			
Germany	54	-0.01	53	114	-0.08			
France	55	0.00	54	110	-0.05			
United Kingdom	49	0.02	48	139	-0.09			
Italy	95	0.03	94	154	-0.01			
Spain	61	-0.01	59	105	-0.03			
Other EU-15	76	0.00	76	134	-0.04			
Poland	2	-0.13	2	52	-0.15			
Bulgaria and	0	-0.26	0	46	-0.25			
Romania								
Other EU-12	38	-0.09	37	85	-0.11			

a) The emissions price for EU-27 is the price of the EU ETS; at Member State level the carbon tax is shown of the non-regulated sectors

We therefore explore the consequences of raising transport fuel excises to the extent that the CO₂ emission reductions originating from road traffic become similar to the case of a 10% biofuel target. Specifically, we assume that biofuel use is kept at policy baseline levels. We calculate the reduction in CO₂ emissions in the transport sector due to a 10% biofuel target (with fully excised biofuels and current import tariffs), correct it for the indirect emissions in biofuel production and impose this modified target on the transport sector. Thus, we obtain a scenario that imposes three emissions caps: one for the EU ETS at the EU-level, a second one for the transport sector (separately in each Member State) and a third one for the remainder of the non-regulated sectors (again separately in each Member State). Raising fuel excises instead of imposing a 10% biofuel target to reduce transport CO₂ emissions implies a rise of carbon taxes for the non-regulated sectors, substantially larger increases in the taxation of road fuel use and a small decrease of the EU ETS emissions price (see Table 12). The impacts of a further rise of transport fuel excises on economic welfare are negative in all Member States (except for Bulgaria and Romania). Apparently, further increasing distortionary taxation of the transport sector is detrimental for economic welfare and hence an unattractive alternative to promoting a 10% biofuels share.

3.4 Conclusions

Our assessment of fostering biofuel use is against a policy baseline which has the EU ETS in place and a 2020 reduction target that is 20% below 1990 emissions. In all other countries of Annex I emission caps are present too, though generally the targets are less ambitious. Our analysis shows that the emissions price of the EU ETS is hardly affected when various targets for the share of biofuels in transport fuels are imposed. Hence, promoting biofuel use in road transport is a form of enhancing the use of renewables that will *not* affect the EU ETS price and therefore will not prevent (or postpone) the commercial advent of cleaner technologies in the regulated sectors.

Increasing biofuel shares in transport fuels will have a mitigating effect on the policy efforts needed to curb emissions in the non-regulated sectors. In our assessments this is reflected by a drop in the carbon taxes of the non-regulated sectors in all Member States where this tax is positive. Hence, the negative impacts of these distortionary taxes on economic welfare will decline. The introduction of biofuels will, in general and depending on the biofuel excise regime and the lowering of the carbon tax, raise the price of transport fuels, which affects economic welfare negatively. On balance the net effect on economic welfare is very small compared to the policy baseline. When carbon taxes are small or even zero the benefits of reducing them fall short of the burden of raising biofuel usage. Hence, overall economic welfare declines in the new Member States. When the targets for biofuel use are raised above 10% the beneficial impacts on welfare disappear: the additional benefits of reducing distortionary carbon taxes tend to outweigh the additional costs of raising biofuel usage.

In our study the impacts of biofuel promotion on food prices turn out to be small. Land rents may rise considerably, but agricultural producer prices are affected rather modestly and food consumer prices almost negligibly. Though these results are robust for alternative values of the relevant model parameter (see Annex 3c), partial equilibrium agricultural models show larger impacts on agricultural prices. Here one should bear in mind however, that the WorldScan model does not focus on the peculiarities of agricultural production and food production. In our 10% biofuel target scenarios biofuel use is raised from 16 Mtoe in 2004 to 63 Mtoe in 2020 globally. According to IEA (2006) 13.8 mln ha was devoted to biofuel crop production in 2004. This is about 1% of the global arable area. Without any yield improvements 54.3 mln ha would be needed worldwide in 2020 according to our 10% scenarios. With an annual yield increase of 1.5% of biofuel crops still 42.8 mln ha would be needed. Though this area is enormous, it would amount to only 3% of current global arable acreage. Hence, large impacts on food prices are hardly to be expected.

When existing biofuel tariffs are slashed, biofuels become cheaper (enhancing welfare) but carbon taxes in the non-regulated sectors remain at a higher level (reducing welfare). On balance the improvement of economic welfare is rather small when biofuels are imported rather than produced domestically. Due to the relatively high tariffs on ethanol the increase of ethanol imports is relatively large when biofuel trade is fully liberalised. Liberalisation yields a noticeable welfare increase for ethanol-exporting Brazil. Biofuel targets aiming to reduce emissions are to be preferred to a further increase of excise taxes on transport fuels targeted at obtaining similar emissions reductions. The latter policy further raises the tax distortions of transport services that are already very distortionary due to high existing transport fuel excises.

4 General conclusions

Under the Lisbon process, the European Union aims at becoming the most competitive and dynamic knowledge-driven economy in the world. At the same time, the EU pursues ambitious climate policies in order to fulfil its emissions reduction targets under the Kyoto Protocol. Two policy actions that have been proposed in order to achieve the environmental goals are a strengthening of the EU Emissions Trading Scheme (ETS) and accelerating the development of sustainable biofuels. In order to assess the competitiveness effects of trading emissions and fostering technologies for meeting the EU's Kyoto targets, we apply two complementary methodological approaches: (i) a quantitative macroeconomic modelling approach using two general equilibrium models and (ii) an ex-post empirical policy analysis to detect the competitiveness effects of the EU ETS using firm-level data. As the first assessment of the EU ETS we integrate data on allowance allocation from our empirical assessment into the model-based approach.

Assessing the economy-wide competitiveness effects of emissions regulation under the EU ETS, we find that the terms of trade of EU-15 Member States are decreased by 1.5% under NAP I and 1.2% under NAP II. While for the new Member States these negative effects are much less pronounced under NAP I, they are comparable to those of the new Member States under NAP II. In general, the losses in economy-wide competitiveness for the EU can be largely neutralized by means of government CDM access for the European economies. In order to decompose the national competitiveness effect on the sectoral level, we assess three explicit indicators: Revealed Comparative Advantage (RCA), Relative World Trade Shares (RWS) and Relative Trade Balance (RTB). Our simulation results with respect to the RCA indicator show that the environmental regulation under NAP I induces large competitiveness gains for the covered EU ETS sectors vis-à-vis the remaining (non-covered) industries of EU economies who face losses in competitiveness: Given a relatively high allowance allocation, it is the non-covered sectors that - in the absence of the CDM - account for the major emissions reductions and economic burden. A stricter allowance allocation under NAP II increases the burden on ETS sectors, thereby eliminating the competitiveness gains of the covered sectors and reducing the competitiveness losses of the non-covered sectors. Regarding the RWS indicator, we find that decreasing the allocation may turn a low competitiveness gain for the covered EU ETS sectors vis-à-vis comparable sectors outside Europe under NAP I into a competitiveness loss under NAP II. While CDM access for covered industries leaves these results unchanged, government CDM can largely balance these opposed effects of covered and non-covered EU industries, compensating the latter by importing low-cost emissions credits from developing countries. Here, sectoral competitiveness impacts are relatively low.

We analyse the proposed EU climate policy strategy to achieve a 20% reduction of greenhouse gas emissions by 2020 versus 1990 levels combined with a stricter allowance allocation in a potential third trading period of the EU ETS (which we approximate by a 20% decrease of *NAP II* allocation factors). We find that the stricter reduction targets and tighter allowance allocation in 2020 results in a substantially higher allowance price and induces larger levels of production and aggregate welfare losses than under *NAP II* emissions regulation and the national Kyoto targets in 2010. However, it shows that facilitating government CDM under a (post) Kyoto Protocol leads to comparable price and macroeconomic effects in 2010 and 2020. The extensive economic flexibility in emissions abatement by means of CDM access for all sectors of the economy thus enables EU Member

States to implement far stricter climate policy measures at comparable macroeconomic adjustment costs. Our simulated competitiveness implications of EU climate policy in 2020 confirm these findings at the economy-wide level. Moreover, it shows that the stricter climate policy in 2020 induces competitiveness gains for the covered EU ETS sectors vis-à-vis the remaining industries of EU economies, while it may generate losses vis-à-vis comparable sectors outside Europe.

We also assess the impacts of raising the share of conventional biofuels to at least 10% within the policy environment of the EU ETS. Within this specific policy environment our analysis shows that the emissions price of the EU ETS is indeed hardly affected when various targets for the share of biofuels in transport fuels are met. Hence, promoting biofuel use in road transport is a form of enhancing the use of renewables that will not - by lowering the emissions price – hinder the commercial advent of cleaner technologies in EU ETS sectors. Increasing biofuel shares in transport fuel use does have a mitigating effect on the policy efforts needed to curb emissions in the other sectors, which is reflected by a drop in the carbon taxes at the Member State level. Hence, the negative impacts of these distortionary taxes on economic welfare will decline. The introduction of biofuels may, depending on the biofuel excise regime and the impact on the carbon tax, raise the user price of transport fuels, which affects economic welfare negatively. On balance the net effects on economic welfare turn out to be very small. When carbon taxes are very small the benefits of reducing them fall short of the extra burden of raising biofuel usage. Hence, overall economic welfare is declining in the new Member States. When biofuel targets are increased above 10% the negative impacts on welfare tend to dominate: the additional benefits of reducing distortionary carbon taxes tend to fall short of the extra costs of raising biofuel usage. The impacts on food prices of conventional biofuel promotion up to the 10% target turn out to be negligible. However, one should bear in mind however, that the WorldScan model does not focus on the peculiarities of agricultural production and food production. Meeting the 10% target would require an increase of the biofuel feedstock share in current global arable acreage from 1% to approximately 3%. Hence, large impacts on food prices are hardly to be expected. Full liberalisation of biofuel trade will make biofuels cheaper (enhancing welfare) but leave carbon taxes in non-ETS sectors at a higher level (reducing welfare). On balance economic welfare does increase when biofuels are imported rather than produced domestically, but the change is rather small. For ethanol-exporting Brazil the welfare increase will be most noticeable.

All in all, our policy analyses suggest that the overall competitiveness effects of strengthening the EU Emissions Trading Scheme and accelerating the development of sustainable biofuels are limited. Moreover, we find that the interactions between these two environmental policies are not pronounced. A central insight of our analysis is that the scope of economic impacts and competitiveness effects crucially depends on the design of the respective policy instrument – such as the target share of biofuels in total transportation fuel use or the stringency of allowance allocation within the EU ETS. Moreover, the national and EU-wide economic impacts are determined by complementary environmental policy measures applying to the same or other segments of European economies, such as unilateral energy taxation of EU Member States. Our methodology-based analysis thus suggests that while assessing the national competitiveness effects of environmental regulation is of great importance, the respective (heterogeneous) sectoral impacts may provide extensive insights as they are able to decompose the economy-wide effects.

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Annex 1: Competitiveness effects of the EU ETS

Annex 1a: Nontechnical description of the core PACE model

In order to quantify the competitiveness effects of EU ETS at the sectoral and economy-wide level, it is crucial to account for complexities such as detailed production structures and various market interactions. Computable general equilibrium (CGE) models have become the standard tool for applied economy-wide analysis of policy measures (for surveys on applications to environmental policies see Conrad 1999, 2001). The main virtue of the CGE approach is its comprehensive representation of price-dependent market interactions based on rigorous microeconomic theory. The simultaneous explanation of the origin and spending of agents' incomes makes it possible to address both economy-wide efficiency as well as distributional impacts of policy interference.

For our numerical analysis of competitiveness implications of EU ETS, we adapt the *PACE* model (*Policy Assessment based on Computable Equilibrium*; see Böhringer and Vogt 2003), a standard CGE model of open economies, in order to reflect key features of the EU ETS from a single country perspective: EU Member States are committed to specific carbon emissions constraints $\overline{CO2}$ agreed upon in the EU Burden Sharing Agreement. Each Member State must specify a cap \overline{E} and the allocation rule for free emissions allowances to energy-intensive installations in five downstream sectors that are eligible for international emissions trading (electricity, oil refineries, iron and steel, non-ferrous mineral industries, and paper and pulp production). As the EU trading system covers only energy-intensive industries, it implies complementary domestic abatement policies for the remaining sectors in order to comply with the remaining national emissions budget($\overline{CO2}-\overline{E}$).

Figure 10 provides a diagrammatic structure of the generic open-economy model. A representative agent RA_r in each region r is endowed with three primary factors: labour \overline{L}_r , capital \overline{K}_r , and fossil-fuel resources $\overline{Q}_{ff,r}$ (used for fossil fuel production). The representative agent maximizes utility from consumption of a composite good C_r which combines demands for energy and non-energy commodities at a constant-elasticity-of-substitution (CES). Production Y_{ir} of commodities i in region r is captured by nested separable CES functions that describe the price-dependent use of capital, labour, energy and material in production. Carbon emissions are linked in fixed proportions to the emissions-relevant use of fossil fuels with carbon coefficients differentiated by the specific carbon content of fuels. Carbon abatement can take place by fuel switching or energy savings in production and final consumption.



Figure 10: Diagrammatic overview of the model structure

Trade is specified using the Armington approach of product heterogeneity (Armington, 1969), so domestic and foreign goods of the same variety are distinguished by origin. All goods used on the domestic market in intermediate and final demand correspond to a CES composite A_{ir} that combines the domestically produced variety Y_{ir} and imports M_{ir} of the same variety from other regions. Domestic production Y_{ir} either enters the formation of the Armington good A_{ir} or is exported to satisfy the import demand of other regions. Trade with other regions is represented by a set of horizontal export demand and import supply functions at exogenous world import and export prices. A balance of payment constraint, which is warranted through flexible exchange rates, incorporates the benchmark trade deficit or surplus.

The model is based on consistent accounts of national production and consumption, trade and energy flows for 2001 as provided by the GTAP database (for an introduction to GTAP data see Dimaranan and McDougall 2002). The GTAP database version 6 that represents global production and trade data for 87 regions and 57 sectors in the baseyear 2001. For this application, the data set will be aggregated regionally and sectorally in order to reduce the dimensionality of the computational problem, but at the same time keep sufficient detail for the carbon-relevant regions and sectors. Reconciliation of these data sources yields the benchmark data of our model.

Annex 1b: Model regions and sectors

Abbr.	Region
aut	Austria
bel	Belgium
deu	Germany
dnk	Denmark
fin	Finland
fra	France
gbr	United Kingdom
grc	Greece
Irl	Ireland
ita	Italy
nld	Netherlands
prt	Portugal
esp	Spain
swe	Sweden
hun	Hungary
pol	Poland
cze	Czech Republic
svk	Slovakia
bgr	Bulgaria
rom	Romania
1 1	
bai	Bartic States (Estonia, Latvia, Litnuania)
reu	Rest of EU (Slovenia, Luxembourg, Maita, Cyprus)
inn	Japan
JPII can	Canada
rus	Russian Federation
xsii	Rest of Former Soviet Union
aus	Australia
nzl	New Zealand
usa	United States
chn	China including Hong Kong
ind	India
xes	Rest of East South Asia
bra	Brazil
csa	Central and South America
zaf	South Africa
xrw	Rest of World

Table 13: PACE model regions

 Table 14: PACE model sectors

Sector	Sectors covered by the EU ETS directive (DIR):									
oil	Refined oil products									
ele	Electricity									
ore	Iron and steel industry									
ppp	Paper products and publishing									
nfm	Non-ferrous metals									
nmm	Mineral products									
Other energy-intensive sectors:										
Other	energy-intensive sectors:									
<i>Other</i> coa	energy-intensive sectors: Coal									
Other coa cru	energy-intensive sectors: Coal Crude oil									
Other coa cru gas	energy-intensive sectors: Coal Crude oil Natural gas									
Other coa cru gas	energy-intensive sectors: Coal Crude oil Natural gas									
Other coa cru gas Sector	energy-intensive sectors: Coal Crude oil Natural gas rs not covered by the EU ETS directive (NDIR):									
Other coa cru gas Sector roi	energy-intensive sectors: Coal Crude oil Natural gas rs not covered by the EU ETS directive (NDIR): Rest of Industry - Other manufactures and services									

Annex 1c: Benchmark data sources

The main data source underlying the model is the GTAP version 6 database that represents global production and trade data for 87 regions and 57 sectors in the baseyear 2001. For this application, the data set has been aggregated to 36 regions and 10 sectors in order to reduce the dimensionality of the computational problem, but at the same time keep sufficient detail for the carbon-relevant regions and sectors (see Table 13 and Table 14 in Annex 1b). Reconciliation of these data sources yields the benchmark data of our model.

In a second step, we perform a forward calibration of the 2001 economies to the target years, which are 2005, 2010 and 2020 for our assessments of current and future EU ETS designs. For this purpose we employ baseline estimates for GDP growth, energy demand and future energy prices as well as carbon emissions. We rely on energy trends for EU Member States (European Commission, 2003) and on international energy projections for non-European economies (US Department of Energy, 2005). The magnitude and distribution of costs associated with the implementation of future emissions constraints depend on the baseline projections for GDP, fuel prices, energy efficiency improvements etc. In our comparative-static framework, we measure the costs of abatement relative to a baseline, i.e. relative to the BAU structure of the model regions for the target year.

As an overview on the emissions data underlying our analysis, Table 15 shows baseline emissions and reduction requirements of Annex-B countries in 2005 and 2010. Contrasting baseline carbon emissions in the respective year to the respective Kyoto reduction target vs. 1990 emissions levels yields the effective emissions reduction requirement of a region.

	Baseli	ne CO ₂ Emissi (Mt of CO ₂)	ons	Kyoto reduction target (% vs. 1990)	Effective reduction requirement (% vs. baseline)			
Year	1990	2005	2010	2010	2005	2010		
Austria	55.1	60.3	60.7	13.0	20.5	21.0		
Belgium	106.3	113.6	112.2	7.5	13.4	12.4		
Denmark	52.8	48.4	46.6	21.0	13.8	10.5		
Finland	53.2	55.4	51.4	0.0	4.0	-3.5		
France	354.1	389.9	406.4	0.0	9.2	12.9		
Germany	943.0	815.6	823.6	21.0	8.7	9.5		
United Kingdom	569.1	526.9	519.4	12.5	5.5	4.1		
Greece	71.1	97.8	105.6	-25.0	9.1	15.8		
Ireland	29.7	44.6	46.5	-13.0	24.8	27.8		
Italy	390.8	416.7	422.2	6.5	12.3	13.5		
Netherlands	152.9	164.6	174.0	6.0	12.7	17.4		
Portugal	39.0	61.2	67.9	-27.0	19.1	27.1		
Spain	203.8	292.6	302.6	-15.0	19.9	22.5		
Sweden	50.6	52.6	54.0	-4.0	0.0	2.5		
Luxemburg	10.6	10.6	11.6	28.0	28.0	34.2		
Hungary	68.5	57.7	62.2	6.0	-11.6	-3.5		
Poland	340.1	272.5	286.2	6.0	-17.3	-11.7		
Cyprus	4.5	7.5	8.1	-	-	-		
Czech Republic	158.8	103.2	103.1	8.0	-41.6	-41.7		
Malta	2.5	2.9	3.3	-	-	-		
Slovakia	51.4	37.3	41.6	8.0	-26.8	-13.7		
Slovenia	10.9	14.2	14.0	8.0	29.4	28.4		
Estonia	36.6	15.6	14.2	8.0	-115.8	-137.1		
Latvia	16.9	7.5	8.3	8.0	-107.3	-87.3		
Lithuania	32.2	13.7	17.2	8.0	-116.2	-72.2		
Bulgaria	73.6	42.2	42.9	8.0	-60.5	-57.8		
Romania	168.6	82.7	90.3	8.0	-87.6	-71.8		
Canada	473.0	613.0	681.0	6.0	27.5	34.7		
Japan	990.0	1229.2	1211.0	6.0	24.3	23.2		
Russia	2347.0	1586.8	1732.0	0.0	-47.9	-35.5		
Rest of FSU	1452.0	914.4	1072.0	0.0	-58.8	-35.4		
Australia	294.0	467.1	520.0	-8.0	32.0	38.9		
United States	4989.0	5995.9	6561.0	7.0	22.6	29.3		

Table 15: Baseline emissions and Kyoto reduction requirements of ratifying Annex-B regions

Sources: European Commission (2003): European Energy and Transport Trends to 2030; US Department of Energy (2005): International Energy Outlook; own calculations

The table shows a mixed picture of effective reduction requirements for EU-27 Member States, ranging from reductions of over 30 percent versus baseline emissions levels to negative requirements of over 100 percent for Eastern European states. This translates into a relatively low emissions constraint for the aggregate EU-27. Taking into account other Annex B countries that ratified the Kyoto Protocol such as Canada and Japan, however, increases the aggregate reduction requirement. For Russia and Ukraine we observe large negative effective reduction requirements. For the non-ratifying Annex B countries Australia and the United States Table 15 shows relatively large effective reduction requirements versus BAU implied by their (non-binding) emissions reduction targets.

Annex 1d: Competitiveness indicators

We implement the following indicators into the PACE model in order to account for sectoral and economy-wide competitiveness effects:

• Terms of Trade (ToT):

$$ToT_i = \frac{P_{X_i}}{P_{M_i}}$$

where P_{X_i} denotes the price of exports and P_{M_i} denotes the price of imports, for a particular region *i* the ToT index expresses the price of its exports in terms of its imports. The Terms of Trade deteriorate as the index falls.

• Revealed Comparative Advantage (RCA)

For a particular region and sector, this index compares the ratio of exports by a specific sector over its imports with the ratio of exports over imports across all sectors of the region. Letting X denote exports, M imports, i the region and j the sector, the index for revealed comparative advantage (RCA) for region i in sector j can be presented as follows:

$$RCA_{ij} = \frac{X_{ij} / M_{ij}}{\sum_{j} X_{ij} / \sum_{j} M_{ij}}$$

If the sectoral export-import ratio is identical to the economy-wide ratio, the RCA index takes the neutral value of one ($RCA_{ij} = 1$). Thus, a region *i* is said to have a revealed comparative advantage in sector *j* if the RCA index exceeds unity ($1 < RCA \le \infty$). By contrast, a region *i* has a revealed comparative disadvantage in sector *j* if the RCA index takes the values between zero and one ($0 \le RCA < 1$).

• Relative World Trade Shares (RWS)

This index compares the ratio of country's exports in a certain sector over the world's exports in this sector with the ratio of country's overall exports over the world's exports in all sectors:

$$RWS_{ij} = \frac{X_{ij} / \sum_{i} X_{ij}}{\sum_{j} X_{ij} / \sum_{i} \sum_{j} X_{ij}}.$$

The RWS indicator lies in the same value range as the RCA indicator $(0 \le RWS_{ij} \le \infty)$ and thus may be interpreted in a similar way.

• Relative Trade Balance (RTB)

This index compares the trade balance (exports minus imports) for a product to the total trade (exports plus imports) of that product.

$$RTB_{ij} = \frac{X_{ij} - M_{ij}}{X_{ij} + M_{ij}}$$

The RTB index has the neutral value of zero (*RTB* $_{ij} = 0$) and lies in the value range of $-1 \le RTB_{ij} \le 1$.

Annex 1e: Quantitative simulation results

Scenario Region	NOTRADE NAP I		NAP I_ CDM_dir	NAP I_ CDM_all	NAP II	NAP II_ CDM_dir	NAP II_ CDM_all					
		20	05		2010							
	CO_2 value in DIR sectors (in constant \$US per ton of CO_2)											
EU-27	_	0.20	0.21	0	9.53	3.70	4.19					
EU-15	_	0.20	0.21	0	9.53	3.70	4.19					
EU-10	_	0.20	0.21	0	_	_	_					
EU-12	-	-	-	-	9.53	3.70	4.19					
			Produc	tion impact (in % vs	. BaU)							
EU-27	-0.24	-0.86	-0.86	-0.04	-0.54	-0.52	-0.05					
EU-15	-0.25	-0.91	-0.91	-0.05	-0.56	-0.55	-0.05					
EU-10	-0.16	-0.25	-0.25	-0.01	_	_	_					
EU-12	_	_	_	_	-0.21	-0.15	-0.04					
			Welfa	re impact (in % of I	HEV)							
<i>EU-27</i>	-0.04	-0.37	-0.37	-0.02	-0.10	-0.10	-0.02					
EU-15	-0.04	-0.38	-0.38	-0.02	-0.11	-0.10	-0.02					
EU-10	-0.06	-0.13	-0.13	-0.01	_	_	_					
EU-12	_	_	_	_	-0.02	-0.06	-0.01					

 Table 16: EU Emissions Trading Scheme – Emissions-market and macroeconomic indicators for aggregate EU regions

Scenario Region	NOTR	ADE	NA	PI	NAI CDM	P I_ [_dir	NAI CDM	P I_ 1_all	NAI	P II	NAF CDM	NAP II_ CDM_dir		PII_ 1_all
				200	05				2010					
						Terms of T	Frade imp	act (in %	vs. BAU)					
<i>EU-27</i>		-0.70		-1.40		-1.40		-0.10		-1.20		-1.10		-0.10
EU-15		-0.70		-1.50		-1.50		-0.10		-1.20		-1.20		-0.10
<i>EU-10</i>		0		-0.30		-0.30		0		_		_		_
EU-12		-		-		_		-		-1.20		-0.20		-0.10
					Revealed	Compara	tive Advar	ntage – RC	CA (in % v	s BAU)				
	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR
<i>EU-27</i>	-2.29	0.28	3.40	-0.39	3.42	-0.40	0.22	-0.03	0.84	-0.10	1.64	-0.20	-0.38	0.05
EU-15	-2.77	0.32	3.74	-0.42	3.76	-0.43	0.22	-0.03	1.30	-0.16	1.91	-0.23	-0.22	0.03
<i>EU-10</i>	1.15	-0.19	0.54	-0.08	0.55	-0.08	0.19	-0.03	-	_	_	_	_	_
EU-12	-	_	-	-	_	_	_	_	-3.10	0.55	-0.86	0.17	-1.67	0.28
					Relativ	e World T	rade Shar	res – RWS	(in % vs I	BAU)				
	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR
<i>EU-27</i>	-1.42	0.23	0.24	0.01	0.23	0.01	-0.06	0	-0.50	0.10	-0.20	0.05	-0.29	0.03
EU-15	-1.81	0.26	0.26	0	0.25	-0.01	-0.07	0	-0.35	0.07	-0.16	0.04	-0.20	0.02
<i>EU-10</i>	1.22	-0.12	-0.02	0.12	-0.03	0.12	-0.02	-0.01	-	_	_	_	_	_
EU-12	-	_	-	-	_	_	_	_	-1.78	0.42	-0.68	0.21	-0.94	0.16
					Rela	tive Trade	Balance	– RTB (in	n % vs BA	U)				
	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR
<i>EU-27</i>	-145.54	-12.37	92.62	-59.51	93.63	-59.55	7.57	-2.87	-13.09	-35.57	19.93	-36.49	-18.32	-1.43
EU-15	-550.06	-12.96	329.08	-64.9	332.29	-64.94	22.75	-3.16	4.57	-39.64	61.88	-40.33	-27.99	-2.07
<i>EU-10</i>	14.97	-4.33	3.54	-7.76	3.78	-7.77	2.80	-0.06	_	_	_	_	_	_
EU-12	-	-	_	-	_	_	-	_	-24.76	1.87	-7.46	-1.21	-12.09	4.54

Table 17: EU Emissions Trading Scheme – Economy-wide and sectoral competitiveness indicators for aggregate EU regions

Scenario Region	NOTR	ADE	NA	P I	NAI CDM	P I_ [_dir	NAI CDM	P I_ [_all	NAI	P II	NAF CDM	NAP II_ CDM_dir		PII_ [_all
				200	95				2010					
						Terms of T	Frade imp	act (in %)	vs. B AU)					
USA		0.30		0.50		0.50		0.10		0.40		0.40		0.10
Japan		0		-0.10		-0.10		0		0.00		0.00		0.00
China		0.20		0.20		0.20		-0.10		0.20		0.10		0.00
India		0.20		0.40		0.40		-0.20		0.20		0.10		-0.10
					Revealed	Compara	tive Advar	ntage – RC	CA (in % v	s BAU)				
	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR
USA	1.38	-0.11	-1.82	0.14	-1.78	0.14	0.13	-0.01	-0.50	0.04	-0.80	0.06	0.40	-0.03
Japan	0.88	-0.07	-2.38	0.20	-2.33	0.19	0.28	-0.02	-0.93	0.08	-1.12	0.09	0.50	-0.04
China	0	-0.07	0	0.18	0	0.18	0	0.07	0.00	0.06	0.00	0.11	0.00	0.04
India	0	-0.17	0	0.24	0	0.24	0	0.08	0.00	0.06	0.00	0.14	0.00	0.03
					Relativ	e World T	rade Shar	es – RWS	(in % vs I	BAU)				
	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR
USA	39.81	-0.07	38.44	-0.08	38.44	-0.08	37.88	-0.01	40.53	-0.07	40.18	-0.07	39.77	-0.01
Japan	39.81	-0.08	38.73	-0.09	38.74	-0.09	38.06	-0.02	40.72	-0.08	40.44	-0.07	39.93	-0.02
China	0	-0.05	0	-0.08	0	-0.09	0	0.01	0.00	-0.06	0.00	-0.06	0.00	0.01
India	0	-0.11	0	-0.02	0	-0.02	0	0.03	0.00	-0.05	0.00	-0.03	0.00	0.01
					Rela	tive Trade	Balance	– RTB (in	n % vs BA	U)				
	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR
USA	-10.75	1.90	8.62	6.66	8.30	6.68	-1.39	0.82	0.45	4.99	2.73	5.10	-3.66	0.77
Japan	15.26	-1.07	-43.85	1.60	-42.82	1.55	4.93	-0.32	-8.13	0.67	-9.78	0.87	4.24	-0.62
China	0	0.95	0	4.20	0	4.22	0	-0.49	0.00	2.63	0.00	2.33	0.00	-0.07
India	0	0.11	0	2.28	0	2.27	0	-0.41	0.00	0.89	0.00	0.82	0.00	-0.31

Table 18: EU Emissions Trading Scheme – Economy-wide and sectoral competitiveness indicators for central non-EU regions

Scenario Region	EU	EU^+	EU^{++}	EU_ CDM_all	EU ⁺ _ CDM_all	EU ⁺⁺ _ CDM_all
				2010		
		CO_2 va	ulue in DIR sectors (in	constant \$US per ton o	of CO_2)	
<i>EU-27</i>	11.37	9.68	7.01	7.86	7.86	5.86
EU-15	11.37	9.68	7.01	7.86	7.86	5.86
EU-12	11.37	9.68	7.01	7.86	7.86	5.86
			Production impa	ct (in % vs. BaU)		
<i>EU-27</i>	-0.54	-0.51	-0.51	-0.12	-0.12	-0.12
EU-15	-0.57	-0.55	-0.54	-0.13	-0.13	-0.12
EU-12	-0.16	-0.11	-0.10	-0.04	-0.04	-0.03
			Welfare impact	(in % of HEV)		
EU-27	-0.08	-0.08	-0.08	-0.01	-0.01	-0.01
EU-15	-0.09	-0.08	-0.08	-0.02	-0.02	-0.01
EU-12	0.03	0.02	0.01	0.01	0.01	0.00

Table 19: Linked Emissions Trading Schemes – Emissions-market and macroeconomic indicators for aggregate EU regions

Scenario Region	E	U	EU	·J+	EU	7++	EU CDM	U_ 1_all	EU CDM	7+ 1_all	EU CDM	***
						20.	10					
					Terms o	f Trade imp	oact (in % v	s. BAU)				
<i>EU-27</i>		-1.10		-1.10		-1.10		-0.20		-0.20		-0.20
EU-15		-1.20		-1.20		-1.20		-0.30		-0.30		-0.20
EU-12		-0.20		-0.20		-0.10		0.00		0.00		0.10
		Revealed Comparative Advantage – RCA (in % vs BAU)										
	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR
<i>EU-27</i>	2.11	-0.25	1.27	-0.15	1.89	-0.23	0.06	-0.01	0.06	-0.01	0.53	-0.06
EU-15	2.64	-0.31	1.73	-0.21	2.25	-0.26	0.33	-0.04	0.33	-0.04	0.72	-0.08
EU-12	-2.44	0.43	-2.71	0.48	-1.29	0.24	-2.19	0.37	-2.19	0.37	-1.08	0.18
				Rel	lative World	Trade Sha	res – RWS	(in % vs BA	U)			
	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR
EU-27	1.53	0.00	0.50	0.05	0.98	-0.01	-0.25	0.01	-0.25	0.01	0.13	-0.03
EU-15	1.75	-0.03	0.68	0.02	1.09	-0.02	-0.10	0.00	-0.10	0.00	0.22	-0.04
EU-12	-0.30	0.35	-0.99	0.38	-0.03	0.22	-1.39	0.21	-1.39	0.21	-0.63	0.08
				1	Relative Tra	de Balance	- RTB (in	% vs BAU)				
	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR
<i>EU-27</i>	36.94	-38.51	5.44	-35.52	30.30	-36.61	-6.79	-6.62	-6.78	-6.62	12.28	-7.57
<i>EU-15</i>	123.60	-43.17	45.21	-40.08	92.27	-40.92	6.37	-8.29	6.37	-8.29	42.32	-9.02
<i>EU-12</i>	-18.53	4.43	-20.19	6.38	-9.63	2.96	-15.07	8.76	-15.07	8.77	-6.86	5.81

Table 20: Linked Emissions Trading Schemes – Economy-wide and sectoral competitiveness indicators for aggregate EU regions

Scenario Region	E	U	<i>EU</i> ⁺⁺ <i>EU</i> ⁺⁺		7++	EU CDM	V_ [_all	EU CDM	"[EU CDM	++ [_all	
						20	10					
					Terms of	f Trade imp	act (in % v	s. BAU)				
Japan		-1.70		-4.00		-3.90		-0.20		-0.20		-0.10
Canada		0.70		2.30		2.30		0.50		0.50		0.60
Russia		7.70		8.00		5.20		2.30		2.30		0.00
		Revealed Comparative Advantage – RCA (in % vs BAU)										
	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR
Japan	-3.44	0.29	15.31	-1.05	16.40	-1.12	1.71	-0.14	1.71	-0.14	2.39	-0.19
Canada	-13.62	2.11	15.38	-2.01	16.83	-2.20	-0.73	0.08	-0.73	0.08	0.30	-0.07
Russia	2.69	-1.69	0.86	-0.82	-9.26	3.22	2.48	-1.25	2.48	-1.25	-6.05	2.05
				Rel	ative World	Trade Sha	res – RWS	(in % vs BA	U)			
	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR
Japan	38.31	0.17	43.82	-0.22	44.61	-0.26	40.42	-0.06	40.42	-0.06	41.01	-0.09
Canada	31.66	1.29	52.34	-1.40	53.63	-1.56	38.89	0.04	38.89	0.04	39.85	-0.07
Russia	45.82	-1.73	43.86	-0.98	37.32	2.41	41.23	-1.13	41.23	-1.13	41.23	1.64
				1	Relative Tra	de Balance	– RTB (in	% vs BAU)				
	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR
Japan	-43.95	-25.73	84.53	-90.55	92.92	-90.43	12.76	-5.45	12.76	-5.45	18.78	-5.44
Canada	-30.85	-25.63	35.51	-1.95	38.24	-0.62	-0.48	-5.43	-0.48	-5.43	1.96	-4.72
Russia	7.67	-5.69	6.54	-6.88	-3.65	-8.32	3.66	-1.02	3.66	-1.02	-4.96	-2.01

Table 21: Linked Emissions Trading Schemes – Economy-wide and sectoral competitiveness indicators for ratifying non-EU regions

Scenario Region	E	U	EU	J ⁺	EU	7 ++	EU CDM	U_ [_all	EU CDM	7+_ 1_all	EU CDM	*** [all
						20	10					
					Terms o	f Trade imp	oact (in % v	s. <i>BAU</i>)				
USA		-1.10		-1.20		-1.20		0.30		0.30		0.30
Australia		1.40		1.10		1.10		2.80		2.80		2.80
China		0.60		0.60		0.60		-0.50		-0.50		-0.50
India		0.90		0.80		0.80		-1.10		-1.10		-1.10
			<u> </u>	Revea	led Compa	rative Adva	ntage – RC	A (in % vs l	BAU)	<u>,</u>		
	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR
USA	-5.23	0.45	-10.43	0.92	-10.54	0.94	-0.56	0.05	-0.56	0.05	-0.65	0.06
Australia	-42.14	10.25	-43.40	10.61	-43.30	10.58	-7.88	1.67	-7.88	1.67	-7.66	1.61
China	0.00	-0.21	0.00	-0.02	0.00	-0.03	0.00	0.15	0.00	0.15	0.00	0.13
India	0.00	-0.32	0.00	-0.12	0.00	-0.12	0.00	0.22	0.00	0.22	0.00	0.21
				Rel	ative World	Trade Sha	res – RWS	(in % vs BA	<i>U</i>)			
	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR
USA	38.75	0.12	34.43	0.28	34.44	0.28	38.95	0.03	38.95	0.03	38.95	0.03
Australia	-4.53	8.31	-6.49	8.57	-6.23	8.53	31.49	1.40	31.49	1.40	31.89	1.34
China	0.00	-0.16	0.00	-0.10	0.00	-0.10	0.00	0.02	0.00	0.02	0.00	0.02
India	0.00	-0.20	0.00	-0.12	0.00	-0.13	0.00	0.08	0.00	0.08	0.00	0.07
				1	Relative Tra	de Balance	- RTB (in	% vs BAU))			
	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR	DIR	NDIR
USA	46.75	-6.98	87.67	-2.84	88.56	-2.73	2.02	3.43	2.02	3.43	2.67	3.58
Australia	-81.33	-51.19	-85.37	-51.20	-85.14	-50.88	-7.90	-20.10	-7.90	-20.10	-7.54	-19.90
China	0.00	4.00	0.00	6.16	0.00	6.02	0.00	-3.43	0.00	-3.43	0.00	-3.52
India	0.00	1.91	0.00	2.36	0.00	2.30	0.00	-2.83	0.00	-2.83	0.00	-2.85

Table 22: Linked Emissions Trading Schemes – Economy-wide and sectoral competitiveness indicators for non-ratifying non-EU regions

Annex 2: Empirical policy analysis – data and approach

Data on EU ETS allocation

Our analysis is based on data on approximately 12,000 installations being covered by the EU ETS legislation. Each installation has an "operator holding account" in its national registry to which the allowances are submitted, and each Member State of the European Union has an obligation to interlink the national registry with the EU-wide databank *Community transaction log*. The Community transaction log's web pages contains information on allowances that have been allocated in accordance with the final National Allocation Plans, verified emissions, surrendered allowances and compliance status for all installations in Member States with registries. We assessed the emissions data from the Community Transaction Log in two steps:

- Data extraction from the Community transaction log and data processing
- Aggregation of installation-level data on the sectoral and national level

The AMADEUS database

Besides the emissions data from the Community transaction log, economic data is of great importance for assessing the competitiveness effects of the EU ETS. AMADEUS is a comprehensive, pan-European database containing economic and financial information on 9 million public and private companies. In this analysis, cash flow data, calculated as net income (profits) plus changes in deferred taxes, as well as information on the number of employees of the respective firms, both from 2003 and 2004, is used. Sectoral information is based on the four digit NACE (industry) codes of the firms provided by AMADEUS. According to this, we have created several indicator variables that are given the value 1 for a company that forms part of the respective industry, and 0 otherwise. The indicator variables are "electricity" (13% of the sample firms; NACE code between 4000 and 4020, "production and distribution of electricity"), "energy" (7% of the sample firms; NACE code between 4020 and 4500, "manufacture of gas; distribution of gaseous fuels through mains", "steam and hot water supply", "collection, purification and distribution of water"), "pulp and paper" (10% of the sample firms; NACE code between 2100 and 2200, industry subsection "manufacture of pulp, paper, and paper products"), "mining" (10% of the sample firms; NACE code between 1000 and 1500, industry subsection "mining and quarrying"), "coke & petroleum" (2% of the sample firms; NACE code between 2300 and 2400, "manufacture of coke, refined petroleum products and nuclear fuel"), "other manufacturing" (24% of the sample firms; NACE code between 2600 and 3700, manufacture of non-metallic mineral products, basic metals and fabricated metal products, machinery and equipment, electrical and optical equipment, transport equipment, other manufacturing), and "business" (5% of the sample firms; NACE code between 7000 and 7500, section "real estate, renting, and business activities").

The CREDITREFORM database

This database is a financial and economic database that includes information of sales and employment of German firms. It is coherent with the AMADEUS database. From the CREDITREFORM database, we use levels and differences from firm revenue and employment data between 2002 and 2005, from AMADEUS, we use generated sectoral indicator variables (see above). Those data have been matched with the allocation factor (allowances allocated divided by verified emissions) from the "community transaction log".

Empirical Approach

For our regression analysis, we apply ordinary least squares (OLS) technique. Given that, following a Breusch-Pagan test, the null hypothesis of no heteroskedasticity can be rejected in our regressions at the 1%- (dependent variable: revenues 2005-2004) and 10%-level (no. employees 2005-2004), respectively, we use White robust standard errors so that significance tests for the estimated model parameters are valid under circumstances of heteroskedasticity. The results obtained are robust to controlling for outliers that could have a strong influence on the regression results. This has been tested in a so-called "robust regression" using Huber-weights in order to control for outliers.

Annex 3: The potential for biofuels alongside the EU ETS

Annex 3a: The WorldScan model

The quantitative, economic characteristics of the various scenarios are based on simulation outcomes from WorldScan (Lejour et al., 2006), which is a general equilibrium model for the world economy. This model was developed in the 1990s for scenario construction and is often used both for scenario studies and policy analyses, also in the field of energy markets and global warming (see, for example, Bollen et al., 2004, Bollen et al., 2005, and Boeters et al., 2007). The model is based on neo-classical theory and shows the outcome of microeconomic behaviour of the agents, subject to equilibrium conditions and additional restrictions. In establishing an equilibrium for the global economy, the welfare of the various consumers is maximised and all balance equations and eventual policy restrictions (such as CO_2 emissions ceilings or biofuel targets) are met.

Regions	Sectors	Inputs
Germany	Cereals	Factors
France	Oilseeds	Low-skilled labour
United Kingdom	Sugar crops	High-skilled labour
Italy	Other agriculture	Capital
Spain	Minerals	Land
Netherlands	Oil	Natural resources
Other EU-15	Coal	
Poland	Petroleum, coal products	Energy carriers:
Bulgaria and Romania	Natural gas	Coal
Other new Member States	Electricity	Petroleum, coal products
United States	Energy intensive and chemical	· •
	goods	Natural gas
Other OECD	Vegetable oils	Biodiesel
Former Soviet Union	Other food products	Ethanol
Brazil	Non-food consumer goods	Other renewables
China	Capital goods and durables	
India	Road and rail transport	Other intermediates
Other South East Asia	Other transport	Cereals
Rest of World	Other services	Oilseeds
	Biodiesel	Sugar crops
	Ethanol	Other agriculture
		Minerals
		Oil
		Electricity
		Energy intensive and chemical goods
		Vegetable oils
		Other food products
		Non-food consumer goods
		Capital goods and durables
		Road and rail transport
		Other transport
		Other services

Table 23: Overview of regions, sectors and production inputs in WorldScan

General equilibrium models generally take account of the interdependencies between individual markets for various goods and production factors. It is usually assumed that there are no frictions in these markets, so that each of the production factors is fully utilised. In addition, the use of production factors can be immediately reallocated across the various sectors. This means that the model outcomes for the policy scenarios can be seen as 'longterm' reactions to the policy used: the costs of restructuring and modifications in the medium term are not taken into account.

WorldScan takes its data for the base year (2001) from the GTAP-6 database (Dimanaran and McDougall, 2006), which contains integrated data of bilateral trade flows and input-output data for 57 sectors and 87 countries (or groups of countries). The WorldScan version used in this study distinguishes twenty markets for goods and services and factor markets for labour, capital and agricultural land in each of the 20 countries and regions shown in Table 23. Six different energy carriers are distinguished: coal, oil refinery products, natural gas, biodiesel, ethanol, and other renewable energy. Only the first three of these contribute to the CO_2 emissions generated by the model.

Annex 3b: Details of convential biofuel implementation

Table 24: Biofuel production costs in euro	per toe p	produced	
Biodiesel from crude vegetable oils (EU-27)	672		
Inputs			
Crude vegetable oil	596		
Energy	52		
Alcohol	27		
Capital	46		
Labour	11		
Byproduct			
Glycerin	-61		
Ethanol from sugar cane (Brazil)	368	Ethanol from sugar beet (EU-27)	628
Inputs			
Sugar crops	217		515
Chemicals	20		22
Energy			38
Capital	17		113
Labour	114		27
Byproducts			
Animal feed			-88
Ethanol from maize (USA)	478	Ethanol from wheat (EU-27)	544
Inputs			
Cereals	348		502
Chemicals	44		-31
Energy	75		22
Capital	63		147
Labour	60		37
Byproducts			
Animal feed	-112		-134

Sources: IES, 2006; OECD, 2006; Smeets et al., 2005

Compilation: CPB

At the basis of the biofuel modelling in WorldScan are the cost data about biofuel production technologies from well-to-wheel analyses as compiled in Table 24. We selected from the cost assessments of IES (2006) the ones that correspond to an oil price of 25 euro per barrel as this price was closest to the oil price in our base year data for 2001. Table 24 gives information only for specific regions (EU, USA, Brazil). We assume that all regions can use these technologies, whenever the respective agricultural inputs are locally available. The availability assumptions about agricultural inputs are summarised in Table 25.

Table 25: Availability of agricultural inputs to biofuel production

	Biodiesel from veg. oil	Ethanol from sugar beet	Ethanol from wheat	Ethanol from corn	Ethanol from sugar
Germany	home	(home)	home	ves	no
France	home	(home)	home	ves	no
United Kingdom	home	(home)	home	yes	no
Italy	home	(home)	home	yes	no
Spain	home	(home)	home	yes	no
Netherlands	home	(home)	home	yes	no
Other EU 15	home	(home)	home	yes	no
Poland	home	(home)	home	yes	no
Other EU 25	home	(home)	home	yes	no
Bulgaria and Romania	home	(home)	home	yes	no
United States	yes	no	yes	home	no
Other OECD			yes	yes	
	yes	no	(Australia)	(Australia)	no
Brazil	yes	no	no	no	home
China	yes	no	no	no	yes
India	yes	no	no	no	yes
Other South East Asia	yes	no	no	no	yes
Former Soviet Union	no	no	no	no	no
Rest of the World	no	no	no	no	no

"home": original data available for active technology

"(home)": original data available, but inactive because too expensive

"yes": technology available, price of main input relative to home region necessary for calibration

"no": technology not available

In those regions where a technology is assumed to be in use, but where no original data on cost structures are available, we adjusted the cost of the main agricultural input according to Table 26. The costs of the other inputs are left unchanged.

	Biodiesel from veg. oil	Ethanol from sugar beet	Ethanol from wheat	Ethanol from corn	Ethanol from sugar cane
Germany	0.40	0.040	0.13		
France	0.40	0.040	0.13		
United Kingdom	0.40	0.040	0.13		
Italy	0.40	0.040	0.13		
Spain	0.40	0.040	0.13		
Netherlands	0.40	0.040	0.13		
Other EU 15	0.40	0.040	0.13		
Poland	0.40	0.040	0.13		
Other EU 25	0.40	0.040	0.13		
Bulgaria and Romania	0.40	0.040	0.13		
United States	0.38		0.12	0.10	
Other OECD	0.42		0.16	0.11	
Brazil					0.011
China	0.31				0.023
India	0.23				0.018
Other South East Asia	0.26				0.032
Former Soviet Union					
Rest of the World					

Sources: Trade Analysis System for vegetable oil, FAOSTAT for other products

For vegetable oil prices we took export prices for rapeseed oil (EU), palm oil (China, India, Rest of South East Asia), soya bean oil (USA) and specific other oils (Other OECD).

For ethanol, we choose for each country/region the cheapest available technology.

	Biodie	sel		Ethanol	
	before	after	before	after	production
	adjustment	adjustment	adjustment	adjustment	technology
Germany	672	470	544	343	wheat
France	672	449	544	321	wheat
United Kingdom	672	490	544	362	wheat
Italy	672	461	544	333	wheat
Spain	672	457	544	329	wheat
Netherlands	672	531	544	403	wheat
Other EU 15	672	459	544	331	wheat
Poland	672	457	544	330	wheat
Other EU 25	672	468	544	340	wheat
Bulgaria and Romania	672	480	544	352	wheat
United States	642	426	478	262	maize
Other OECD	701	529	513	341	maize
Brazil	538	336	369	167	sugar cane
China	419	239	544	365	sugar cane
India	463	251	507	295	sugar cane
Other South East Asia	448	257	783	591	sugar cane
Former Soviet Union	672	470	544	343	wheat
Rest of the World	672	449	544	321	wheat

Table 27: Biofuel production costs by region (before and after adjustment) in euro/toe

The technologies chosen are applied for the whole time span of the scenario. Hence, the possibility of an endogenous switch of technologies due to adjustments of relative prices is

not considered. With these specifications, we arrive at production technologies and total production costs given in Table 27.

The basic cost input data (columns "before adjustment" in Table 27) had to be adjusted because the implicit GTAP average energy prices for petroleum products considerably deviate from the (before-tax) price of transport fuels in the IEA data (van Leeuwen, 2006). In this situation, there are in principle three options for introducing biofuel prices into the model: keeping the price relation constant, keeping the absolute deviation constant or keeping the absolute biofuel price constant. We chose the second option because we consider the absolute price difference as most important for welfare analysis. As a consequence, the relative price difference between biofuels and conventional fuels is too high, and the absolute biofuel prices are too low in the model.

Biofuels and conventional fuels are inputs to the production sector "road and rail transport" and the consumption good "consumer transportation" (the share of consumer transportation in the total use of petroleum products by private households is listed in Table 28). All transport fuels are modelled as perfect substitutes. The split between biofuels and conventional fuels is exogenously determined by the biofuel targets, the split between biodiesel and ethanol follows the actual split between diesel and gasoline in 2001 (see Table 28). These shares do not respond endogenously to the relative price of the fuel varieties. The user price of the fuel aggregate is determined as the weighted average of the prices of the individual fuel varieties.

Tuble 20. Rota traffic fuel shares in wortuscan		
		Share of transport in
	Share of gasoline in total	total use of petroleum
	fuel use for transport	products by households
Germany	0.53	0.48
France	0.33	0.42
United Kingdom	0.57	0.17
Italy	0.48	0.33
Spain	0.33	0.27
Netherlands	0.44	0.02
Other EU 15	0.46	0.41
Poland	0.59	0.21
Other EU 25	0.47	0.06
Bulgaria and Romania	0.46	0.17
United States	0.78	0.12
Other OECD	0.66	0.16
Brazil	0.36	0.32
China	0.70	0.37
India	0.27	0.64
Other South East Asia	0.46	0.34
Former Soviet Union	0.75	0.22
Rest of the World	0.56	0.40

Table 28: Road traffic fuel shares in WorldScan

Source: IEA

For the calculations of the policy alternative of raising fossil fuel excises, we need information about the indirect CO_2 emissions in biofuel production. Though this information is implicit in the model, it is difficult to extract because the indirect effects extend over all sectors and countries, and because it is almost impossible to disentangle quantity and price induced effects. Therefore we used exogenous information about the indirect emissions of

biofuels (Table 29) to arrive at assessments of the emissions reductions involved in imposing a 10% biofuel share.

Table 29: CO ₂ emissions of different fuel varieties		
	gCO ₂ /km	in % of fossil fuel
	-	average
Ethanol from wheat	100	64.52
Ethanol from sugar beet	75	48.39
Ethanol from sugar cane	25	16.13
Ethanol from corn	100	64.52
Gasoline	160	103.23
Biodiesel	65	41.94
Diesel	150	96.77
Fossil fuels	155	

Source IES, 2006, WTW 2b

Note: corn taken from wheat

Biofuel targets are imposed on top of what is already used in the policy baseline. From 2004 onwards the biofuel shares are frozen in this baseline (see Table 30).

Table 30: Biofuel shares in the baseline scenario (cons	stant after 2004)	
• · · · ·	Biodiesel	Ethanol
Germany	1.22	0
France	0.74	0.16
United Kingdom	0	0
Italy	0.62	0
Spain	0	0.42
Netherlands	0	0
Other EU 15	0.16	0.09
Poland	0	0.59
Other EU 25	0.59	0.05
Bulgaria and Romania	0	0
United States	0	1.16
Other OECD	0	0.07
Brazil	0	23.22
China	0	0.35
India	0	0.32
Other South East Asia	0	0
Former Soviet Union	0	0
Rest of the World	0	0

Source: EurObserv'ER, June 2005

The import shares for biofuels are a highly speculative issue. This is because actual flows are low and erratic, so they cannot be used to extrapolate the structure of international trade in biofuels in a situation where these fuels would make up a considerable share of total fuel use and would be produced in many countries. We assume that in a reference situation where prices are the same for all import varieties, the biofuel import shares would mirror trade in vegetable oils (for biodiesel) and the production of the relevant inputs of ethanol (plus a home-market bias of 80%). The resulting reference shares are listed in Table 31.

Table 31: Reference import shares for biofuels

		Biodiesel			Ethanol	
	domestic	EU	outside EU	domestic	EU	outside EU
Germany	97.19	2.14	0.67	80.00	3.66	16.34
France	82.25	15.81	1.94	80.00	3.26	16.74
United Kingdom	71.97	24.22	3.81	80.00	3.85	16.15
Italy	82.03	14.03	3.94	80.00	4.05	15.95
Spain	94.86	1.91	3.23	80.00	4.07	15.93
Netherlands	36.45	19.99	43.56	80.00	4.21	15.79
Other EU 15	82.55	14.68	2.77	80.00	3.88	16.12
Poland	96.08	3.43	0.50	80.00	4.00	16.00
Other EU 25	90.06	8.54	1.40	80.00	3.92	16.08
Bulgaria and Romania	97.82	1.57	0.61	80.00	4.00	16.00

Annex 3c: Sensitivity analysis with respect to land allocation

The modelling of agricultural land supply for biofuel production is a key element of the comprehensive assessment of biofuel promotion. In partial equilibrium studies (OECD, 2006; Economic Commission, 2006) even moderate increases in biofuel use may have significant effects on land and food prices.

A global general equilibrium model like WorldScan cannot be expected to give a picture of land allocation that is as accurate as in specialised partial-equilibrium agricultural studies. Similar to the representation of production processes with aggregate, smooth constant-elasticity-of-substitution (CES) production functions, we must take resort to a relative coarse way of land supply modelling. The usual way of representing the intricacies of different sorts of land with varying yield coefficients per crop within a CGE framework is through constant-elasticity-of-transformation (CET) functions (see OECD, 2003, Golub et al., 2007). The CET setup assumes that transformation between different uses is possible, but not frictionless. The more land is claimed by a specific use, the higher becomes the marginal rate of transformation, i.e. the more units of land in other uses have to be sacrificed to generate one unit of land for the use in question.

It is obvious that such a modelling approach produces difficulties in interpretation. After all, one hectare of land remains one hectare, irrespectively of how exactly it is used. The outcome of the CET modelling approach is thus usually interpreted in terms of "efficient land units". However, there remains an interpretation problem. There is no straightforward way to recover the land use in hectares from the efficient units without an explicit assumption about the distribution of the yield coefficients over the area available.

Even if we agree that CET is a reasonable representation of land supply in efficient units within a general equilibrium framework and restrain from being explicit about land use in hectares, we are left with the choice of the elasticity parameter. Unfortunately, empirical estimates that lend themselves to an interpretation of a CET elasticity are rare, and actual CGE models apply widely varying elasticities. Golub et al. (2007) start from an empirically based elasticity of transformation (EOT) between agricultural and forestry land of 1.5 and set
the elasticity between crops and livestock at 3.0. The EOT between different sort of crops (not specified in the Golub et al. model) should then even be higher. In contrast, the OECD "PEM" model (OECD, 2003) uses significantly lower elasticities: 0.1 between COP (cereals, oil seeds and protein) crops and other farm uses, 0.4 between the three COP crops. (In a "high" variant for sensitivity analysis, the respective values are 0.3 and 0.8, still far below what seems reasonable according to Golub et al.)

We explore the consequences of this wide range of elasticities in a sensitivity analysis. The core version of WorldScan (used for the simulations in the main text) uses an EOT of 2.0, which can be considered middle ground between the high Golub et al. and the low OECD numbers. We contrast this with simulation runs where we put the EOT at 0.5 and 15 (close to perfect transformability) respectively (see Table 32).

	EOT = 0.5		EOT = 2.0		EOT = 15	
	Arable land rents	Economic welfare	Arable land rents	Economic welfare	Arable land rents	Economic welfare
No excise, target 10%						
No trade liberalization	2.2	0.03	2.2	0.03	2.1	0.03
Full trade liberalization	1.4	0.03	1.5	0.03	1.5	0.03
Competitive excise, target						
10%						
No trade liberalization	2.2	0.02	2.3	0.02	2.1	0.02
Full trade liberalization	1.5	0.02	1.6	0.02	1.5	0.02
Full excise, target 10%						
No trade liberalization	2.2	-0.01	2.2	0.00	2.1	0.00
Full trade liberalization	1.5	0.00	1.6	0.00	1.6	0.00
Full excise, target 15%						
No trade liberalization	3.4	-0.02	3.4	-0.01	3.2	-0.01
Full trade liberalization	2.3	-0.01	2.4	-0.01	2.4	0.00
Full excise, target 20%						
No trade liberalization	4.6	-0.03	4.6	-0.03	4.3	-0.02
Full trade liberalization	3.1	-0.02	3.3	-0.02	3.2	-0.01
Raising fossil fuel excises						
No trade liberalization	0.3	-0.06	0.3	-0.06	0.3	-0.06
Full trade liberalization	0.3	-0.06	0.3	-0.06	0.2	-0.06

Table 32: Arable land rents and economic welfare, in % deviation from the policy baseline, 2020, Sensitivity analysis with respect to the elasticity of transformation for arable land

Source: WorldScan

Table 32 shows that, as we would expect, land prices are in general lower and welfare is higher if land can be transformed more easily from one use to another (from left to right in the table). However, in quantitative terms, the differences between the variants of the model are hardly noticeable. They become somewhat larger if we move on to higher biofuel quotas (as we explored in some additional scenario runs), but even then the conclusions do not change fundamentally. We conclude that within the CET framework of land use modelling, our simulation results are fairly robust. We cannot be certain, though, that this would remain the case if we substituted the CET function by a representation of land-use patterns that would reflect more agricultural detail.