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Quantitative analysis of international emissions trading

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1 Introduction

Aiming at a cost-efficient achievement of the EU emission reduction commitments under the Kyoto Protocol, the European Commission launched the European Emissions Trading System (ETS) which is operating since January 2005 (EU, 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 CO_2 producing sites such as power, heat and steam generation, oil refineries, coke ovens in iron and steel production, mineral industries (e.g., glass, cement), or pulp and paper plants.

Besides emissions trading the amending directive linking the European trading scheme with the Kyoto Protocol's project-based mechanisms (EU, 2004) enables European ETS companies to generate emission reductions by means of the Clean Development Mechanism (CDM) and Joint Implementation (JI). While the former facilitates project-based investments in emission 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 they are interchangeable with European allowances.

While emission reductions generated by CDM project activities can be used by Annex B Parties to help meet their emissions targets under the Kyoto Protocol, the purpose of the CDM is to assist developing countries in achieving sustainable development. In this context, the transfer of clean technologies to developing countries via the CDM assumes a central role. Besides the importance of transferred technologies, their diffusion and subsequent follow-on innovation for economic development, also industrialized economies may benefit from an increased export demand of technology-producing sectors.

Despite their potential for cost-efficient emission abatement, the attractiveness of the project-based mechanisms can be substantially decreased by investment barriers. Risks associated with investments in climate change mitigation arise as most mitigation projects are located in developing countries, where regulatory certainty as well as economic and political stability is often weak and it is not always clear whether all the envisaged reductions will be credited. Taking these risks into account may considerably reduce the benefits and scope of the project-based mechanisms. Similarly, transaction costs associated with CDM and JI projects may occur from initiating and completing projects, such as finding partners, negotiating, obtaining advice from lawyers or experts, as well as establishing monitoring agreements.

The objective of this study is to quantify the macroeconomic and industrial impacts of international emissions trading, with special regard to the project-based mechanisms of the Kyoto Protocol. For the numerical analysis, an established large-scale computable general equilibrium model of international trade and energy use is extended to represent the European market for tradable CO_2 allowances. The model is further developed to reflect a world-wide emissions trading system encompassing JI and CDM with transition and developing countries and to incorporate indicators of the investment climate into the analysis. Hence, this study pursues the following goals:

- To consider EU national allocation plans for the period 2008-2012
- To quantify the economic and emission impacts of CDM and JI access for EU-27 Member States as well as central world regions in the year 2010
- To incorporate explicit project-based CDM supply curves into a top-down modelling framework
- To incorporate project-based transaction costs and assess the corresponding economic implications
- To incorporate CDM and JI specific investment risk and assess the corresponding economic implications
- To analyse CDM projects implemented through international emissions trading

The study is structured as follows. In section 2, the emissions market in the year 2010 is analysed. Section 3 explains the numerical framework, and section 4 presents the inputs for our quantitative analysis. In section 5 we compile the scenarios of climate policy underlying the simulation analysis. Section 6 presents the numerical results. In section 7, we summarize and conclude. In the appendix the numerical results are offered in more detail.

2 The emissions market in 2010

As a background for the subsequent quantitative analysis, this section briefly analyses the market for carbon emissions in the year 2010. The European Emissions Trading Scheme will have entered its second phase. While the allowance allocation will be stricter as compared to the first phase, there will also be better linkages between the EU ETS and international emissions trading set up by the Kyoto Protocol and all its flexibility mechanisms such as CDM and JI. Among the Annex B countries which have committed themselves to binding emission targets, European Union Member States as well as Canada and Japan can be expected to generate a net permit demand. Russia and other states of the Former Soviet Union (mainly Ukraine) serve as potential suppliers of excess emission permits – so-called “Hot Air” – due to lower projected business-as-usual (BAU) carbon emissions than the target level implied by their reduction commitment under the Kyoto Protocol. Furthermore, a major source of permit supply is expected to emerge from CDM project activities in Non-Annex B (i.e. developing) countries due to the availability of low-cost emission abatement options.

We first sketch effective emission reduction requirements of Annex-B countries in 2010. As Table 1 shows, contrasting baseline carbon emissions in 2010 to the respective Kyoto reduction target vs. 1990 emission levels yields the effective emission reduction requirement of a region.

Table 1: *Baseline emissions and reduction requirements of Annex-B countries*

	Baseline CO_2 Emissions (Mt of CO_2)			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

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 emission levels to negative requirements of over 100 percent for Eastern European states. This translates into a relatively low emission 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. As a consequence, the amount of "Hot Air" that will flow into the carbon market will have a strong impact on the price of carbon permits. However, the question of Russian "Hot Air" and the potential of Russia using its supply-side market power to restrict the permit supply in order to keep the price from falling to very low levels will not be the focus of this study. Instead we will consider different scenarios where Russian "Hot Air" will, or will not be allowed to enter the international emissions trading market. This will provide us at least with the order of magnitude of the possible price impact.

The supply side is complemented by CDM project activities in Non-Annex B countries: Table 2 presents emission reduction potential in Non-Annex-B countries for the year 2010 from about 400 greenhouse gas emission reduction options, as identified in TETRIS work package 3.

Table 2: *Identified emission reduction potential in Non-Annex-B regions in 2010*

Region	CDM supply potential in 2010 (Mt CO_2)
Brazil	67.2
China including Hong Kong	616.9
Central and South America	195.9
India	390.0
Rest of East South Asia	213.1
South Africa	37.7
Rest of World	125.8
TOTAL	**1646.6**

Source: Energy research Centre of the Netherlands (ECN)

The table reveals significant emission abatement potential in non-Annex B countries by means of CDM projects. Moreover, it shows that China and India account for more than 60 percent of the total emission reduction potential in developing countries. The associated CDM supply function (relating abatement potential to marginal abatement costs) will be presented in section 6.3 – showing that abatement potential at zero or negative costs amounts to about 600 $MtCO_2$. Comparing this with the aggregate reduction requirement of the Kyoto Annex-B parties combined of roughly 700 $MtCO_2$ suggests that – depending on additional barriers to the availability of CDM credits to the market – prices will fall to very low levels.

Against this background of potentially high permit supply, considering barriers to CDM investments such as transaction costs and investment risks becomes even more relevant for analysing the global carbon market in 2010. In addition to risk and transaction costs any climate policy design issues that restrict the access to CDM credits will be crucial. In order to account for these aspects, we will also consider climate policy design issues such as *Additionality* (restriction to CDM projects which would not be undertaken without the provision of the flexibility mechanisms) and *Supplementarity* (requiring that a minimum of abatement efforts should be undertaken domestically).

3 Numerical Framework

In order to quantify the economic impacts of international emissions trading it is crucial to account for complexities such as detailed production structures and various market interactions. Against this background, 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 emissions trading, 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 emission trading scheme from a single country perspective: EU Member States are committed to specific carbon emission 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 emission allowances to energy-intensive installations in five downstream sectors that are eligible for international emission 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 emission budget $\left(\overline{CO2}-\overline{E}\right)$.

Below, we start with a brief non-technical summary of the CGE model underlying our numerical analysis. The detailed model algebra and parameterization can be downloaded from ftp://ftp.zew.de/pub/zew-docs/div/allocation.pdf. We then lay out the central policy scenarios and interpret the simulation results. Finally, we discuss the robustness of our findings.

Model Summary

Figure 1 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: labor $\overline{L}_r$, 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, labor, energy and material in production. Carbon emissions are linked in fixed proportions to the emission-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.

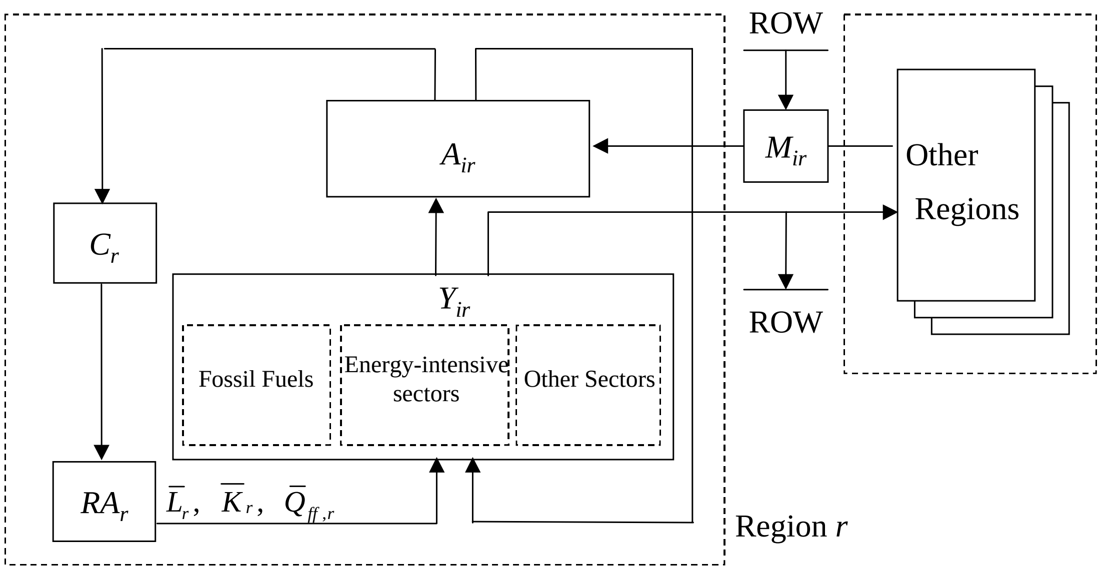

Figure 1*: Diagrammatic overview of the model structure*

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 GTAP6 database – for an introduction to GTAP data see Dimaranan and McDougall 2002). As is customary in applied general equilibrium analysis, the benchmark data for quantities and prices together with exogenous elasticities determine the free parameters of the functional forms. The effects of policy interference are measured with respect to the benchmark situation – usually termed business-as-usual (*BAU*) – where no policy changes apply.

4 Inputs for the quantitative analysis

In this section we present the set of relevant inputs for our numerical analysis. These include benchmark data sources, allocation of emission allowances, but also data provided by other work packages within the TETRIS project. Explicit technology-based CDM supply curves, including project-based transaction costs have been provided by work package 3. CDM specific investment risk indicators have been established by work package 1.

4.1 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 33 regions and 12 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 34 and Table 35 in the Appendix). 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 year, which is 2010 in our case, employing baseline estimates for GDP growth, energy demand and future energy prices as well as carbon emissions. For this purpose 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 emission 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.

4.2 Emission allowance allocation in 2010

According to Article 9 of the EU Emissions Trading Directive, each Member State has to develop a National Allocation Plan (NAP) that (i) specifies an overall cap on emission allowances for installations (sectors) included in the trading scheme, and (ii) prescribes in detail how these allowances will be allocated to installations.[1]

For the model simulations we have to assume the allocation of emission allowances for EU Member States in the second trading period of the EU Emissions Trading Scheme (2008 to 2012). Numerically, emission allocation can be described by so-called *fulfilment factors*, i.e. the fraction of baseline emissions that are freely allocated as allowances.

EU fulfilment factors for the year 2010 are derived as follows: As a reference, yearly allowance allocations for the first trading period (2005 to 2007) compared to CO_2 emissions of the trading sector in 2003 were extracted from a recent study on greenhouse gas emission trends and projections in Europe (European Environment Agency, 2005). In order to reflect CO_2 emission levels in 2010 as the basis for fulfilment factors in the second trading period, the 2003 emission levels were extrapolated to the year 2010 (as the central year of the second trading period), assuming emission projections based on energy trends for EU Member States (European Commission, 2003). According to EU (2005) we assume an allocation reduced by about six percent for the second trading period (2008 to 2012) as compared to the first period. Table 3 presents the resulting fulfilment factors for the second trading period, i.e. the ratio between allocated allowances and baseline emissions in the year 2010.[2]

[1] Note that we consider the acceding countries Bulgaria and Romania as EU Member States in 2010.
[2] Due to lacking data for the first trading period, for Bulgaria and Romania we assume a fulfilment factor equal to 1, as both acceding countries are well on path to fulfil their commitments under the Kyoto Protocol (European

Table 3*: Fulfilment factors by region in 2010*

Country	Model region	Fulfilment factor
Austria	aut	0.857
Belgium	bel	0.943
Germany	deu	0.924
Denmark	dnk	1.015
Spain	esp	0.909
Finland	fin	1.026
France	fra	0.982
United Kingdom	gbr	0.950
Greece	grc	0.860
Ireland	irl	0.933
Italy	ita	0.936
Netherlands	nld	0.951
Portugal	prt	0.946
Sweden	swe	0.948
Hungary	hun	0.811
Poland	pol	1.061
Cyprus	cyp	1.065
Czech Republic	cze	1.125
Malta	mlt	1.350
Slovakia	svk	0.963
Slovenia	svn	0.892
Estonia	est	1.241
Latvia	lva	0.919
Lithuania	ltu	1.137
Bulgaria	bgr	1.000
Romania	rom	1.000

Source: ZEW

4.3 Explicit project-based CDM supply curves

Marginal abatement cost (MAC) functions, i.e. CDM supply curves, for the Non-Annex B region may either be implemented into the modelling framework implicitly or explicitly. While the implicit approach calibrates marginal abatement cost functions from aggregate (top-down) production technology, the explicit approach incorporates marginal abatement cost functions based on detailed (bottom-up) information about abatement technology options. We aim at the explicit approach in order to represent the project-based character of the CDM. The bottom-up implementation incorporates marginal abatement cost functions, e.g., via a step function. Such an approach enables the exclusive assessment of emission market effects for the respective CDM host countries, while macroeconomic impacts may be assessed for all other world regions.

Environment Agency, 2005) and are thus not expected to implement a very strict emission allocation in the

The incorporated bottom-up CDM supply curves for the Non-Annex B region rely on a database of greenhouse gas (GHG) reduction options as developed in work package 3 of the TETRIS project. The database was built through review, comparison, evaluation and aggregation of GHG emissions reduction studies and concrete (implemented) CDM projects in non-Annex B countries. It comprises information on the abatement potential and cost of greenhouse gas reduction options for 30 non-Annex B countries on the national, sectoral and technology level. In total, more than 400 greenhouse gas emissions reduction options have been identified, of which 371 reduction options appear relevant for the CDM and the majority were identified in the power sector. Table 4 presents an excerpt of the comprehensive database.

In order to construct bottom-up CDM supply curves, the abatement potential and cost data was translated into a step-function, relating marginal abatement costs to abatement potential, and implemented into the numerical model framework. To ensure compatibility with the microeconomic model framework, so-called "No-regret" options were assumed to be implemented at zero cost, as soon as there is a positive *Certified Emission Reduction* (CER) price.

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second period.

Table 4*: Technology-based data on CDM abatement potential and costs (excerpt)*

Country	Model region	Model sector	Technology	Abatement potential (10^6 tCO_2)	Abatement costs (US$/$tCO_2$)	Transaction costs (US$/$tCO_2$)	Total abatement cost (US$/$tCO_2$)
Brazil	bra	ele	Electricty conservation	35.9	-74.5	0.2	-74.3
Brazil	bra	ele	Natural gas	5.2	-11.4	0.2	-11.2
Brazil	bra	agr	Plantation	2.3	0.2	0.7	0.9
Brazil	bra	ele	Wind energy	7.0	4.1	0.2	4.3
Brazil	bra	ele	Ethanol with electricty cogeneration	16.9	5.5	0.2	5.7
China	chn	agr	Forestry Rotation and Regeneration options	31.9	-143.6	0.1	-143.5
China	chn	public	Technical renovation of motor for general use	99.4	-27.0	0.2	-26.8
China	chn	i_s	Cutting ratio of iron/steel in steel & iron industry	9.5	-24.0	0.2	-23.8
China	chn	roi	Renovation of kilns for wet cement production	13.2	-12.8	0.2	-12.6
China	chn	roi	Cement (innovation of wet process kilns)	0.3	-12.4	0.2	-12.2
China	chn	roi	Cement (dry kilns replacing wett kilns)	0.3	-10.2	0.2	-10.0
China	chn	public	Energy-saving lighting	39.6	-8.7	0.7	-8.0
China	chn	roi	Comprehensive process renovation of synthetic ammonia	11.4	-7.6	0.2	-7.4
China	chn	i_s	Pulverized coal injection into blast furnace	0.3	-4.9	0.2	-4.7
China	chn	i_s	Installation of continous casting lines	2.1	-3.9	0.2	-3.7
China	chn	i_s	Continuous casting of steel making	7.7	-3.8	0.2	-3.6
China	chn	public	Demand side management	2.9	-4.3	0.7	-3.6
China	chn	ele	CFBC (Circulating Fluidized bed combustion)	0.5	-2.0	0.2	-1.8
China	chn	roi	Industrial boilers (optimizing combustion)	84.3	0.3	0.2	0.5
China	chn	roi	Industrial boilers (operational improvement)	77.0	0.3	0.2	0.5
China	chn	roi	Industrial boilers (prefuel process)	40.3	0.3	0.2	0.5
China	chn	agr	Seeding or dry nursery and thinnig planting	6.8	1.9	0.2	2.1
China	chn	ele	Renovation and reconstruction of conventional thermal power plant	13.9	2.9	0.2	3.1
China	chn	roi	Anaerobic technology for wastewater treatment and energy recovery in alcohol plants	5.5	3.0	0.2	3.2
China	chn	roi	Industrial boilers (high-efficiency boilers)	22.0	4.8	0.2	5.0
China	chn	ele	Supercritical coal	2.5	5.4	0.2	5.6
China	chn	ele	Scrap & Build	35.6	8.3	0.2	8.5
China	chn	ele	Hydro power	20.7	20.0	0.2	20.2
China	chn	ele	Natural gas	0.4	22.1	0.2	22.3

Source: Energy research Centre of the Netherlands (ECN)

4.4 Technology-based transaction costs

Project-based emission reductions are considered an important instrument to promote sustainable development with respect to improved environmental quality as well as better economic performance of developing countries. Yet, there are concerns that the potential benefits of project-based abatement measures 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.

With regard to the bottom-up CDM supply curves described in the previous section we incorporate bottom-up transaction costs for various GHG abatement technologies as developed in work package 3 of the TETRIS project. The resulting transaction costs take into account the difference between regular and small-scale CDM projects and the average amount of annual greenhouse gas emission reductions of the project's technology type. An excerpt of technology-specific transaction costs associated with the abatement options of the previous section can be found in Table 4.

In our numerical framework, transaction costs enter the model via the following zero-profit equilibrium condition for a CDM host country:

$$MAC + TC = p$$

with *MAC* as marginal abatement costs, *TC* as transaction costs and *p* as CER price.

For the quantitative analysis, we pursue the following procedure:

- Technology-based constant transaction costs are represented by an absolute premium on marginal abatement costs of CDM host countries (typically ranging between 0.2 and 0.7 US\$/tCO_2)
- Transaction costs increase marginal abatement costs and induce an upward shift of the CDM supply curve

4.5 CDM and JI specific investment risk indicators

Assessing the investment risk involved in financing carbon-abatement projects is central for a more realistic assessment of the efficiency gains from project-based emission crediting under the Kyoto Protocol. In this section we incorporate indicators of investment risk associated with CDM and JI projects into the numerical model framework.

We base our risk analysis on a composite indicator of the risks of investing in climate change mitigation projects, as developed within work package 1 of the TETRIS project. This indicator has been computed on the basis of a large pool of data for 143 countries, which were divided into industrialized countries (JI host countries) and developing and transition countries (CDM host countries). As a central characteristic, the indicator explicitly considers investment risk specific to the Kyoto Protocol's project-based mechanisms. It consists of three components:

- Institutional environment for JI and CDM activities
- Regulatory environment
- Economic environment

Information on Annex B and Non-Annex B countries pertaining to each component was gathered, weighted and aggregated. The resulting composite risk indicator ranks the countries according to the total risk of investing in GHG abatement projects. In work package 1 this composite indicator was transformed into a CDM-specific risk premium on the permit price (in percent) via existing country-risk premia ranging between 0.6 and 10 percent. The transformation is based on a simple model explaining the impact of country-related risks on investment decisions of greenhouse gas abatement projects. In the model, the resulting CDM-specific risk premium increases not only with the country premium but also with the lifetime of a project. Table 5 presents the resulting CDM-specific investment risk premia for developing regions.[3]

[3] Note that for regions that comprise several countries, the risk premia developed in work package 1 of the TETRIS project have been aggregated to fit the model regions by calculating an average weighted by the emissions of the most relevant regions.

Table 5: *CDM-specific investment risk premia for developing regions*

Region	Model region	Risk premium (%)
Brazil	bra	4.6
China including Hong Kong	chn	1.8
Central and South America	csa	3.0
India	ind	1.8
Rest of East South Asia	xes	12.0
South Africa	zaf	7.3
Rest of World	xrw	16.0

Source: ECOPLAN

In our numerical framework, investment risk enters the model via the following zero-profit equilibrium condition for a CDM host country:

$$MAC = p(1 - RISK)$$

with *MAC* as marginal abatement costs, *p* as CER price and *RISK* as investment risk indicator.

For the quantitative analysis, we pursue the following procedure:

- Investment risk specific to the project-based mechanisms is represented by a relative discount on the CER price (in %)
- Investment risk lowers the expected return of CDM projects and effectively induces an upward rotation of the CDM supply curve

5 Scenarios of climate policy

As a conceptual framework for our economic impact assessment, we set up alternative climate policy regimes for the year 2010. Against the background of parallel regulation under the EU ETS and the Kyoto Protocol in 2010, Table 6 presents how climate policy instruments are applied in different regions.

First, we account for emission regulation at the European level through the EU Emission Trading Directive which enables the covered energy-intensive installations (i.e. companies) to trade emissions across EU Member States. In the following, these sectors covered by the directive are denoted *DIR* sectors. Furthermore, the amending directive linking the European

ETS with the Kyoto Protocol's project-based mechanisms enables European companies to generate emission reductions by means of CDM or JI. In order to account for realistic emission allocation in the second ETS phase, we assume a proportional decrease in allowances under national allocation plans in 2008 to 2012 of six percent as compared to the allocation in the first phase (for region-specific fulfillment factors compare Table 3).

Table 6*: Climate policy regulation by region in 2010*

Policy Instrument / **Model Region**	**International emissions trading** (EU ETS directive)	**International emissions trading** (Kyoto Protocol)	**CDM** (EU ETS linking directive and Kyoto Protocol)
EU-27	*DIR sectors*	*Economy-wide*	*Economy-wide*
Rest of ratifying Annex B parties Russian Federation Rest of Former Soviet Union Japan Canada	-	*Economy-wide*	*Economy-wide*
CDM host countries China incl. Hong Kong India Rest of East South Asia Brazil Central + South America South Africa	-	-	*Economy-wide*

Second, the table shows emission regulation for Europe under the Kyoto Protocol. In 2010, EU emission regulation at the company level (enabling international trading among the *DIR* sectors) occurs simultaneously with international government trading at the country level under the Kyoto Protocol. Thereby, the entire economy including sectors not covered by the EU ETS directive (in the following denoted as *NDIR* sectors) may participate in international emissions trading. Consistently, also CDM projects may be undertaken both by companies in European *DIR* sectors (via the EU linking directive) and governments for their *NDIR* sectors (via the Kyoto Protocol), implying economy-wide CDM access. Note that in the model framework JI corresponds to international emissions trading, as it exclusively involves Annex B parties.

As we abstract from linking the EU emissions trading scheme internationally, non-EU ratifiers of the Kyoto Protocol only take part in economy-wide government trading under the Protocol and participate in the CDM as donor countries. Developing countries host CDM projects on an economy-wide level. Countries not having ratified the Kyoto Protocol do not take part in the international climate policy regime in 2010.

In order to assess the economic impacts of international emissions trading for EU Member States and the consequences of CDM access for the global carbon market, we set up institutional climate policy scenarios reflecting the interplay of policy instruments, as well as barriers to CDM investments such as transaction costs and investment risk. Together with the climate policy regime of Table 6, these scenarios are implemented into the numerical framework. As a reference case we employ the *NOTRADE* scenario that represents the absence of any flexible mechanisms of the Kyoto Protocol. Table 7 shows the resulting institutional constellations.

Table 7: *Institutional climate policy scenarios in 2010*

Scenario	Regulatory scheme	CDM access	Transaction costs	Investment risk
NOTRADE	*Domestic carbon taxation*	*No*	*No*	*No*
ET	*Emissions trading*	*No*	*No*	*No*
ET_CDM	*Emissions trading*	*Yes*	*No*	*No*
ET_CDM_TC	*Emissions trading*	*Yes*	*Yes*	*No*
ET_CDM_TC_RISK	*Emissions trading*	*Yes*	*Yes*	*Yes*

Regarding CDM and JI, the Marrakech Accords to the Kyoto Protocol demand that domestic actions (as opposed to the use of the flexible mechanisms Emissions Trading, Joint Implementation and the Clean Development Mechanism) constitute a "significant element" of the efforts made by each Annex B Party to meet its target under the Kyoto Protocol (UNFCCC, 2002). While they do not set a quantified proportion that is to be met through domestic action, the decisions require that Annex B Parties provide information in their national communications under the Protocol to demonstrate that their use of the mechanisms is "supplemental to domestic action" to achieve their targets. One attempt to quantify a CER import limit as a *Supplementarity* rule was made by the European Union, essentially stating that not more than 50 percent of an Annex B reduction commitment may be fulfilled by imports from the project-based mechanisms (Langrock and Sterk, 2004).

Moreover, the Marrakech Accords effectively define *Additionality* for emission-reduction CDM projects by specifying that "a CDM project activity is additional if anthropogenic emissions of greenhouse gases by sources are reduced below those that would have occurred in the absence of the registered CDM project activity" (UNFCCC, 2002).

Against the background of a potentially large excess permit supply on the global carbon market and the associated impact on the carbon price, regulatory restrictions of permit supply or imports from the CDM as well as of purchases of excess permits ("Hot Air") may become more prominent on the political agenda of Annex B countries. As a consequence, complementary to the institutional scenarios in Table 7 we apply the following sensitivity analyses regarding emission permit supply and demand restrictions:

- *No Hot Air*: Zero supply of excess permits by Russia and Rest of Former Soviet Union
- *Additionality*: Emission abatement options in Non-Annex B countries with negative abatement costs (so-called *No-Regret* options) are not eligible for the CDM
- *Supplementarity*: A maximum of 50 percent of the effective national reduction requirement of Annex B countries may be achieved via the import of CDM credits

For comprehensiveness, combinations of these sensitivity cases, such as *Additionality (Hot Air)* or *Additionality (No Hot Air)*, will be analyzed.

6 Numerical results

This section presents quantitative simulation results for the economic impacts of carbon abatement restrictions under the Kyoto Protocol for the institutional climate policy scenarios presented in the previous section.

6.1 Emission market impacts

We first concentrate on the international market for emission allowances. Table 8 presents the price for emission permits for alternative institutional scenarios.[4] It shows that the CO_2 permit price resulting from international emissions trading with full "Hot-Air" supply in the absence of the CDM amounts to roughly 3 US$. This finding is mainly due to the relatively low effective emission reduction requirements of Annex B countries combined with a large supply of excess permits by Russia and the remaining Former Soviet Union. However, the price almost quadruples under a climate policy regime in which no "Hot Air" is supplied.

Table 8: *International carbon permit price by institutional scenario ($US per ton of CO_2)*

Restriction \ Scenario	***ET***	***ET_CDM***	***ET_CDM_TC***	***ET_CDM_TC_RISK***
Hot Air	3.19	0.00	0.20	0.23
No Hot Air	12.62	0.71	0.81	0.98
Additionality (Hot Air)	-	0.86	0.92	0.98
Additionality (No Hot Air)	-	2.47	2.75	2.80

In a policy regime with unlimited access of Annex B regions to CDM project activity and unlimited supply of "Hot Air" the CO_2 value falls to zero, if no additional barriers of CDM investments are taken into account: The permit supply by Russia and the remaining Former

[4] If prices are reported with two digits, this should not imply corresponding accuracy but help to identify qualitative effects at low price levels.

Soviet Union and a large low-cost CDM potential of more than 1.6 Gt CO_2 (as described in Table 2) induce a situation of excess supply on the international market for emission permits. Considering investment barriers like transaction costs – which imply increased total costs for CO_2 permit generation and thereby decreased permit supply – leads to an allowance price of 0.2 US$ in this setting. Investment risk of CDM projects – decreasing the supply of CDM credits – induces a further increase of the (very low) CO_2 value by 15 percent. In the absence of "Hot Air" supply, for unlimited CDM access we observe a positive permit price of 0.7 US$, which rises in total by more than 20 percent due to transaction costs and investment risk.

An *Additionality* criterion restricts the number of projects eligible for the CDM, aiming at filtering so-called "No-Regret" options. Thereby, the CDM abatement volume available for Annex B countries is decreased substantially. Table 8 shows that such a criterion restricting permit supply on the international emissions market would increase the CO_2 value significantly: While the permit price of zero no longer persists in the case of unlimited supply of "Hot Air", the price increases to about 2.5 US$ in the absence of excess permit sales. As in the case of unrestricted CDM projects, transaction costs and investment risk cause a price increase.

Under a *Supplementarity* rule, regional marginal abatement costs are composed of the international permit price and region-specifc marginal abatement costs for domestic action. Consequently, instead of the permit price we present the resulting overall marginal abatement costs by region and institutional scenario in Table 14 (for the case of "Hot Air") and Table 15 (for the case of no "Hot Air") of Appendix 9.1.1. A *Supplementarity* rule restricts CDM permit imports (i.e. demand) on the international emissions market and thereby decreases the value of CDM credits. However, as a minimum of 50 percent of the effective national reduction requirement of Annex B countries has to be achieved through domestic action (such as domestic carbon taxation), the overall marginal abatement costs of the constrained regions are substantially higher than the international permit price resulting from unlimited CDM access. Transaction costs and investment risk do not influence these marginal costs significantly, as a major part of costs stems from domestic action and is unaffected from barriers to project-based emission abatement.

CDM investments may substantially affect domestic emission abatement of constrained regions. Table 9 and figure 2 present emission reductions versus Businnes-as-Usual (BAU) emission levels of the EU-27 for alternative institutional scenarios (regionally disaggregated results as well as results for non-EU countries can be found in Appendix 9.1.2).

Table 9: *Emissions reduction for EU-27 by institutional scenario (% vs. BAU)*

Scenario / **Restriction**	***ET***	***ET_CDM***	***ET_CDM_TC***	***ET_CDM_TC_RISK***
Hot Air	-4.5	0.0	-0.4	-0.4
No Hot Air	-12.5	-1.2	-1.3	-1.6
Additionality (Hot Air)	-	-1.4	-1.5	-1.6
Additionality (No Hot Air)	-	-3.7	-4.0	-4.1
Supplementarity (Hot Air)	-	-6.1	-6.2	-6.2
Supplementarity (No Hot Air)	-	-6.3	-6.4	-6.4

Emission reductions reflect the international price for CO_2 permits, since for constrained regions domestic abatement serves as a substitute for the purchase of emission allowances and for non-constrained regions the CO_2 value serves as an incentive for emission reductions to be exported. As a consequence, the higher the permit price, the higher the resulting domestic emission reductions. This is reflected in Table 9, where we observe an almost threefold increase in EU-27 emission abatement through the limitation of “Hot Air” supply. Considering the CDM on the international emissions market leads to very low emission reduction levels by EU-27 due to large permit imports in order to comply with the respective Kyoto targets. While larger emission abatement is induced in a climate policy regime with an *Additionality* criterion restricting CDM supply, the largest reductions are achieved through a *Supplementarity* rule capping CDM imports. Transaction costs and investment risks increase emission abatement only to a small extent. Figure 2 presents emission reductions for the EU-27 for selected scenarios.

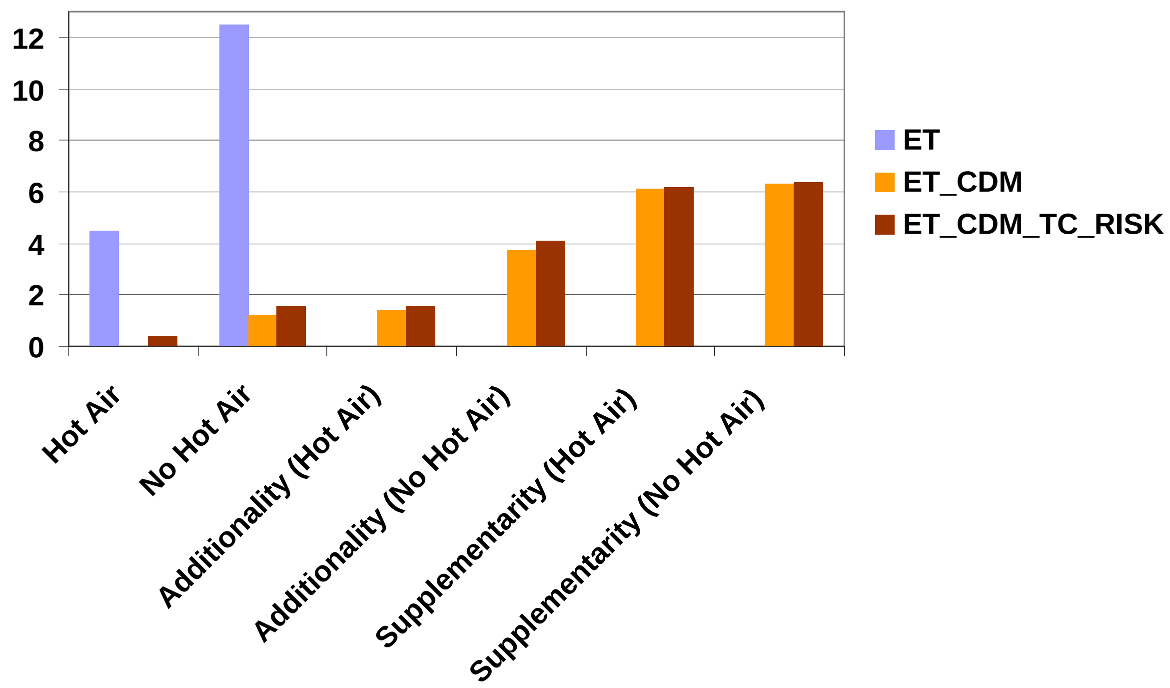

Figure 2: *Emissions reduction within the EU-27 for the alternative scenarios*

6.2 Macroeconomic impacts

From a general equilibrium perspective, economic effects of climate change policies surpass the emissions market due to market spillovers. First, the domestic emissions market and the goods market (associated with production and consumption levels) are interlinked. For potential emission 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. In order to analyze these general equilibrium (i.e. multi-market) impacts from climate policy in greater detail, in the following we focus on aggregate macroeconomic indicators such as production and social welfare. Table 10 summarizes production impacts for the EU-27 resulting from the carbon abatement restrictions under the Kyoto Protocol for our institutional climate policy scenarios (the regionally disaggregated production effects as well as results for non-EU countries can be found in Appendix 9.1.3).

Table 10: *Production impacts for EU-27 by institutional scenario (% change vs. BAU)*

Restriction \ Scenario	*ET*	*ET_CDM*	*ET_CDM_TC*	*ET_CDM_TC_RISK*
Hot Air	-0.04	0.00	0.00	0.00
No Hot Air	-0.15	-0.01	-0.01	-0.01
Additionality (Hot Air)	-	-0.01	-0.01	-0.01
Additionality (No Hot Air)	-	-0.03	-0.03	-0.04
Supplementarity (Hot Air)	-	-0.09	-0.10	-0.10
Supplementarity (No Hot Air)	-	-0.10	-0.10	-0.10

The table shows that although production impacts are generally low across all scenarios (below 0.2 percent), nevertheless there are differences between scenarios: First, the restriction of "Hot-Air" supply from Russia and Rest of Former Soviet Union more than triplicates production losses for the EU-27. Establishing unlimited access to the CDM can however decrease these production losses substantially. While an *Additionality* criterion restricting CDM supply on the international emissions market increases production losses due to an increased CO_2 permit price, this effect is even stronger for a *Supplementarity* rule limiting permit imports from the CDM. As in the latter case a minimum of 50 percent of the effective national reduction requirement of Annex B countries has to be achieved through domestic action, the relatively high marginal abatement costs are responsible for these larger production losses. Although transaction costs and investment risk do affect the permit price, the impact of these CDM investment barriers on the macroeconomic indicator production is limited.

In order to quantify the overall economic impacts resulting from climate change policies, as an overarching economic indicator we use social welfare, representing aggregate utility. 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 and as well as macroeconomic impacts. Table 11 presents welfare effects for the EU-27 for alternative institutional scenarios (regionally disaggregated welfare impacts as well as results for non-EU countries can be found in Appendix 9.1.4).

Table 11: *Welfare impacts for EU-27 by institutional scenario (% change in Hicksian Equivalent Variation)*

Scenario / Restriction	*ET*	*ET_CDM*	*ET_CDM_TC*	*ET_CDM_TC_RISK*
Hot Air	-0.01	0.00	0.00	0.00
No Hot Air	0.00	0.00	0.00	0.00
Additionality (Hot Air)	-	0.00	0.00	0.00
Additionality (No Hot Air)	-	-0.01	-0.01	-0.01
Supplementarity (Hot Air)	-	-0.01	-0.01	-0.01
Supplementarity (No Hot Air)	-	-0.01	-0.02	-0.02

The table shows generally low welfare impacts for the EU-27 from the emission reduction requirements under the Kyoto Protocol across our institutional scenarios. This is in line with our findings for production. Accounting for the CDM, welfare losses are only present in the case of an *Additionality* criterion and a *Supplementarity* rule which restrict CDM supply and demand and thereby increase adjustment costs. Compared to the production effects, in general we observe a lower magnitude of welfare impacts – a finding that is due to the inclusion of permit exports revenues for Eastern European Member States (with negative effective reduction requirements) in the welfare indicator. The highest welfare losses can be observed in a *Supplementarity* setting where “Hot Air” is simultaneously restricted. Although transaction costs and investment risk do generally not affect the welfare impacts significantly, in this last setting welfare losses are slightly increased through transaction costs of CDM projects.

6.3 Implemented CDM projects and international emissions trading

In this section we analyze the implementation of CDM projects associated with the numerical simulation results of the previous section. In order to determine which projects would be implemented in alternative scenarios, we follow a two-step procedure: From the scenario-specific CO_2 permit prices determined in section 6.1 we can derive marginal abatement cost levels on the project-based CDM supply curves developed in section 4.3. From the corresponding CDM database we can then identify the projects implemented up to the respective cost level, according to the model simulations and the CDM supply data.

As a background for our project implementation assessment, Figure 3 illustrates the part of the aggregate Non-Annex B marginal abatement cost curve (i.e. CDM supply curve) associated with the CDM supply data presented in section 4.3 for prices between zero and four dollars per ton of CO_2. It reflects again that in developing countries a large abatement (i.e. CDM supply) potential is available at relatively low marginal cost. Moreover, the figure presents a CDM supply curve including transaction costs, as well as a curve including transaction costs and investment risk – both of which represent an upwardly shifted original supply curve.

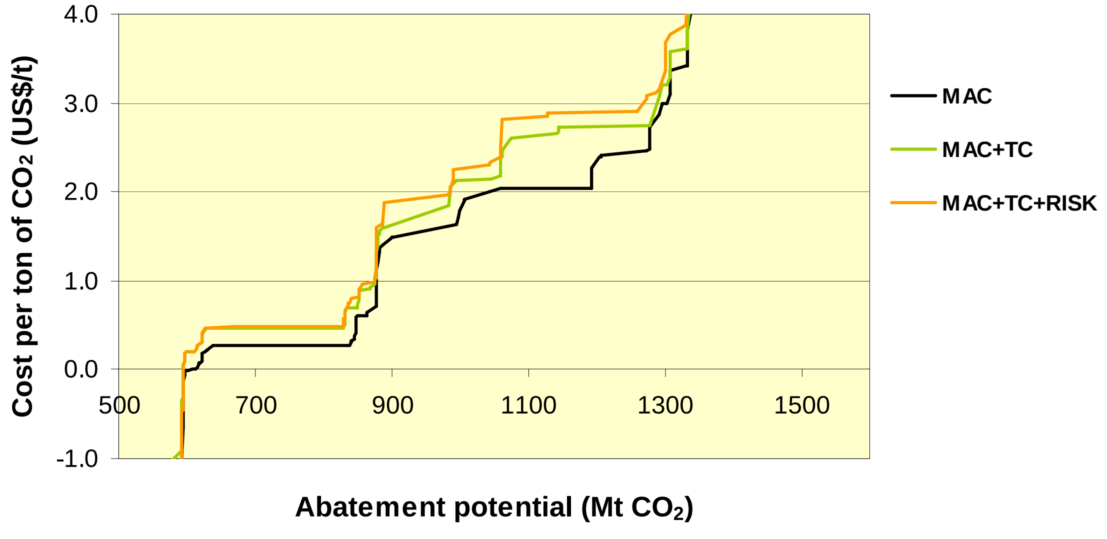

Figure 3: *Aggregate marginal abatement cost (MAC) for the Non-Annex B region considering transaction costs (TC) and investment risk (RISK)*

In order to assess the implementation of CDM projects associated with our numerical simulation results in a transparent manner, we focus on a set of institutional scenarios, all of which in the absence of “Hot Air”, specifically involving (i) the CDM without investment barriers, (ii) CDM with transaction costs and investment risk as well as (iii) these two settings including an *Additionality* criterion. Table 12 presents the number of implemented CDM projects by region and sector for alternative institutional scenarios considering the respective permit prices. Note that all presented numbers are based on the underlying dataset comprising in total 371 CDM projects. Rather than drawing conclusions from absolute numbers, our objective here is to compare the number of implemented projects across scenarios.

First, regarding the regional distribution of the number of implemented projects, we find that generally China, Central and South America as well as Rest of East South Asia represent the dominant CDM host regions. The sectoral distribution is generally dominated by Electricity, Agricultural Products and Forestry as well as the Public Sector (the latter comprising demand-side management).

Second, considering the total number of implemented projects under alternative institutional scenarios, we first observe that implemented projects under unlimited CDM supply are decreasing by more than 50 percent under an *Additionality* criterion, by which “No-Regret” options are not eligible for the CDM. Moreover, it shows that the CDM barriers transaction costs and investment risk deter a number of projects from being implemented. Finally, the regional and sectoral distribution of implemented CDM projects is varying considerably across scenarios, i.e. through an *Additionality* criterion or barriers to CDM investments. As an example, India’s role as a CDM host country is substantially emphasized by the introduction of an *Additionality* criterion, as the increased permit price makes higher-cost abatement options profitable. In turn, China, Central and South America as well as Rest of East South Asia – partly supplying “No-Regret” options, e.g. in the electricity sector – experience a drastic decline in the number of implemented projects, which is mainly affecting Electricity and the Public Sector.

Table 12: Number of implemented CDM projects by institutional scenario (No Hot Air)

Scenario / ***Region/ Sector***	***ET_CDM***	***ET_CDM_TC_RISK***	***ET_CDM Additionality***	***ET_CDM_TC_RISK Additionality***
Permit price (US$/$tCO_2$)	0.71	0.98	2.47	2.80
Region				
Brazil	3	3	1	1
China including Hong Kong	16	16	4	4
Central and South America	47	42	24	23
India	2	1	5	6
Rest of East South Asia	79	76	20	17
South Africa	17	17	3	3
Rest of World	45	39	23	24
Sector				
Agricultural Products and Forestry	22	8	23	23
Coal	3	3	1	1
Crude oil	1	1	2	2
Electricity	38	38	18	16
Natural gas	1	1	1	1
Iron and steel industry	4	4	0	0
Paper product	3	3	1	1
Public sector	61	60	11	11
Rest of Industry	64	64	23	23
Transport	12	12	0	0
TOTAL	**209**	**194**	**80**	**78**

Analogously, Table 13 presents the abatement volume of implemented CDM projects by region and sector for alternative institutional scenarios. Figure 4 displays the abatement volume of the implemented projects by regions. First, as in the previous table on the number of implemented projects, it shows that China, Central and South America as well as Rest of East South Asia are the dominant CDM host regions regarding abatement volume. Also the sectoral distribution of abatement volume is dominated by Electricity, Agricultural Products and Forestry as well as the Public Sector.

Second, considering the total abatement volume of implemented projects under alternative institutional scenarios, we observe that the volume under unlimited CDM supply is decreasing by more than 30 percent (more than 20 percent considering investment barriers) under an *Additionality* criterion. Interestingly, while transaction costs and investment risk decrease the total CDM-project volume for unrestricted CDM supply, the total volume is *increased* by investment barriers in an *Additionality* setting. Comparing the number of projects with the volume of abated emissions in this setting we find that without *Additionality* the average project size in terms of CO_2 is significantly lower (around 4.2 Mt CO_2). This figure rises slightly to about 4.5 Mt if we include transaction costs. When assuming an *Additionality* criterion the average project size is drastically higher, at about 7.6 Mt per project. In this case, including transaction costs into the analysis increases the average project size by more than 10 percent. We therefore find that the existence of investment barriers enforces the implementation of “large-scale” projects with high abatement potential.

The regional and sectoral distribution of the abatement volume of implemented CDM projects is varying considerably across scenarios – here, India’s role as a CDM host country is boosted by the introduction of an *Additionality* criterion. This setting suggests the implementation of higher-cost, large-scale Indian projects through an increased permit price. In turn, China, Central and South America as well as Rest of East South Asia experience a drastic decline also in the volume of implemented projects and mainly for options in the electricity sector.

Table 13: *Emission abatement volume of implemented CDM projects by institutional scenario (No Hot Air) in Mt CO_2*

Scenario / ***Region/ Sector***	***ET_CDM***	***ET_CDM_TC_RISK***	***ET_CDM Additionality***	***ET_CDM_TC_RISK Additionality***
Permit price (US$/tCO$_2$)	0.71	0.98	2.47	2.80
Region				
Brazil	43.4	43.4	2.3	2.3
China including Hong Kong	420.5	420.5	208.4	208.4
Central and South America	163.7	163.2	32.5	31.8
India	20.4	12.9	299.1	366.5
Rest of East South Asia	136.7	136.5	40.7	27.4
South Africa	17.9	17.9	12.3	12.3
Rest of World	74.2	74.0	15.5	15.7
Sector				
Agricultural Products and Forestry	74.1	66.0	101.6	101.6
Coal	9.3	9.3	5.7	5.7
Crude oil	1.7	1.7	4.4	4.4
Electricity	190.5	190.5	40.9	94.6
Natural gas	0.7	0.7	0.7	0.7
Iron and steel industry	19.6	19.6	0.0	0.0
Paper product	1.9	1.9	1.6	1.6
Public sector	206.3	206.1	147.6	147.6
Rest of Industry	362.2	362.2	308.3	308.3
Transport	10.7	10.7	0.0	0.0
TOTAL	**876.9**	**868.5**	**610.7**	**664.4**

As an illustration of the above findings, Figure 5 presents regional shares of abatement volume for selected institutional scenarios. For comparison, the respective shares of total available CDM volume (CDM potential) are shown.

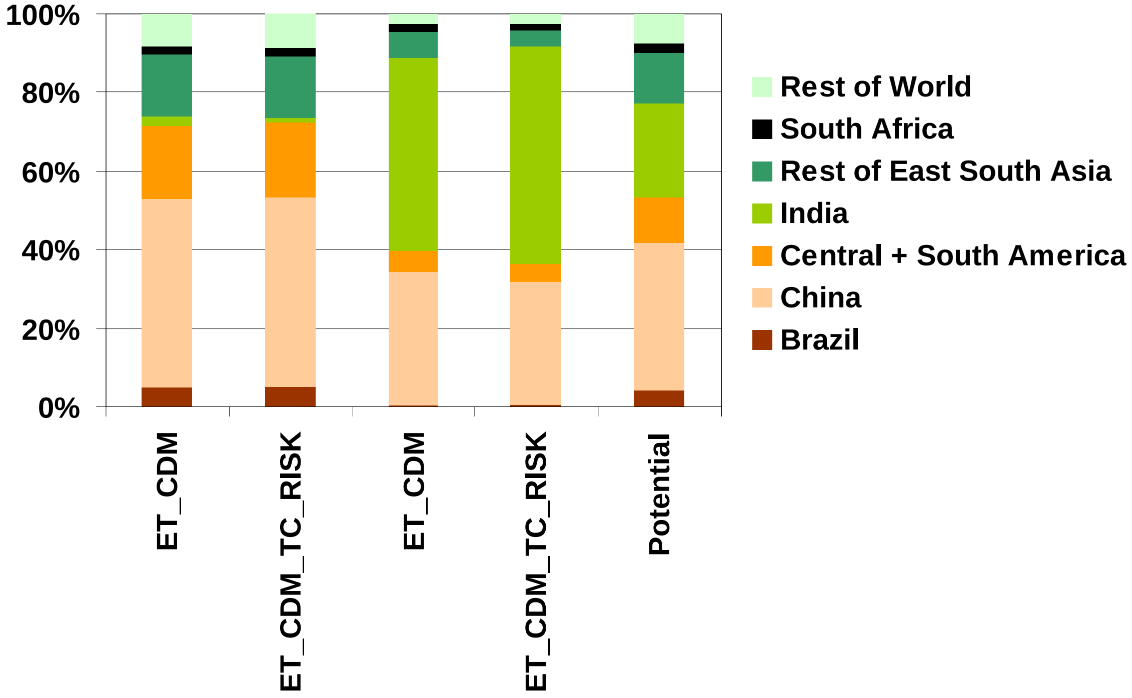

Figure 5*: Host country shares of abatement volume of implemented CDM projects by institutional scenario; CDM potential*

7 Conclusions

This study quantifies the macroeconomic impacts of international emissions trading, with special regard to the project-based mechanisms of the Kyoto Protocol. For the numerical analysis, a large-scale computable general equilibrium model of international trade and energy use is employed to represent the European market for tradable CO_2 allowances and to reflect world-wide emissions trading encompassing JI and CDM with transition and developing countries in the year 2010. We consider National Allocation Plans for the period 2008 to 2012 and – based on data generated within the TETRIS project – incorporate project-based CDM supply curves, project-based transaction costs and CDM-specific investment risk into a top-down modelling framework. Besides the international price for emission permits, economic impacts such as welfare and production changes are quantified for the EU-27 as well as key countries of the Kyoto Protocol.

In the numerical simulations, both the resulting permit price and the macroeconomic impacts are considerably low. This is due to a large permit supply of the CDM and comparably low effective emission reduction requirements of Annex B countries. Although transaction costs and investment risk do affect the permit price considerably, the impact of these CDM investment barriers on macroeconomic indicators such as production and social welfare is limited. We apply a number of further analyses regarding *Additionality* of CDM projects, *Supplementarity* rules and a restriction of “Hot-Air” supply from Russia and Ukraine, all of which may increase the permit price and the economy-wide adjustment costs substantially. These impacts are often stronger than price increases generated by including risk and transaction costs. While an *Additionality* criterion restricting CDM supply on the international emissions market increases production losses due to an increased CO_2 permit price, this effect is even stronger for a *Supplementarity* rule limiting permit imports from the CDM.

Furthermore, we analyze the implementation of CDM projects associated with our numerical simulation results. Regarding the regional distribution of the number of implemented projects, we find that generally China, Central and South America as well as Rest of East South Asia represent the dominant CDM host regions. The sectoral distribution is generally dominated by Electricity, Agricultural Products and Forestry as well as the Public Sector (comprising demand-side management). Both the number of implemented CDM projects and the associated abatement volume are decreasing significantly through an *Additionality* criterion, by which “No-Regret” options are not eligible for the CDM. Moreover, it shows that the CDM barriers transaction costs and investment risk deter projects from being implemented, and change the project portfolio in favour of large-scale abatement options.

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9 Appendix

9.1 Regionally disaggregated simulation results

9.1.1 Marginal abatement costs by region

Table 14: *Supplementarity (Hot Air) – Marginal abatement costs by region ($US / ton of CO_2)*

Region \ Scenario	*ET_CDM*	*ET_CDM_TC*	*ET_CDM_TC_RISK*
Austria	29.21	29.25	29.25
Belgium	27.69	27.72	27.72
Denmark	3.76	3.77	3.77
Finland	0.00	0.20	0.20
France	16.88	16.89	16.89
Germany	3.52	3.53	3.53
United Kingdom	5.33	5.34	5.34
Greece	3.64	3.65	3.65
Ireland	16.08	16.08	16.08
Italy	14.19	14.19	14.19
Netherlands	13.94	13.95	13.95
Portugal	16.97	16.98	16.98
Spain	19.51	19.52	19.52
Sweden	4.45	4.47	4.47
Hungary	1.04	1.06	1.06
Poland	0.00	0.20	0.20
Czech Republic	0.00	0.20	0.20
Slovakia	0.00	0.20	0.20
Bulgaria	0.00	0.20	0.20
Romania	0.00	0.20	0.20
Rest of EU	28.12	28.13	28.13
Baltic States	0.00	0.20	0.20
EU-27	0.00	0.00	0.00
Canada	0.00	0.20	0.20
Japan	0.00	0.20	0.20
Russian Federation	0.00	0.20	0.20
Rest of FSU	0.00	0.20	0.20

Table 15: *Supplementarity (No Hot Air) – Marginal abatement costs by region ($US / ton of CO_2)*

Scenario / Region	*ET_CDM*	*ET_CDM_TC*	*ET_CDM_TC_RISK*
Austria	29.25	29.28	29.29
Belgium	27.72	27.73	27.73
Denmark	3.77	3.78	3.78
Finland	0.27	0.47	0.48
France	16.89	16.89	16.89
Germany	3.53	3.53	3.53
United Kingdom	5.33	5.34	5.34
Greece	3.65	3.66	3.66
Ireland	16.08	16.08	16.08
Italy	14.19	14.20	14.20
Netherlands	13.95	13.95	13.95
Portugal	16.98	17.00	17.00
Spain	19.52	19.52	19.52
Sweden	4.47	4.48	4.48
Hungary	1.07	1.08	1.08
Poland	0.27	0.47	0.48
Czech Republic	0.27	0.47	0.48
Slovakia	0.27	0.47	0.48
Bulgaria	0.27	0.47	0.48
Romania	0.27	0.47	0.48
Rest of EU	28.13	28.15	28.15
Baltic States	0.27	0.47	0.48
EU-27	0.00	0.00	0.00
Canada	0.27	0.47	0.48
Japan	0.27	0.47	0.48
Russian Federation	0.00	0.00	0.00
Rest of FSU	0.27	0.47	0.48

9.1.2 Emissions reduction by region

Table 16: *Hot Air – Emissions reduction by region (% vs. BAU)*

Region \ Scenario	*ET*	*ET_CDM*	*ET_CDM_TC*	*ET_CDM_TC_RISK*
Austria	-2.10	0.00	-0.10	-0.20
Belgium	-1.80	0.00	-0.10	-0.20
Denmark	-5.50	0.00	-0.40	-0.50
Finland	-2.50	0.00	-0.20	-0.20
France	-1.90	-0.20	-0.30	-0.40
Germany	-4.80	0.00	-0.30	-0.40
United Kingdom	-3.50	0.00	-0.20	-0.30
Greece	-6.50	-0.10	-0.60	-0.60
Ireland	-3.60	0.00	-0.30	-0.30
Italy	-2.40	0.00	-0.20	-0.20
Netherlands	-2.90	0.00	-0.20	-0.20
Portugal	-3.70	0.00	-0.30	-0.40
Spain	-3.10	0.00	-0.20	-0.30
Sweden	-3.10	-0.40	-0.60	-0.60
Hungary	-8.10	0.00	-0.60	-0.70
Poland	-9.70	0.00	-0.70	-0.80
Czech Republic	-14.20	0.00	-1.20	-1.30
Slovakia	-8.50	0.00	-0.60	-0.70
Bulgaria	-11.00	-0.10	-0.90	-1.00
Romania	-8.50	0.00	-0.70	-0.80
Rest of EU	-3.10	0.00	-0.20	-0.30
Baltic States	-10.00	-1.30	-2.00	-2.10
EU-27	-4.50	0.00	-0.40	-0.40
Canada	-2.90	0.00	-0.20	-0.20
Japan	-4.70	0.00	-0.30	-0.40
Russian Federation	-3.00	0.00	-0.20	-0.20
Rest of FSU	-7.80	0.00	-0.60	-0.70

Table 17: *No Hot Air – Emissions reduction by region (% vs. BAU)*

Scenario / Region	*ET*	*ET_CDM*	*ET_CDM_TC*	*ET_CDM_TC_RISK*
Austria	-6.40	-0.50	-0.60	-0.70
Belgium	-5.70	-0.40	-0.50	-0.60
Denmark	-15.20	-1.40	-1.60	-1.90
Finland	-8.20	-0.60	-0.70	-0.80
France	-5.60	-0.60	-0.70	-0.80
Germany	-14.00	-1.20	-1.40	-1.60
United Kingdom	-10.70	-0.90	-1.00	-1.20
Greece	-14.70	-1.70	-1.90	-2.30
Ireland	-10.40	-0.90	-1.00	-1.20
Italy	-7.10	-0.60	-0.70	-0.80
Netherlands	-9.70	-0.70	-0.80	-1.00
Portugal	-10.50	-1.00	-1.10	-1.30
Spain	-8.70	-0.80	-0.90	-1.10
Sweden	-7.90	-1.10	-1.20	-1.40
Hungary	-19.60	-2.20	-2.50	-3.00
Poland	-25.80	-2.50	-2.80	-3.40
Czech Republic	-31.90	-4.00	-4.50	-5.40
Slovakia	-22.80	-2.20	-2.50	-3.00
Bulgaria	-27.30	-2.90	-3.30	-4.00
Romania	-20.50	-2.30	-2.60	-3.10
Rest of EU	-9.40	-0.80	-0.90	-1.10
Baltic States	-23.20	-3.70	-4.10	-4.60
EU-27	-12.50	-1.20	-1.30	-1.60
Canada	-11.70	-0.60	-0.70	-0.90
Japan	-12.70	-1.20	-1.30	-1.60
Russian Federation	0.50	0.00	0.00	0.00
Rest of FSU	-19.00	-2.20	-2.40	-2.90

Table 18: *Additionality (Hot Air) – Emissions reduction by region (% vs. BAU)*

Region \ **Scenario**	***ET_CDM***	***ET_CDM_TC***	***ET_CDM_TC_RISK***
Austria	-0.60	-0.70	-0.70
Belgium	-0.50	-0.60	-0.60
Denmark	-1.70	-1.80	-1.90
Finland	-0.70	-0.80	-0.80
France	-0.70	-0.70	-0.80
Germany	-1.40	-1.50	-1.60
United Kingdom	-1.00	-1.10	-1.20
Greece	-2.00	-2.10	-2.30
Ireland	-1.10	-1.20	-1.20
Italy	-0.70	-0.80	-0.80
Netherlands	-0.80	-0.90	-0.90
Portugal	-1.20	-1.20	-1.30
Spain	-0.90	-1.00	-1.10
Sweden	-1.20	-1.30	-1.30
Hungary	-2.60	-2.80	-2.90
Poland	-3.00	-3.20	-3.40
Czech Republic	-4.70	-5.00	-5.30
Slovakia	-2.60	-2.80	-3.00
Bulgaria	-3.50	-3.70	-3.90
Romania	-2.80	-2.90	-3.10
Rest of EU	-0.90	-1.00	-1.00
Baltic States	-4.10	-4.30	-4.50
EU-27	-1.40	-1.50	-1.60
Canada	-0.80	-0.80	-0.90
Japan	-1.40	-1.50	-1.60
Russian Federation	-0.80	-0.90	-0.90
Rest of FSU	-2.50	-2.70	-2.90

Table 19: *Additionality (No Hot Air) – Emissions reduction by region (% vs. BAU)*

Region \ Scenario	*ET_CDM*	*ET_CDM_TC*	*ET_CDM_TC_RISK*
Austria	-1.70	-1.90	-1.90
Belgium	-1.40	-1.60	-1.60
Denmark	-4.50	-4.90	-5.00
Finland	-2.00	-2.20	-2.20
France	-1.60	-1.70	-1.70
Germany	-3.90	-4.30	-4.30
United Kingdom	-2.80	-3.10	-3.10
Greece	-5.30	-5.70	-5.80
Ireland	-2.90	-3.20	-3.20
Italy	-1.90	-2.10	-2.20
Netherlands	-2.30	-2.50	-2.60
Portugal	-3.00	-3.30	-3.40
Spain	-2.50	-2.70	-2.80
Sweden	-2.60	-2.80	-2.90
Hungary	-6.60	-7.20	-7.30
Poland	-7.80	-8.60	-8.70
Czech Republic	-11.70	-12.70	-12.90
Slovakia	-6.90	-7.60	-7.70
Bulgaria	-9.00	-9.80	-9.90
Romania	-7.00	-7.60	-7.70
Rest of EU	-2.50	-2.80	-2.80
Baltic States	-8.80	-9.50	-9.60
EU-27	-3.70	-4.00	-4.10
Canada	-2.20	-2.40	-2.50
Japan	-3.80	-4.10	-4.20
Russian Federation	0.10	0.10	0.10
Rest of FSU	-6.40	-7.00	-7.10

Table 20: *Supplementarity (Hot Air) – Emissions reduction by region (% vs. BAU)*

Region \ Scenario	*ET_CDM*	*ET_CDM_TC*	*ET_CDM_TC_RISK*
Austria	-13.50	-13.50	-13.50
Belgium	-11.10	-11.10	-11.10
Denmark	-6.10	-6.10	-6.10
Finland	0.30	0.20	0.20
France	-7.10	-7.10	-7.10
Germany	-5.00	-5.00	-5.00
United Kingdom	-5.40	-5.40	-5.40
Greece	-7.20	-7.20	-7.20
Ireland	-12.10	-12.10	-12.10
Italy	-7.70	-7.70	-7.70
Netherlands	-10.80	-10.80	-10.80
Portugal	-13.10	-13.10	-13.10
Spain	-11.60	-11.60	-11.60
Sweden	-4.00	-4.00	-4.00
Hungary	-2.50	-2.50	-2.50
Poland	0.60	-0.20	-0.20
Czech Republic	1.90	0.70	0.60
Slovakia	1.40	0.70	0.70
Bulgaria	0.60	-0.30	-0.30
Romania	0.40	-0.30	-0.30
Rest of EU	-17.40	-17.40	-17.40
Baltic States	-0.40	-1.10	-1.10
EU-27	-6.10	-6.20	-6.20
Canada	0.00	-0.10	-0.10
Japan	0.00	-0.30	-0.30
Russian Federation	0.10	-0.10	-0.10
Rest of FSU	0.10	-0.50	-0.50

Table 21: *Supplementarity (No Hot Air) – Emissions reduction by region (% vs. BAU)*

Region \ Scenario	*ET_CDM*	*ET_CDM_TC*	*ET_CDM_TC_RISK*
Austria	-13.50	-13.50	-13.50
Belgium	-11.10	-11.10	-11.10
Denmark	-6.10	-6.10	-6.10
Finland	0.10	-0.10	-0.10
France	-7.10	-7.10	-7.10
Germany	-5.00	-5.00	-5.00
United Kingdom	-5.40	-5.40	-5.40
Greece	-7.20	-7.20	-7.20
Ireland	-12.10	-12.10	-12.10
Italy	-7.70	-7.70	-7.70
Netherlands	-10.80	-10.80	-10.80
Portugal	-13.10	-13.10	-13.10
Spain	-11.60	-11.60	-11.60
Sweden	-4.00	-4.00	-4.00
Hungary	-2.50	-2.50	-2.50
Poland	-0.40	-1.20	-1.20
Czech Republic	0.20	-1.00	-1.10
Slovakia	0.50	-0.20	-0.20
Bulgaria	-0.60	-1.40	-1.50
Romania	-0.60	-1.20	-1.30
Rest of EU	-17.40	-17.40	-17.40
Baltic States	-1.40	-2.20	-2.20
EU-27	-6.30	-6.40	-6.40
Canada	-0.20	-0.40	-0.40
Japan	-0.50	-0.80	-0.80
Russian Federation	0.10	0.10	0.10
Rest of FSU	-0.80	-1.40	-1.40

9.1.3 Production impacts by region

Table 22: *Hot Air – production impacts by region (% change vs. BAU)*

Region \ Scenario	*ET*	*ET_CDM*	*ET_CDM_TC*	*ET_CDM_TC_RISK*
Austria	-0.10	0.00	-0.01	-0.01
Belgium	-0.05	0.00	0.00	0.00
Denmark	-0.02	0.00	0.00	0.00
Finland	-0.04	0.00	0.00	0.00
France	-0.06	0.00	0.00	0.00
Germany	-0.02	0.00	0.00	0.00
United Kingdom	-0.04	0.00	0.00	0.00
Greece	-0.02	0.00	0.00	0.00
Ireland	-0.04	0.00	0.00	0.00
Italy	-0.03	0.00	0.00	0.00
Netherlands	-0.08	0.00	-0.01	-0.01
Portugal	-0.05	0.00	0.00	0.00
Spain	-0.03	0.00	0.00	0.00
Sweden	-0.05	0.00	0.00	0.00
Hungary	-0.08	0.00	-0.01	-0.01
Poland	-0.05	0.00	0.00	0.00
Czech Republic	-0.07	0.00	0.00	0.00
Slovakia	-0.06	0.00	0.00	0.00
Bulgaria	-0.23	0.00	-0.02	-0.02
Romania	-0.06	0.00	0.00	0.00
Rest of EU	-0.04	0.00	0.00	0.00
Baltic States	-0.18	0.00	-0.01	-0.01
EU-27	-0.04	0.00	0.00	0.00
Canada	0.00	0.00	0.00	0.00
Japan	-0.02	0.00	0.00	0.00
Russian Federation	-0.13	0.00	-0.01	-0.01
Rest of FSU	-0.70	0.00	-0.05	-0.05

Table 23: *No Hot Air – production impacts by region (% change vs. BAU)*

Region \ Scenario	*ET*	*ET_CDM*	*ET_CDM_TC*	*ET_CDM_TC_RISK*
Austria	-0.30	-0.02	-0.02	-0.03
Belgium	-0.14	-0.01	-0.01	-0.01
Denmark	-0.07	-0.01	-0.01	-0.01
Finland	-0.10	-0.01	-0.01	-0.01
France	-0.21	-0.01	-0.01	-0.02
Germany	-0.08	-0.01	-0.01	-0.01
United Kingdom	-0.14	-0.01	-0.01	-0.01
Greece	-0.07	0.00	0.00	-0.01
Ireland	-0.15	-0.01	-0.01	-0.01
Italy	-0.09	-0.01	-0.01	-0.01
Netherlands	-0.28	-0.02	-0.02	-0.02
Portugal	-0.17	-0.01	-0.01	-0.01
Spain	-0.11	-0.01	-0.01	-0.01
Sweden	-0.16	-0.01	-0.01	-0.01
Hungary	-0.27	-0.02	-0.02	-0.02
Poland	-0.19	-0.01	-0.01	-0.01
Czech Republic	-0.23	-0.01	-0.01	-0.02
Slovakia	-0.16	-0.01	-0.01	-0.01
Bulgaria	-0.81	-0.05	-0.06	-0.07
Romania	-0.31	-0.01	-0.01	-0.01
Rest of EU	-0.12	-0.01	-0.01	-0.01
Baltic States	-0.43	-0.03	-0.03	-0.04
EU-27	-0.15	-0.01	-0.01	-0.01
Canada	0.03	0.00	0.00	0.00
Japan	-0.09	-0.01	-0.01	-0.01
Russian Federation	-0.08	-0.01	-0.01	-0.01
Rest of FSU	-2.45	-0.16	-0.18	-0.22

Table 24: *Additionality (Hot Air) – production impacts by region (% change vs. BAU)*

Scenario / Region	*ET_CDM*	*ET_CDM_TC*	*ET_CDM_TC_RISK*
Austria	-0.03	-0.03	-0.03
Belgium	-0.01	-0.01	-0.02
Denmark	-0.01	-0.01	-0.01
Finland	-0.01	-0.01	-0.01
France	-0.02	-0.02	-0.02
Germany	-0.01	-0.01	-0.01
United Kingdom	-0.01	-0.01	-0.01
Greece	-0.01	-0.01	-0.01
Ireland	-0.01	-0.01	-0.01
Italy	-0.01	-0.01	-0.01
Netherlands	-0.02	-0.02	-0.02
Portugal	-0.01	-0.02	-0.02
Spain	-0.01	-0.01	-0.01
Sweden	-0.01	-0.01	-0.02
Hungary	-0.02	-0.02	-0.02
Poland	-0.01	-0.02	-0.02
Czech Republic	-0.02	-0.02	-0.02
Slovakia	-0.02	-0.02	-0.02
Bulgaria	-0.07	-0.07	-0.07
Romania	-0.01	-0.02	-0.02
Rest of EU	-0.01	-0.01	-0.01
Baltic States	-0.05	-0.05	-0.06
EU-27	-0.01	-0.01	-0.01
Canada	0.00	0.00	0.00
Japan	-0.01	-0.01	-0.01
Russian Federation	-0.03	-0.04	-0.04
Rest of FSU	-0.19	-0.21	-0.22

Table 25: *Additionality (No Hot Air) – production impacts by region (% change vs. BAU)*

Scenario / Region	ET_CDM	ET_CDM_TC	ET_CDM_TC_RISK
Austria	-0.07	-0.08	-0.08
Belgium	-0.03	-0.04	-0.04
Denmark	-0.02	-0.02	-0.02
Finland	-0.02	-0.03	-0.03
France	-0.04	-0.05	-0.05
Germany	-0.02	-0.02	-0.02
United Kingdom	-0.03	-0.03	-0.03
Greece	-0.01	-0.02	-0.02
Ireland	-0.03	-0.03	-0.04
Italy	-0.02	-0.02	-0.02
Netherlands	-0.06	-0.07	-0.07
Portugal	-0.04	-0.04	-0.04
Spain	-0.02	-0.03	-0.03
Sweden	-0.03	-0.04	-0.04
Hungary	-0.06	-0.06	-0.06
Poland	-0.04	-0.04	-0.04
Czech Republic	-0.04	-0.05	-0.05
Slovakia	-0.03	-0.04	-0.04
Bulgaria	-0.18	-0.20	-0.20
Romania	-0.04	-0.04	-0.04
Rest of EU	-0.02	-0.03	-0.03
Baltic States	-0.09	-0.10	-0.10
EU-27	-0.03	-0.03	-0.04
Canada	0.00	0.00	0.00
Japan	-0.02	-0.02	-0.02
Russian Federation	-0.02	-0.02	-0.02
Rest of FSU	-0.53	-0.59	-0.60

Table 26: *Supplementarity (Hot Air) – production impacts by region (% change vs. BAU)*

Scenario / Region	*ET_CDM*	*ET_CDM_TC*	*ET_CDM_TC_RISK*
Austria	0.02	0.01	0.01
Belgium	-0.03	-0.03	-0.03
Denmark	-0.04	-0.04	-0.04
Finland	-0.09	-0.09	-0.09
France	-0.17	-0.17	-0.17
Germany	-0.06	-0.06	-0.06
United Kingdom	-0.07	-0.07	-0.07
Greece	-0.03	-0.03	-0.03
Ireland	-0.15	-0.15	-0.15
Italy	-0.07	-0.07	-0.07
Netherlands	-0.24	-0.24	-0.24
Portugal	-0.13	-0.13	-0.13
Spain	-0.11	-0.11	-0.11
Sweden	-0.08	-0.08	-0.08
Hungary	-0.10	-0.11	-0.11
Poland	-0.09	-0.09	-0.09
Czech Republic	-0.23	-0.23	-0.23
Slovakia	-0.22	-0.22	-0.22
Bulgaria	-0.05	-0.06	-0.06
Romania	-0.09	-0.09	-0.09
Rest of EU	0.08	0.07	0.07
Baltic States	-0.14	-0.15	-0.15
EU-27	-0.09	-0.10	-0.10
Canada	-0.01	-0.01	-0.01
Japan	0.00	0.00	0.00
Russian Federation	-0.02	-0.03	-0.03
Rest of FSU	-0.02	-0.07	-0.07

Table 27: *Supplementarity (No Hot Air) – production impacts by region (% change vs. BAU)*

Region \ Scenario	*ET_CDM*	*ET_CDM_TC*	*ET_CDM_TC_RISK*
Austria	0.01	0.01	0.01
Belgium	-0.03	-0.03	-0.03
Denmark	-0.04	-0.05	-0.05
Finland	-0.09	-0.09	-0.09
France	-0.17	-0.18	-0.18
Germany	-0.06	-0.06	-0.06
United Kingdom	-0.07	-0.07	-0.07
Greece	-0.03	-0.04	-0.04
Ireland	-0.15	-0.15	-0.15
Italy	-0.07	-0.07	-0.07
Netherlands	-0.24	-0.24	-0.24
Portugal	-0.13	-0.13	-0.13
Spain	-0.11	-0.11	-0.11
Sweden	-0.08	-0.08	-0.08
Hungary	-0.11	-0.11	-0.11
Poland	-0.09	-0.09	-0.09
Czech Republic	-0.23	-0.22	-0.22
Slovakia	-0.21	-0.21	-0.21
Bulgaria	-0.07	-0.08	-0.08
Romania	-0.09	-0.09	-0.09
Rest of EU	0.07	0.07	0.07
Baltic States	-0.15	-0.16	-0.16
EU-27	-0.10	-0.10	-0.10
Canada	-0.01	-0.01	-0.01
Japan	0.00	-0.01	-0.01
Russian Federation	-0.03	-0.03	-0.03
Rest of FSU	-0.08	-0.13	-0.13

9.1.4 Welfare impacts by region

Table 28: *Hot Air – Welfare impacts by region (% change in Hicksian Equivalent Variation)*

Region \ Scenario	*ET*	*ET_CDM*	*ET_CDM_TC*	*ET_CDM_TC_RISK*
Austria	-0.03	0.00	0.00	0.00
Belgium	-0.03	0.00	0.00	0.00
Denmark	-0.02	0.00	0.00	0.00
Finland	0.01	0.00	0.00	0.00
France	-0.01	0.00	0.00	0.00
Germany	-0.01	0.00	0.00	0.00
United Kingdom	-0.01	0.00	0.00	0.00
Greece	-0.03	0.00	0.00	0.00
Ireland	-0.03	0.00	0.00	0.00
Italy	-0.02	0.00	0.00	0.00
Netherlands	-0.04	0.00	0.00	0.00
Portugal	-0.05	0.00	0.00	0.00
Spain	-0.04	0.00	0.00	0.00
Sweden	-0.01	0.00	0.00	0.00
Hungary	-0.03	0.00	0.00	0.00
Poland	0.08	0.00	0.00	0.00
Czech Republic	0.20	0.00	0.01	0.01
Slovakia	0.09	0.00	0.00	0.01
Bulgaria	0.46	0.00	0.03	0.03
Romania	0.42	0.00	0.03	0.03
Rest of EU	-0.09	0.00	-0.01	-0.01
Baltic States	0.52	0.00	0.03	0.04
EU-27	-0.01	0.00	0.00	0.00
Canada	-0.14	0.00	-0.01	-0.01
Japan	-0.02	0.00	0.00	0.00
Russian Federation	0.52	0.00	0.03	0.04
Rest of FSU	-0.01	0.00	-0.01	-0.01

Table 29: *No Hot Air – Welfare impacts by region (% change in Hicksian Equivalent Variation)*

Scenario / Region	*ET*	*ET_CDM*	*ET_CDM_TC*	*ET_CDM_TC_RISK*
Austria	-0.11	-0.01	-0.01	-0.01
Belgium	-0.10	-0.01	-0.01	-0.01
Denmark	-0.05	-0.01	-0.01	-0.01
Finland	0.06	0.00	0.00	0.00
France	-0.04	0.00	0.00	0.00
Germany	-0.01	0.00	0.00	0.00
United Kingdom	-0.03	0.00	0.00	0.00
Greece	-0.06	-0.01	-0.01	-0.01
Ireland	-0.11	-0.01	-0.01	-0.01
Italy	-0.07	-0.01	-0.01	-0.01
Netherlands	-0.11	-0.01	-0.01	-0.01
Portugal	-0.17	-0.01	-0.01	-0.02
Spain	-0.11	-0.01	-0.01	-0.01
Sweden	-0.01	0.00	0.00	0.00
Hungary	0.02	-0.01	-0.01	-0.01
Poland	0.48	0.01	0.02	0.02
Czech Republic	1.02	0.04	0.04	0.05
Slovakia	0.55	0.02	0.02	0.02
Bulgaria	2.18	0.09	0.11	0.13
Romania	1.87	0.09	0.10	0.13
Rest of EU	-0.31	-0.02	-0.02	-0.03
Baltic States	2.20	0.11	0.13	0.16
EU-27	0.00	0.00	0.00	0.00
Canada	-0.49	-0.03	-0.04	-0.04
Japan	-0.05	0.00	-0.01	-0.01
Russian Federation	-0.05	0.00	0.00	0.00
Rest of FSU	0.72	-0.02	-0.02	-0.03

Table 30: *Additionality (Hot Air) – Welfare impacts by region (% change in Hicksian Equivalent Variation)*

Region \ Scenario	*ET_CDM*	*ET_CDM_TC*	*ET_CDM_TC_RISK*
Austria	-0.01	-0.01	-0.01
Belgium	-0.01	-0.01	-0.01
Denmark	-0.01	-0.01	-0.01
Finland	0.00	0.00	0.00
France	0.00	0.00	0.00
Germany	0.00	0.00	0.00
United Kingdom	0.00	0.00	0.00
Greece	-0.01	-0.01	-0.01
Ireland	-0.01	-0.01	-0.01
Italy	-0.01	-0.01	-0.01
Netherlands	-0.01	-0.01	-0.01
Portugal	-0.02	-0.02	-0.02
Spain	-0.01	-0.01	-0.01
Sweden	0.00	0.00	0.00
Hungary	-0.01	-0.01	-0.01
Poland	0.02	0.02	0.02
Czech Republic	0.05	0.05	0.05
Slovakia	0.02	0.02	0.02
Bulgaria	0.12	0.12	0.13
Romania	0.11	0.12	0.12
Rest of EU	-0.02	-0.03	-0.03
Baltic States	0.14	0.15	0.16
EU-27	0.00	0.00	0.00
Canada	-0.04	-0.04	-0.04
Japan	-0.01	-0.01	-0.01
Russian Federation	0.14	0.15	0.16
Rest of FSU	-0.03	-0.03	-0.03

Table 31: *Additionality (No Hot Air) – Welfare impacts by region (% change in Hicksian Equivalent Variation)*

Region \ Scenario	*ET_CDM*	*ET_CDM_TC*	*ET_CDM_TC_RISK*
Austria	-0.03	-0.03	-0.03
Belgium	-0.02	-0.03	-0.03
Denmark	-0.02	-0.02	-0.02
Finland	0.01	0.01	0.01
France	-0.01	-0.01	-0.01
Germany	-0.01	-0.01	-0.01
United Kingdom	-0.01	-0.01	-0.01
Greece	-0.02	-0.03	-0.03
Ireland	-0.03	-0.03	-0.03
Italy	-0.02	-0.02	-0.02
Netherlands	-0.03	-0.03	-0.03
Portugal	-0.04	-0.05	-0.05
Spain	-0.03	-0.03	-0.03
Sweden	0.00	0.00	-0.01
Hungary	-0.02	-0.03	-0.03
Poland	0.06	0.07	0.07
Czech Republic	0.15	0.17	0.17
Slovakia	0.07	0.08	0.08
Bulgaria	0.35	0.39	0.40
Romania	0.32	0.36	0.37
Rest of EU	-0.07	-0.08	-0.08
Baltic States	0.40	0.45	0.46
EU-27	-0.01	-0.01	-0.01
Canada	-0.11	-0.12	-0.12
Japan	-0.01	-0.02	-0.02
Russian Federation	-0.01	-0.01	-0.01
Rest of FSU	-0.02	-0.02	-0.02

Table 32: *Supplementarity (Hot Air) – Welfare impacts by region (% change in Hicksian Equivalent Variation)*

Region \ Scenario	*ET_CDM*	*ET_CDM_TC*	*ET_CDM_TC_RISK*
Austria	-0.03	-0.03	-0.03
Belgium	-0.01	-0.01	-0.01
Denmark	-0.02	-0.02	-0.02
Finland	0.00	0.00	0.00
France	-0.01	-0.01	-0.01
Germany	-0.01	-0.01	-0.01
United Kingdom	-0.01	-0.01	-0.01
Greece	-0.01	-0.01	-0.01
Ireland	-0.03	-0.03	-0.03
Italy	-0.02	-0.02	-0.02
Netherlands	-0.01	-0.01	-0.01
Portugal	-0.06	-0.06	-0.06
Spain	-0.03	-0.04	-0.04
Sweden	0.00	0.00	0.00
Hungary	-0.01	-0.01	-0.01
Poland	0.00	0.01	0.01
Czech Republic	0.01	0.02	0.02
Slovakia	0.02	0.02	0.02
Bulgaria	0.02	0.04	0.04
Romania	0.00	0.03	0.03
Rest of EU	-0.16	-0.16	-0.16
Baltic States	-0.01	0.02	0.02
EU-27	-0.01	-0.01	-0.01
Canada	0.00	-0.01	-0.01
Japan	0.00	0.00	0.00
Russian Federation	-0.01	0.02	0.02
Rest of FSU	0.00	-0.01	-0.01

Table 33: *Supplementarity (No Hot Air) – Welfare impacts by region (% change in Hicksian Equivalent Variation)*

Region \ Scenario	*ET_CDM*	*ET_CDM_TC*	*ET_CDM_TC_RISK*
Austria	-0.03	-0.03	-0.03
Belgium	-0.01	-0.01	-0.01
Denmark	-0.02	-0.02	-0.02
Finland	0.00	0.00	0.00
France	-0.01	-0.01	-0.01
Germany	-0.01	-0.01	-0.01
United Kingdom	-0.01	-0.01	-0.01
Greece	-0.01	-0.01	-0.01
Ireland	-0.03	-0.04	-0.04
Italy	-0.02	-0.02	-0.02
Netherlands	-0.01	-0.01	-0.01
Portugal	-0.06	-0.07	-0.07
Spain	-0.04	-0.04	-0.04
Sweden	0.00	0.00	0.00
Hungary	-0.01	-0.02	-0.02
Poland	0.01	0.01	0.01
Czech Republic	0.02	0.03	0.03
Slovakia	0.03	0.03	0.03
Bulgaria	0.05	0.08	0.08
Romania	0.04	0.06	0.06
Rest of EU	-0.17	-0.17	-0.17
Baltic States	0.03	0.07	0.07
EU-27	-0.01	-0.02	-0.02
Canada	-0.02	-0.03	-0.03
Japan	0.00	0.00	0.00
Russian Federation	-0.01	-0.01	-0.01
Rest of FSU	-0.01	-0.02	-0.02

9.2 Regional model coverage

Table 34*: PACE model regions*

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
bal	Baltic States (Estonia, Latvia, Lithuania)
reu	Rest of EU (Slovenia, Luxembourg, Malta, Cyprus)
jpn	Japan
can	Canada
rus	Russian Federation
xsu	Rest of Former Soviet Union
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

9.3 Sectoral model coverage

Table 35*: PACE sectors*

ENERGY-INTENSIVE SECTORS	
coa	Coal
cru	Crude oil
gas	Natural gas
oil	Petroleum and coal products (refined)
ele	Electricity
i_s	Iron and steel industry
ppp	Paper product
nfm	Non-ferrous metals
nmm	Mineral products
NON-ENERGY INTENSIVE SECTORS	
agr	Agricultural Products and Forestry
tra	Transport
roi	Rest of Industry - Other manufactures and services

Table 36*: PACE sector composition*

coa	"Coal"
cru	"Oil"
gas	"Gas", "Gas manufacture, distribution"
ppp	"Paper products, publishing"
oil	"Petroleum, coal products"
ele	"Electricity"
nmm	"Mineral products nec"
i_s	"Ferrous metals"
nfm	"Metals nec"
tra	"Transport nec", "Sea transport", "Air transport"

Table 37*: PACE sector composition (continued)*

agr	"Paddy rice", "Wheat", "Cereal grains nec", "Vegetables, fruit, nuts", "Oil seeds", "Sugar cane, sugar beet", "Plant-based fibers", "Crops nec", "Cattle,sheep,goats,horses", "Animal products nec", "Raw milk", "Wool, silk-worm cocoons", "Forestry", "Fishing"
roi	"Minerals nec", "Meat: cattle,sheep,goats,horse", "Meat products nec", "Vegetable oils and fats", "Dairy products", "Processed rice", "Sugar", "Food products nec", "Beverages and tobacco products", "Textiles", "Wearing apparel", "Leather products", "Wood products", "Chemical,rubber,plastic prods", "Metal products", "Motor vehicles and parts", "Transport equipment nec", "Electronic equipment", "Machinery and equipment nec", "Manufactures nec", "Communication", "Financial services nec", "Insurance", "Business services nec", "Recreation and other services", "PubAdmin/Defence/Health/Educat", "Dwellings", "Water", "Construction", "Trade"