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Zentrum für Europäische
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Centre for European
Economic Research

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Niels Anger

Nontechnical Summary

Linkage of the EU Greenhouse Gas Emission Trading Scheme (ETS) to emerging schemes beyond Europe is a central strategic issue of current EU climate policy. At present, non-European countries like Canada, Japan or Australia 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. From 2008 on, company trading among linked schemes would however overlap with trading among countries, as the Kyoto Protocol facilitates international government trading of greenhouse gas emissions at the country level. Moreover, both companies and governments may undertake project-based emission reductions in developing countries via the Clean Development Mechanism (CDM).

The present paper assesses the economic impacts of linking the EU ETS internationally in the presence of a post-Kyoto agreement in 2020. In a quantitative approach it (i) addresses the economic impacts of company-based emission trading *beyond* the European ETS by linking to emerging non-EU schemes, (ii) analyzes the efficiency implications of linking in the presence of *parallel* country-level trading under a post-Kyoto regime, and (iii) introduces a possible *joint* future trading system between ETS companies and Kyoto governments. Based on a numerical multi-country, multi-sector partial equilibrium model of the world carbon market the economic impacts of these climate policy interactions are quantitatively assessed.

The simulations show that linking the European ETS induces only marginal economic benefits: As where-flexibility of international emission trading is restricted to energy-intensive industries that are assigned generous initial emissions, the major compliance burden is carried by non-trading industries excluded from the linked ETS. In the presence of parallel government trading under a post-Kyoto Protocol, the excluded sectors can however be substantially compensated by international trading activities, thus increasing the political attractiveness of the linking process. However, emission markets are still segmented as international trading is feasible only among the same sectors of the linked economies. From an efficiency perspective, a desirable future climate policy regime represents a joint trading system that enables international emission trading between ETS companies and governments, establishing full where-flexibility. While the Clean Development Mechanism (CDM) is not able to alleviate the inefficiencies of linked ETS, in a parallel or joint trading regime government access to low-cost abatement options of developing countries induces large additional cost savings. The restriction of CDM access via a supplementarity criterion does not significantly decrease the economic benefits from project-based emission crediting.

Emission Trading beyond Europe:

Linking Schemes in a Post-Kyoto World

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Abstract. This paper assesses the economic impacts of linking the EU Emission Trading Scheme (ETS) to emerging schemes beyond Europe, in the presence of a post-Kyoto agreement in 2020. Simulations with a numerical multi-country model of the world carbon market show that linking the European ETS induces only marginal economic benefits: As trading is restricted to energy-intensive industries that are assigned generous initial emissions, the major compliance burden is carried by non-trading industries excluded from the linked ETS. In the presence of parallel government trading under a post-Kyoto Protocol, excluded sectors can however be substantially compensated by international trading at the country level, thus increasing the political attractiveness of the linking process. From an efficiency perspective, a desirable future climate policy regime represents a joint trading system that enables international emission trading between ETS companies and governments. While the Clean Development Mechanism (CDM) cannot alleviate the inefficiencies of linked ETS, in a parallel or joint trading regime the access to abatement options of developing countries induces large additional cost savings. Restricting CDM access via a supplementarity criterion does not significantly decrease the economic benefits from project-based emission crediting.

JEL classification: D61, H21, H22, Q58

Keywords: EU ETS, Emission Trading, Kyoto Protocol, Clean Development Mechanism

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1 Introduction

By the initiation of the European Greenhouse Gas Emission Trading Scheme in January 2005, for the first time international trading of carbon emission allowances became feasible for companies at the installation level. Introducing the largest multi-country, multi-sector emission trading scheme (ETS) world-wide, the EU aims at cost-efficient compliance with the reduction commitments of its Member States under the Kyoto Protocol (UNFCCC, 1997). Carbon trading will however 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" (EU, 2003). At the same time, countries beyond the EU 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. From 2008 on, company trading among linked schemes would however overlap with trading among countries, as the Kyoto Protocol facilitates international government trading of greenhouse gas emissions between Annex-B parties at the country level. To quantify the economic impacts of these overlapping future climate policies and their interactions is the goal of the present paper.

Developments of ETS outside the EU have already made substantial progress in Norway and Switzerland who are designing schemes similarly to the European system. Since discussions on linking are already underway, chances are high that these countries will already be linked to the EU ETS until 2010 (Sterk, 2005). In the medium-term perspective up to 2020, further candidates for linking to the EU ETS are to be considered: 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). The scheme is intended to be based on intensity targets and to include a "Price Assurance Mechanism" capping allowance costs at 15 Canadian dollars. 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 – having ratified the Kyoto Protocol – 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 emission permits – so-called "Hot Air" – due to lower *Business-as-Usual* (BAU) than the committed target emissions.

Although the United States and Australia have not ratified the Kyoto Protocol, individual states in both countries are promoting emission trading schemes: In the U.S. the Regional Greenhouse Gas Initiative, aiming at a regional ETS, is pushed by nine Northeast and Mid-Atlantic states (RGGI, 2006). In Australia the New South Wales Greenhouse Gas Abatement Scheme is already operating at the state level (NSW government, 2006) and most recently, Australian state premiers have released early proposals for a national cap and trade system starting in 2010 (Point Carbon, 2006). Also these schemes could quickly arouse interest in EU-ETS decision makers, as "the Commission should examine whether it could be possible to conclude agreements with countries listed in Annex B to the Kyoto Protocol which have yet to ratify the Protocol" (EU, 2004). In summary: There are strong signs for future ETS to be established in non-EU countries and potentially linked with the European scheme by 2020.

At the same time, three flexible mechanisms proposed by the Kyoto Protocol will facilitate various emission market operations by Annex B parties from 2008 on: International Emission Trading makes government trading of *Assigned Amount Units* (AAUs) possible at the country level; the Clean Development Mechanism (CDM) facilitates project-based emission reductions in developing countries in order to generate *Certified Emission Reductions* (CERs) and Joint Implementation (JI) enables project-based abatement in other Annex B regions, generating *Emission Reduction Units* (ERUs).

However, the use of the project-based mechanisms will not be restricted to governments: The amending directive linking the European ETS with the Kyoto Protocol's project-based mechanisms (EU, 2004) enables European companies to generate emission reductions by means of the CDM or JI. Imports of CDM and JI credits may serve as substitutes for ETS allowances since they are interchangeable with the European credits. Moreover, EU ETS allowances are simultaneously labeled as Kyoto units (AAUs). Consequently, four types of emission reduction credits – ETS allowances, Kyoto units, CDM and JI credits – may be used by countries to comply with their reduction commitments under the Kyoto Protocol. This paper analyzes these overlapping climate policies and their interactions due to regulation at the country and installation level by both emission trading and project-based crediting.

Previous quantitative studies have on the one hand focused on efficiency aspects of segmented carbon markets under the current European ETS in partial or general equilibrium frameworks (see Böhringer et al., 2005 or Peterson, 2006), and on interactions between the European ETS and the project-based Kyoto mechanisms (Klepper and Peterson, 2006). On the other hand, economic impacts of country-level trading under the Kyoto Protocol have been assessed through multi-model evaluations (Weyant and Hill, 1999). While these studies focus *either* on the present EU ETS *or* government trading in the first commitment period of the Kyoto Protocol, a comprehensive simultaneous assessment of these overlapping climate policy instruments is lacking. The contribution of the present paper is threefold: In a quantitative approach it (i) addresses the economic impacts of company-based emission trading *beyond* the European ETS by linking to emerging non-EU schemes, (ii) analyzes the efficiency implications of linking in the presence of *parallel* country-level trading and the CDM under a post-Kyoto regime, and (iii) introduces a possible *joint* future trading system between ETS companies and Kyoto governments. Based on a numerical multi-country, multi-sector partial equilibrium model of the world carbon market economic impacts are assessed. The model covers explicit marginal abatement cost functions for 2020 calibrated to energy-system data and considers transaction costs and investment risk for CDM host countries.

The simulations show that linking the European ETS induces only marginal economic benefits: As where-flexibility of international emission trading is restricted to energy-intensive industries that are assigned generous initial emissions, the major compliance burden is carried by non-trading industries excluded from the linked ETS. In the presence of parallel government trading under a post-Kyoto Protocol, the excluded sectors can however be substantially compensated by international trading activities, thus increasing the political attractiveness of the linking process. However, emission markets are still segmented as international trading is feasible only among the same sectors of the linked economies. From an efficiency perspective, a desirable future climate policy regime represents a joint trading system that enables international emission trading between ETS companies and governments, establishing full where-flexibility. While the Clean Development Mechanism (CDM) is not able to alleviate the inefficiencies of linked ETS, in a parallel or joint trading regime government access to low-cost abatement options of developing countries induces large additional cost savings by compensating non-energy-intensive industries. The restriction of CDM access via a supplementarity criterion does not significantly decrease the economic benefits from project-based emission crediting.

The remainder of this paper is organized as follows. In section 2, regional reduction requirements as well as sectoral emission allocations are presented. In section 3, the theoretical background is derived. Section 4 lays out the numerical framework used for the quantitative policy analysis. In section 5, illustrative scenarios of overlapping climate policy in 2020 are specified. Quantitative simulation results are presented in section 6. Section 7 concludes.

2 Reduction commitments and allocation of emissions

2.1 Baseline emissions and a post-Kyoto regime

This section summarizes baseline emissions and reduction commitments associated with a potential post-Kyoto climate policy regime. Carbon dioxide emission trajectories under BAU are based on van Vuuren et al. (2006) who provide a nationally downscaled dataset from the implementation of global IPCC-SRES scenarios (IPCC, 2001) into the environmental assessment model IMAGE 2.2. Emission reduction targets represent a possible Post-Kyoto regime building on the Kyoto Protocol, in which industrial countries agreed on cutting greenhouse gas emissions by 5.2% on average during 2008-2012 as compared to 1990 levels. For this reason, the derivation of post-Kyoto reduction commitments in the year 2020 starts from 2010 as the central year of the protocol's first commitment period.[1]

Emission reduction targets in 2010 for countries that have ratified the agreement correspond to the targets outlined in Annex B of the Protocol. For EU Member States the aggregate eight percent target under Kyoto is redistributed according to an internal Burden Sharing Agreement (EU, 1999). Regarding non-ratifying Annex B parties, the United States national commitment to reduce the greenhouse gas intensity (i.e. emission levels per GDP) by 18 percent by 2012 is translated into an absolute requirement (White House, 2002). Australia is assigned its Kyoto target as the government intends to comply with this commitment despite non-ratification of the Protocol (Commonwealth of Australia, 2002). For non-Annex B regions no emission reduction commitments are assumed, as developing countries have so far refused to assume any quantified targets under the Kyoto Protocol. Since the inclusion of these countries under the CDM requires a baseline, developing regions are assigned their BAU emissions.

Reduction commitments in 2020 are then extrapolated from the 2010 targets: For EU Member States, in 2020 an aggregate emission reduction of 15 percent versus 1990 levels is assumed, which represents the lower bound of a recently proposed range of 15-30 percent (Council of the EU, 2005). It is further assumed that all EU Member States have to contribute the same relative proportion to this aggregate target as in 2010. Emission reduction commitments of non-EU industrial countries in 2020 are derived from the EU-wide rate of reduction. As these

[1] The assumption of an existing binding international agreement in 2020 building on the Kyoto Protocol abstracts from long-term stability aspects of such agreements. For a comprehensive introduction into game-theoretic approaches to international environmental agreements see Finus (2001).

countries have committed to lower reduction targets than the EU in 2010, they are assumed to also exhibit a less ambitious speed of reduction: Emission reduction rates from 2010 to 2020 are five percentage points below the EU-wide rate of reduction in the same period. Similar to the year 2010, developing countries are assumed to not have committed to any quantified reduction targets in 2020.

Table 1 lists regional carbon dioxide emissions from energy and industry for 1990 (the reference year of the Kyoto commitments), as well as projected emissions for 2010 and for 2020. The table further shows the resulting reduction requirements to be very heterogeneous and to become stricter when moving from 2010 to 2020.[2]

Table 1*: CO_2 benchmark emissions and reduction requirements by region*

Regions	CO_2 emissions in 1990 (Mt CO_2)	CO_2 emissions in 2010 (Mt CO_2)	CO_2 emissions in 2020 (Mt CO_2)	Reduction requirements in 2010 (% vs. 1990)	Reduction requirements in 2020 (% vs. 1990)	Reduction requirements in 2020 (% vs. 2020)
Austria	59.6	73.4	74.1	13.0	19.7	35.4
Belgium	110.1	142.7	143.9	7.5	14.7	34.7
Denmark	50.4	58.6	59.1	21.0	27.1	37.9
Finland	54.2	64.7	65.2	0.0	7.7	23.3
France	377.3	418.0	421.0	0.0	7.7	17.3
Germany	988.3	954.6	963.0	21.0	27.1	25.2
Greece	75.8	105.5	106.1	-25.0	-5.3	24.7
Ireland	33.0	49.5	49.8	-13.0	-4.3	30.9
Italy	417.5	508.4	511.7	6.5	13.7	29.6
Netherlands	158.5	200.3	201.8	6.0	13.3	31.9
Portugal	43.6	74.3	74.7	-27.0	-17.2	31.7
Spain	225.8	349.0	351.1	-15.0	-6.1	31.8
Sweden	49.8	49.8	49.8	-4.0	4.0	4.0
United Kingdom	577.4	640.0	646.5	12.5	19.3	27.9
Central Europe	1042.1	893.2	1110.4	-4.8	3.3	9.2
Canada	427.5	597.9	602.3	6.0	8.6	35.1
Japan	1091.4	1264.8	1168.3	6.0	8.6	14.6
Former Soviet Union	3605.4	2489.4	2764.3	0.0	2.7	-26.9
Pacific OECD	292.0	449.7	446.1	-7.0	-4.1	31.9
United States	4890.8	6410.1	6500.0	-27.3	-23.8	6.8
Brazil	214.0	567.4	838.2	-	-	-
China	2495.7	5038.3	6491.2	-	-	-
India	616.1	1764.9	2934.5	-	-	-
Mexico	309.0	572.4	733.7	-	-	-
South Korea	253.7	658.7	853.0	-	-	-

Sources: Netherlands Environment Assessment Agency (Van Vuuren et al., 2006); EU (1999), UNFCCC (1997), own calculations.

[2] Note that the region Pacific OECD primarily consists of Australia (target of +8% vs. 1990) and New Zealand (target of 0% vs. 1990), which explains the aggregate target of 7% additional emissions compared to 1990 levels.

The negative reduction requirement of the Former Soviet Union in 2020 versus BAU levels reflects excess emission permits – so-called “Hot Air” – due to lower projected BAU emissions than the target level implied by its reduction commitment in 2020.

2.2 Allocation of emissions in 2020

At present the EU Emission Trading Directive exclusively covers energy-intensive installations while the remaining industries of EU economies such as household or the transport sector have to be regulated by complementary abatement policies in order to meet the countries’ overall emission budgets. In the absence of the potential use of CDM and JI, domestic policies may include e.g. emission taxes or subsidies for renewable energy use. If the allocation to covered sectors is relatively generous and these sectors feature relatively low-cost abatement options, such a hybrid regulation may cause large inefficiencies: The market segmentation then restricts potential efficiency gains from where-flexibility of international emission trading and shifts abatement to costly reduction options of non-trading sectors (Böhringer et al., 2005). As the Canadian or Japanese proposals suggest, the European ETS could serve as a “blueprint” for emerging schemes, which would make it probable that future non-EU schemes also include mainly energy-intensive industries.

The EU directive prescribes the allocation of emission allowances installations according to historic levels by means of National Allocation Plans (NAPs) of the respective Member States, which specify an overall cap in emissions for covered sectors. Emission allocation can be described by *fulfilment factors* as the fraction of baseline emissions that are freely allocated in terms of emission allowances. Fulfilment factors for EU Member States in the year 2020 are derived from a recent study on European emission allocation in 2005 (Gilbert et al., 2004). The 2005 values, which are presented in Table 2, were then extrapolated to the year 2020, assuming a 20 percent decrease of values in 2020 compared to the year 2005.[3] Consistently, also for non-EU regions fulfilment factors in 2020 represent a 20 percent decrease as compared to 2005. For these regions, 2005 “benchmark” fulfilment factors of equal to one were chosen according to the corresponding EU factors, as the EU scheme is likely to serve as a blueprint for emerging trading systems outside Europe. The base year for emission

[3] This assumption is in line with the European Commission’s planned shortage of the EU’s total emission allocation in the second ETS period (from 2008 on) to some six percent below the first ETS period allocation (EU, 2005). For simplicity it is further assumed that the sectoral coverage by domestic ETS of all regions corresponds to the current EU ETS coverage and does not change until 2020.

allocation reflects the target year of reduction requirements. Table 2 lists the corresponding fulfilment factors by region and year.

Table 2: Fulfilment factors for various regions in 2005 and 2020

	Allocation factors in 2005	Allocation factors in 2020
Austria	0.940	0.752
Belgium	1.042	0.834
Denmark	0.850	0.680
Finland	0.980	0.784
France	0.995	0.796
Germany	1.000	0.800
Greece	1.000	0.800
Ireland	0.970	0.776
Italy	1.074	0.859
Netherlands	1.030	0.824
Portugal	1.035	0.828
Spain	0.940	0.752
Sweden	1.000	0.800
United Kingdom	0.993	0.794
Central Europe	1.000	0.800
Canada	1.000	0.800
Japan	1.000	0.800
Former Soviet Union	1.496	1.269
Pacific OECD	1.000	0.800
United States	1.000	0.800

The table shows that the current allocation implies very low reduction efforts for energy-intensive sectors due to a relatively generous allocation of emissions. Note that for the Former Soviet Union fulfilment factors in 2010 and 2020 are based on the reasoning that the region's excess permits – due to lower BAU emissions than the target level implied by its reduction commitment in the respective year – are allocated to energy-intensive installations proportionally to the corresponding sectors' share of emissions in the entire economy.[4]

3 Theoretical background

The theoretical foundations of the numerical simulation model employed in the next section can be derived by a simple analytical model of the emission market. Given the heterogeneous emission reduction commitments of the previous section, first the analysis will focus on the emission market behavior of countries with alternative reduction targets. Second, the efficiency aspects of emission trading among ETS companies and governments will be

[4] The assumption of excess permit allocation to installations will be relaxed in section 6.

discussed. Third, the parallel existence of linked ETS and government trading is introduced. In a stylized setting, *R* regions are assumed (*r=1,...,R*) committing to individual emission targets (e.g. targets under the Kyoto Protocol), yielding absolute emission budgets $\overline{E}_r$ for each region. Abatement costs of energy-intensive sectors (in the following referred to as *EIS*) and non-energy-intensive sectors (in the following referred to as *NEIS*) in each region are denoted by $AC_r^{EIS}(e)$ and $AC_r^{NEIS}(e)$ respectively. Cost functions are decreasing, convex and differentiable in emissions *e*. Total abatement costs $AC_r(E_r)$ are the sum of sectoral costs $AC_r^{EIS}(e_r^{EIS})$ and $AC_r^{NEIS}(e_r^{NEIS})$.

3.1 Emission market behaviour

On a competitive market for emissions *R* regions are considered, committing to alternative emission targets. A region committing to a binding (absolute) emission target $\overline{E}_r$ aims to minimize its total abatement costs for complying with its commitment. Moreover, it may either buy emission permits from other committing regions (or import them from CDM and JI host countries) or sell them at the exogenous world market price σ, yielding the following cost minimization problem:

$$\min_{e_r^{EIS}, e_r^{NEIS}} \left[AC_r^{EIS}\left(e_r^{EIS}\right) + AC_r^{NEIS}\left(e_r^{NEIS}\right) + \sigma(e_r^{EIS} + e_r^{NEIS} - \overline{E}_r) \right] \qquad (1)$$

A region without a binding emission target, such a CDM host country, aims to maximize its revenues from permit sales $\sigma(\overline{E}_r - e_r^{EIS} - e_r^{NEIS})$ less abatement costs from reducing emissions below the target $\overline{E}_r$ (which for these countries equals BAU emissions) and generating the respective credits. Its profit maximization problem directly corresponds to the cost minimization problem of condition (1): CDM host countries aim to minimize total abatement costs for credit generation and (negative) import costs (i.e. maximize revenues from permit exports).[5]

Consequently, for all regions cost minimization or profit maximization with respect to e_r^{EIS} and e_r^{NEIS} yields the following first-order condition:

$$\sigma = -\frac{\partial AC_r^{EIS}}{\partial e_r^{EIS}} = -\frac{\partial AC_r^{NEIS}}{\partial e_r^{NEIS}} = -\frac{\partial AC_r}{\partial (e_r^{EIS} + e_r^{NEIS})} \qquad (2)$$

[5] Since at a positive permit price any emission reduction below the BAU level results in revenues from permit sales exceeding abatement costs, i.e. in profits, it can be assumed that for this region $e_r^{EIS} + e_r^{NEIS} < \overline{E}_r$ holds and no permits will be imported.

For each region and sectors marginal abatement costs equal the permit price σ and are thereby equalized across all emission sources. A competitive emission market therefore ensures that optimizing behavior of individual market participants with heterogeneous reduction commitments (such as parties of the Kyoto Protocol) and without any commitments (such as CDM host countries) leads to the aggregate cost-efficient solution of equalized marginal abatement costs. Optimal emissions can be derived as $E_r^*, e_r^{EIS^*}, e_r^{NEIS^*}$ where $E_r^* = e_r^{EIS^*} + e_r^{NEIS^*}$. The difference between the total emission budget $\bar{E}_r$ and aggregate optimal emissions E_r^* yields the optimal total trade volume in emission permits.

3.2 Efficiency implications of alternative trading regimes

Besides the emission market behavior of countries with alternative reduction targets, regions with binding commitments may face different compliance costs when deciding for government trading at the country level (in the following referred to as Kyoto trading) or company trading among linked emission trading schemes (in the following referred to as ETS trading). In order to assess the economic impacts of overlapping climate policies, first the two trading systems shall be contrasted theoretically. Figure 1 illustrates the corresponding efficiency aspects from a sectoral perspective – for transparency, in the absence of CDM and JI – in terms of compliance costs.

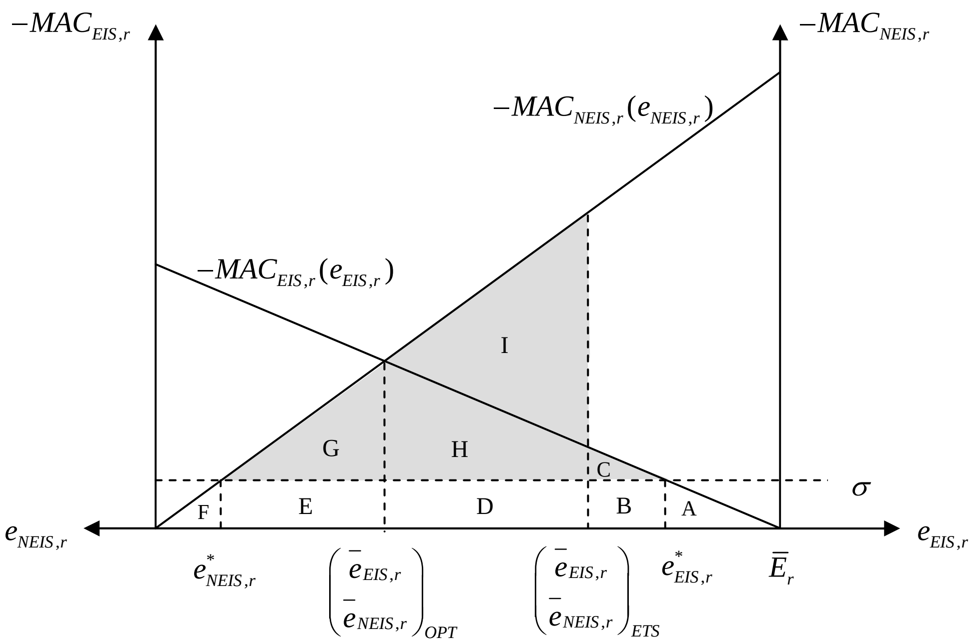

Figure 1: Efficiency gains from international emission trading under alternative regimes

The figure presents the economic impacts of the two trading schemes for a representative region *r* with energy-intensive and non-energy-intensive sectors and – for simplicity linear – respective marginal abatement costs $MAC_{EIS,r}(e_{EIS,r})$ and $MAC_{NEIS,r}(e_{NEIS,r})$. Marginal abatement costs for NEIS are assumed to be generally higher than for EIS (see the section 4 for a numerical underpinning and more complex functional forms). Equal maximum emissions are assumed for EIS and NEIS.

ETS trading currently implies a national allocation of permits $(\bar{e}_{EIS,r}, \bar{e}_{NEIS,r})_{ETS}$, representing a relatively generous allocation to covered industries as compared to the optimal national allocation $(\bar{e}_{EIS,r}, \bar{e}_{NEIS,r})_{OPT}$ (see Table 2). Given a world-market permit price σ arising from the international trading activities among EIS, and a national emission target $\bar{E}_r$, EIS face costs equal to areas A+B in order to comply with the emission target implied by the sectoral budget. This yields internationally optimal emissions $e^*_{EIS,r}$, permit imports equal to $e^*_{EIS,r} - (\bar{e}_{EIS,r})_{ETS}$ and cost savings from international emission trading equal to area C. NEIS face abatement costs equal to areas D+E+F+G+H+I in order to reach the sectoral target, yielding emissions $\bar{e}_{NEIS,r}$. For NEIS no cost savings from international emission trading occur since they do not participate in the trading scheme. Consequently, in the case of internationally linked ETS total compliance costs equal areas A+B+D+E+F+G+H+I including cost-savings from international emission trading equal to C.

While ETS trading exclusively covers energy-intensive industries, country-level (Kyoto) trading *de facto* involves the entire economy. For transparency, the same initial emission allocation and the same world-market permit price as under ETS trading is assumed. While for EIS the same efficiency implications as under ETS trading hold, NEIS may now participate in international emission trading, facing compliance costs equal to areas D+E+F in order to reach the sectoral target. This yields optimal emissions $e^*_{NEIS,r}$ and cost savings from international emission trading equal to areas G+H+I. Consequently, in the case of international trading at the country level total compliance costs equal areas A+B+D+E+F including cost-savings from international emission trading equal to G+H+I+C.

In summary, Kyoto trading at the country level shows a large efficiency advantage over ETS trading. While the former yields optimal emission levels by sector – independent of the national emission allocation by sector – through unrestricted international emission trading, the latter implies an exclusion of NEIS from international emission trading *and* a generous allocation of permits to included EIS. Higher marginal abatement costs of NEIS as compared to EIS *and* large emission abatement of non-trading NEIS induced by the national allocation explain the magnitude of this efficiency advantage.[6]

The project-based mechanisms CDM and JI could serve as an important substitute for high-priced emission permits within the respective trading systems. The potential efficiency gains would however depend on relative permit prices of alternative policy regimes: Only for decreasing world market prices through the inclusion of CDM and JI the cost savings from international emission trading (areas G+H+I and area C) could be increased.

3.3 Parallel existence of trading regimes

While the previous section focused on contrasting ETS trading to Kyoto trading from an efficiency perspective, this section presents the emission market implications of a *parallel* existence of these two trading regimes. This is only the case if a post-Kyoto climate policy agreement establishes international government trading at the country level. A domestic ETS covering exclusively energy-intensive installations enables the respective companies to trade emissions internationally with other covered EIS companies. In the case of a coexisting Kyoto trading regime at the country level, a reasonable assumption is that no double regulation of industries covered by a national ETS takes place. Kyoto trading then only applies to the remaining industries of each region, i.e. takes place between the uncovered non-energy-intensive industries. Figure 2 extends the unilateral perspective of Figure 1 by introducing an additional world region (yielding two regions, 1 and 2) with two sectors.

[6] The illustration of Figure 2 applies to regions with relatively high marginal abatement costs, i.e. regions that are net buyers of emission permits at the world market. A higher international permit price could transform a region into a net permit seller. The presented economic reasoning could however be applied analogically.

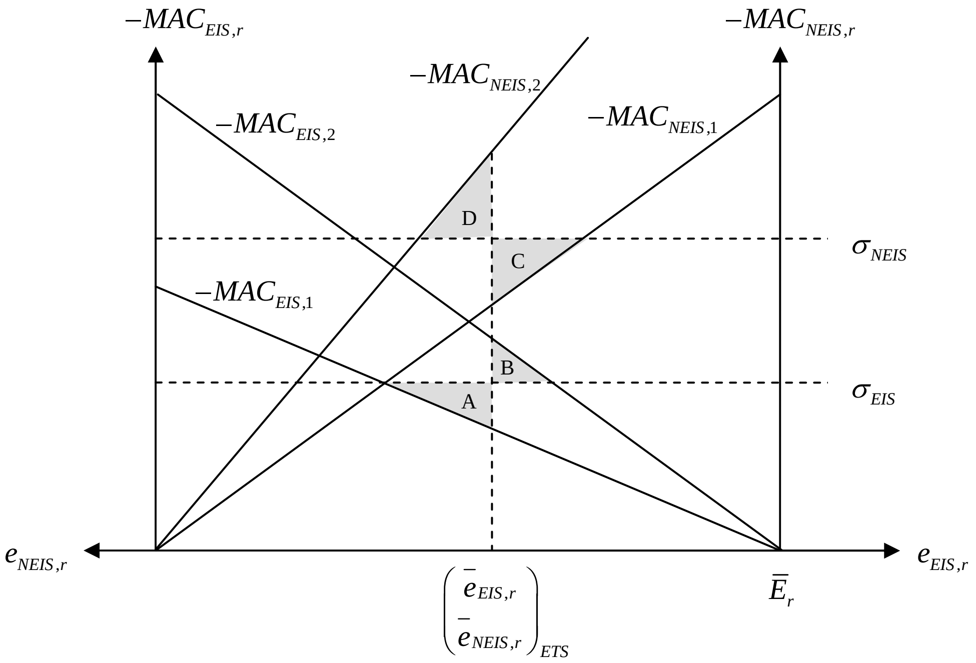

Figure 2: Efficiency gains from parallel international emission trading

In the figure, regional marginal abatement costs are then represented by $MAC_{NEIS,1}(e_{NEIS,1})$ and $MAC_{NEIS,2}(e_{NEIS,2})$. The marginal abatement cost functions of region 2 represent more costly options than of region 1. For transparency, maximum total emissions of both regions are equal and both world regions allocate the same amount of emissions to sectors $(\bar{e}_{EIS,r}, \bar{e}_{NEIS,r})_{ETS}$. As there is no interconnection between the ETS and Kyoto emission market, there are two permit prices (σ_{EIS} and σ_{NEIS}) arising from the sectoral market interactions – the price under Kyoto trading among NEIS (with more costly abatement options) resulting higher than under ETS trading among EIS. On the emission market, region 2 is importing permits from region 1 in each sector: International trading activities of EIS under (linked) ETS trading equalize marginal abatement cost of the two regions, yielding efficiency gains in terms of export benefits for region 1 and cost savings for region 2 (see areas A and B in Figure 2). Parallely, permit export benefits and abatement cost savings from Kyoto trading apply to NEIS of the two regions (see areas C and D). As compared to the initial allocation, the low-cost region 1 emits less, while region 2 increases emissions. In this parallel regime setting, Kyoto trading may serve as a compensation mechanism for the inefficiencies of ETS trading and the otherwise large compliance costs of NEIS.

4 Numerical specification

To assess the magnitude of economic impacts caused by overlapping trading regimes including the CDM for a greater number of regions, a numerical multi-country equilibrium model of the world carbon market is applied. Empirical data on baseline emissions and emission allocation, as presented in section 2, is implemented into the numerical framework. In order to account for real-world complexities, the model incorporates calibrated marginal abatement cost functions. It explicitly divides the regional economies into energy-intensive sectors (EIS) and remaining industries (NEIS). Building on the EU-wide version of Böhringer et al. (2005), the regionally extended model features separated carbon markets for ETS and Kyoto trading, explicitly incorporates CDM host countries as well as CDM access restrictions, and is calibrated to represent the future carbon market in the year 2020. An algebraic formulation is given in Appendix A.1.[7]

To generate marginal abatement cost functions by region and sector, data simulated by the well-known energy system model POLES is used (Criqui et al., 1999), which explicitly covers energy technology options for emission abatement in various world regions as well as in energy-intensive sectors (EIS) and remaining industries (NEIS) for the base-year 2020. In the POLES simulations a sequence of carbon taxes (e.g. 0 to 400 US$ per ton of carbon) is imposed on the respective regions, resulting in associated sectoral emission abatement.

To estimate the coefficents for marginal abatement cost functions in 2020, an ordinary least squares (OLS) regression of tax levels (i.e. marginal abatement costs) on associated emission abatement is employed. In order to assure for functional flexibility, a polynomial of third degree is chosen as the functional form of marginal abatement cost functions. For region *r* and sector *i* this results in the following equation:

$$-MAC_{ir}(e_{ir}) = \beta_{1,ir}(e_{0ir} - e_{ir}) + \beta_{2,ir}(e_{0ir} - e_{ir})^2 + \beta_{3,ir}(e_{0ir} - e_{ir})^3 \qquad (3)$$

with MAC_{ir} as marginal abatement cost in region r and sector $i \in \{EIS, NEIS\}$, $\beta_{1,ir}$, $\beta_{2,ir}$ and $\beta_{3,ir}$ as marginal abatement cost coefficients, e_{0ir} as baseline emission level and e_{ir} as emission level after abatement. Table 3 shows the resulting least-square estimates of marginal abatement cost coefficients by region and sector in 2020.[8]

[7] Note that in this analysis, installation-based trading is implemented as trading at the sectoral level.
[8] The marginal abatement cost coefficients have the following units:
$\beta_{1,ir}$ [(€2005/tCO_2)/MtCO_2, $\beta_{2,ir}$ [(€2005/tCO_2)/(MtCO_2)^2 and $\beta_{3,ir}$ [(€2005/tCO_2)/(MtCO_2)^3].

Table 3: Marginal abatement cost coefficients in 2020 (€2005)

Regions	Energy-intensive sectors (EIS)			Non-energy-intensive sectors (NEIS)		
	$\beta_{1,EIS,r}$	$\beta_{2,EIS,r}$	$\beta_{3,EIS,r}$	$\beta_{1,NEIS,r}$	$\beta_{2,NEIS,r}$	$\beta_{3,NEIS,r}$
Austria	21.1480	-3.3392	0.8094	11.4095	2.8620	-0.1012
Belgium	2.8430	-0.0984	0.0026	5.8176	0.1881	0.0176
Denmark	11.1840	-0.5817	0.0235	59.6656	-12.7515	5.7710
Finland	3.0710	-0.0566	0.0032	75.2956	-14.0624	1.5541
France	0.9439	-0.0078	0.0002	1.5191	0.0784	-0.0007
Germany	0.3668	-0.0017	0.0000	0.9417	0.0111	0.0000
Greece	1.8843	-0.0118	0.0005	30.8964	-1.6083	0.3375
Ireland	3.0683	-0.1585	0.0110	23.4662	-0.3972	0.2788
Italy	0.9413	0.0036	0.0001	2.5992	0.1511	-0.0005
Netherlands	0.8665	0.0393	-0.0004	10.9863	-0.4063	0.1088
Portugal	11.0386	-0.5740	0.0175	56.1921	-9.2007	2.4941
Spain	0.8090	-0.0097	0.0002	10.3924	-0.4192	0.0137
Sweden	7.7433	-0.2814	0.0102	12.5684	1.7070	0.3807
United Kingdom	0.4066	-0.0022	0.0000	1.4731	0.0244	-0.0001
Central Europe	0.1466	0.0001	0.0000	0.7554	0.0008	0.0000
Canada	0.2766	0.0007	0.0000	0.8316	0.0044	0.0001
Japan	0.2666	0.0023	0.0000	1.3130	0.0313	-0.0001
Former Soviet Union	0.0218	0.0002	0.0000	0.1075	0.0004	0.0000
Pacifc OECD	0.7244	-0.0094	0.0001	1.8636	-0.0315	0.0005
United States	0.0245	0.0000	0.0000	0.1453	0.0000	0.0000
Brazil	11.5525	-0.0631	0.0001	4.1163	0.0006	0.0004
China	0.0129	0.0000	0.0000	0.3052	-0.0004	0.0000
India	0.0960	-0.0001	0.0000	2.2685	-0.0346	0.0008
Mexico	0.0116	0.0191	-0.0001	0.3852	0.0204	-0.0001
South Korea	0.3405	-0.0011	0.0000	4.1598	-0.0027	0.0010

5 Scenarios of future climate policy

In the following, scenarios of linking emission trading schemes in the presence of a post-Kyoto agreement in 2020 are specified. The scenarios can be classified by two dimensions: The *regional* dimension distinguishes scenarios of countries that establish a climate policy regime, whereas the *institutional* dimension distinguishes schemes of carbon regulation. Table 4 presents the three regional scenarios: As a reference case, scenario EU represents EU ETS participants in 2020, i.e. current members of the European Union including the acceding countries Bulgaria and Romania.[9] Scenario EU^{+} indicates the potential linkage of the current EU ETS to emerging ETS in countries that ratified the Kyoto Protocol, such as Japan, Canada and the Former Soviet Union (or respective country-level trading). Scenario EU^{++} assumes linking the current EU ETS not only to Kyoto ratifiers but to emerging ETS in countries that

[9] Note that the region EU-27 is approximated by EU-15 Member States (excluding Luxemburg) and the POLES region Central Europe, which essentially covers new Member States as well as Bulgaria and Romania.

have not ratified the Kyoto Protocol, such as Australia and the US. For all regional scenarios alike, five central developing countries are assumed to host CDM projects: China, India, Brazil, Mexico and South Korea.[10]

Table 4: Regional Scenarios for 2020

Regional scenario	Regions participating in emission trading	CDM regions
EU	EU-27	Brazil China India Mexico South Korea
EU^{+}	EU-27 Japan Canada Former Soviet Union	
EU^{++}	EU-27 Japan Canada Former Soviet Union Pacific OECD United States	

Table 5 lists institutional scenarios which in total involve ten cases. As a reference case, *NOTRADE* represents cost-efficient domestic action by the respective regions, e.g. by sectorally uniform domestic carbon taxation. In order to assess linked emission trading schemes, scenario *ETS* describes international emission trading only between energy-intensive companies (i.e. sectors), reflecting a hybrid regulation of permits and taxes and assuming the sectoral emission allocation in 2020 shown in Table 2. For transparency, this setting abstracts from the existence of a country-level trading regime. Scenario *PARALLEL* introduces government trading under a post-Kyoto Protocol, parallel to linked emission trading schemes. This is only the case if a post-Kyoto climate policy agreement establishes international trading at the country level. In this setting of coexisting trading regimes, a reasonable assumption is that no double regulation of industries covered by a national ETS takes place – Kyoto trading then only applies to the remaining industries of each region. Consequently, *PARALLEL* describes ETS trading for energy-intensive sectors, while it

[10] The present analysis focuses on the CDM as a project-based mechanism, as JI projects are hosted by Annex B parties who participate in international emissions trading. Abstracting from its project-based character, JI may therefore be represented by international emissions trading of the respective regions.

assumes Kyoto trading among the remaining non-energy-intensive sectors.[11] Scenario *JOINT* represents a potential interconnection between ETS and Kyoto trading: International emission trading both among energy-intensive sectors via companies, among countries via governments and *between* companies and governments. This institutional setting is equivalent to international trading across all sectors and regions, except of intra-national trading between sectors.

Regarding CDM and JI, the Marrakech Accords to the Kyoto Protocol demand that "the use of the mechanisms shall be supplemental to domestic action" (UNFCCC, 2002). Although the Marrakech formulation lacks precision, one attempt to quantify a CER import limit 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). Besides the supplementarity issue under the Kyoto Protocol regarding government trading, there is a separate supplementarity debate regarding installation-based trading: The EU ETS amending directive states that "Member States may allow operators to use CERs and ERUs from project activities in the Community scheme up to a percentage of the allocation of allowances to each installation" (EU, 2004). Also in the EU ETS amending directive no quantitative limit for the import of CDM and JI credits is specified and it is the obligation of each Member State to quantify the maximum amount of CERs and ERUs that may be used for compliance in its national allocation plan. Potentially large substitution patterns of ETS companies in favor of the CDM may put strict supplementarity considerations on the political agenda, such as an import limit of eight percent of allocated allowances (Langrock and Sterk, 2004).

Within the institutional scenarios for the present analysis, the following CDM regimes are applied: While *ETS_CDM* assumes the *ETS* trading regime including the option of unlimited CER imports (only) by EIS companies from conducting CDM projects, *PARALLEL_CDM* and *JOINT_CDM* represent the respective regime with unlimited CDM access for governments, i.e. all sectors. Supplementarity considerations are taken into account by three scenarios: *ETS_SUP* restricts CER imports of energy-intensive industries to eight percent of allocated permits. *PARALLEL_SUP* reflects a sectorally differentiated supplemetarity rule, limiting CDM access of EIS to eight percent of allocated emissions, while regulating that in NEIS a maximum of 50 percent of the (sectorally downscaled) NEIS emission reduction commitment may be fulfilled via the CDM. Finally, *JOINT_SUP* assumes a uniform CDM

[11] Here it is assumed that each ETS region has committed to a post-Kyoto agreement enabling government trading.

restriction across all sectors, i.e. a 50 percent maximum CDM import share of the national reduction commitment, as sectors are de facto interconnected via joint trading.[12]

Table 5: Institutional scenarios for 2020

<table>
<tr><th>Institutional scenario</th><th colspan="2">CO_2 regulation</th><th colspan="2">International emission trading</th><th colspan="2">CDM access</th></tr>
<tr><th></th><th>EIS</th><th>NEIS</th><th>EIS with</th><th>NEIS with</th><th>EIS</th><th>NEIS</th></tr>
<tr><td>NOTRADE</td><td>Tax</td><td>Tax</td><td>No</td><td>No</td><td>No</td><td>No</td></tr>
<tr><td>ETS</td><td rowspan="3">Permits</td><td rowspan="3">Tax</td><td rowspan="3">foreign EIS</td><td rowspan="3">No</td><td>No</td><td rowspan="3">No</td></tr>
<tr><td>ETS_CDM</td><td>Unlimited</td></tr>
<tr><td>ETS_SUP</td><td>8% of allocation</td></tr>
<tr><td>PARALLEL</td><td rowspan="3">Permits</td><td rowspan="3">Permits</td><td rowspan="3">foreign EIS</td><td rowspan="3">foreign NEIS</td><td>No</td><td>No</td></tr>
<tr><td>PARALLEL_CDM</td><td>Unlimited</td><td>Unlimited</td></tr>
<tr><td>PARALLEL_SUP</td><td>8% of allocation</td><td>50% of reduction</td></tr>
<tr><td>JOINT</td><td rowspan="3">Permits</td><td rowspan="3">Permits</td><td rowspan="3">foreign EIS foreign NEIS</td><td rowspan="3">foreign EIS foreign NEIS</td><td>No</td><td>No</td></tr>
<tr><td>JOINT_CDM</td><td>Unlimited</td><td>Unlimited</td></tr>
<tr><td>JOINT_SUP</td><td colspan="2">50% of national reduction</td></tr>
</table>

The model considers the following barriers to CDM projects: First, it features transaction costs for the purchase of CERs of 0.5 US$ (1 US$) per ton of CO_2 for energy-intensive (non energy-intensive) sectors of CDM host countries.[13] Second, following Böhringer and Löschel (2002) country-specific investment risk for CDM projects, e.g. 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 emission reduction credits generated by CDM projects with the mean risk value of the respective host country. The underlying data stems from the International Monetary Fund's International Financial Statistics (IMF, 2000). Third, a CDM adaptation tax is incorporated amounting to two percent of CER revenues as

[12] Regarding supplementarity rules of non-EU regions, as in the case of sectoral emission allocation similar regulation as in the EU is assumed.
[13] The magnitude of transaction costs is in line with recent estimates (see Michaelowa and Jotzo, 2005).

proposed under the Marrakech Accords (UNFCCC, 2002). Transaction costs, investment risk and CDM tax enter the model via a premium on marginal abatement costs of CDM host countries, thereby increasing the international CER price.[14]

6 Simulation results

In this section, the economic impacts of linking emission trading schemes in the presence of a post-Kyoto agreement are simulated using the numerical multi-country equilibrium model of the world carbon market in 2020 presented in section 4. Regarding climate policy scenarios presented in the previous section, alternative combinations of the regional and institutional dimension are implemented as scenarios in the simulation model. First, the efficiency aspects of alternative trading regimes, such as *ETS*, *PARALLEL* and *JOINT* trading schemes are assessed. Subsequently, the role of the CDM and the associated supplementarity considerations for the international carbon market are addressed.

6.1 Economic impacts of linking ETS

As a reference case, the economic impact assessment starts with the climate policy setting of linking the EU ETS with emerging schemes outside Europe in the absence of a post-Kyoto agreement establishing country-level trading and CDM. The efficiency implications are presented in terms of sectoral and total compliance costs associated with the fulfilment of national emission reduction commitments and are contrasted to the *NOTRADE* scenario. Table 6 shows the corresponding numerical simulation results in the institutional scenario *ETS* for various regional constellations of linked schemes. In the table, e.g. scenario *ETS [*EU^+*]* represents the institutional scenario *ETS* in combination with the regional scenario EU^+. Focusing first on the European Union, it shows that for all regional constellations aggregate EU compliance costs under scenario *ETS* are drastically higher than under *NOTRADE*: Trading emissions among European energy-intensive companies – at a permit price amounting to 30.5 € per ton of CO_2 – implies substantially higher adjustment costs than efficient domestic action (assuming an economy-wide uniform carbon tax). This inefficiency is due to a generous emission allocation to EIS (see section 2) causing high reduction efforts of NEIS. Considering their high marginal abatement costs, these sectors then almost account

[14] An alternative approach to account for barriers to CDM project development is presented in Kallbekken et al. (2006), who introduce a "participation rate" reflecting that only some share of the potentially profitable CDM projects will be implemented.

for the entire economic burden of the reduction commitment (sectoral burden shifting). Comparing regional trading scenarios, the results suggest that linking the European ETS to other domestic schemes is not able to decrease total EU compliance costs by more than one percent (moving from *ETS [EU] to ETS [*EU^{++}]). As ETS trading exclusively covers energy-intensive sectors, only these industries benefit from an enlarged trading scheme (restricted where-flexibility). The essential part of the economic burden is carried by non-trading sectors and cannot be reduced by linking ETS.

The economic impacts for non-EU countries from linking to the EU scheme are very heterogeneous: Linking of Canada, Japan and the Former Soviet Union (yielding regional scenario EU^{+}) implies drastic compliance costs for Canada, while Japan is benefiting and the Former Soviet Union is even net-benefiting from joining the EU scheme.[15] For Canada, compliance costs even exceed total costs from cost-efficient domestic action, an effect which – as in the case of the EU – can be explained by an inefficient domestic allocation of emissions between sectors. Linking to the European Union cannot compensate for the domestic burden-shifting to non-energy-intensive sectors, since exactly these sectors do not benefit from trading. The beneficial effect for Japan is the cause of a relatively heavy economic burden of EIS under domestic action, which can be drastically decreased by international emission trading of these sectors. The international permit price falls from 30.5 to 5.6 € per ton of CO_2 due to the sale of “Hot Air” by the Former Soviet Union, which generates large revenues from excess permit sales at the emission market.

The perspectives of a further enlargement of the EU ETS are even worse: Both Canada and Japan face higher compliance costs when the interlinked ETS with the European Union is further enlarged by Australia and the USA (yielding regional scenario EU^{++}). This effects is due to the increased demand for emission permits which causes a rise in the permit price from 5.6 to 11.5 €. The newly linked states again face higher compliance costs than under *NOTRADE* due to domestic inefficiencies. As a consequence, linking domestic ETS under the regional constellation EU^{++} is not beneficial for any participant except of the Former Soviet Union, which benefits from the increased demand (and price) for its excess permits.

[15] By definition, in each scenario of linking ETS non-participating regions face compliance costs equal to the *NOTRADE* scenario.

Table 6: Linking ETS under alternative trading regimes: Compliance costs by region, sector and scenario (in million €2005)

	NOTRADE			***ETS [EU]***			***ETS [EU$^+$]***			***ETS [EU^{++}]***		
	TOTAL	***EIS***	***NEIS***	***TOTAL***	***EIS***	***NEIS***	***TOTAL***	***EIS***	***NEIS***	***TOTAL***	***EIS***	***NEIS***
EU-27	54747.1	39216.5	15530.6	359401.6	7244.9	352156.7	354695.3	2538.6	352156.7	356754.6	4597.9	352156.7
Canada	7572.4	4960.9	2611.5	7572.4	4960.9	2611.5	22458.5	280	22178.5	22646.8	468.3	22178.5
Japan	5590.5	4412	1178.5	5590.5	4412	1178.5	3047.2	642	2405.2	3627	1221.8	2405.2
Former Soviet Union	0	0	0	0	0	0	-2764.3	-2764.3	0	-6247.7	-6247.7	0
Pacific OECD	3213.8	2393.4	820.4	3213.8	2393.4	820.4	3213.8	2393.4	820.4	8818	488.4	8329.6
United States	2002.7	1725.3	277.4	2002.7	1725.3	277.4	2002.7	1725.3	277.4	4981.4	4981.4	0
	NOTRADE			***PARALLEL [EU]***			***PARALLEL [EU$^+$]***			***PARALLEL [EU^{++}]***		
	TOTAL	***EIS***	***NEIS***	***TOTAL***	***EIS***	***NEIS***	***TOTAL***	***EIS***	***NEIS***	***TOTAL***	***EIS***	***NEIS***
EU-27	54747.1	39216.5	15530.6	74195	7244.9	66950.1	26848.1	2538.6	24309.5	13969.1	4597.9	9371.2
Canada	7572.4	4960.9	2611.5	7572.4	4960.9	2611.5	6400.7	280	6120.7	2827.3	468.3	2359
Japan	5590.5	4412	1178.5	5590.5	4412	1178.5	2242.2	642	1600.2	1905.8	1221.8	684
Former Soviet Union	0	0	0	0	0	0	-24830.8	-2764.3	-22066.5	-12644.9	-6247.7	-6397.2
Pacific OECD	3213.8	2393.4	820.4	3213.8	2393.4	820.4	3213.8	2393.4	820.4	1902.1	488.4	1413.7
United States	2002.7	1725.3	277.4	2002.7	1725.3	277.4	2002.7	1725.3	277.4	178.4	4981.4	-4803
	NOTRADE			***JOINT [EU]***			***JOINT [EU$^+$]***			***JOINT [EU^{++}]***		
	TOTAL	***EIS***	***NEIS***	***TOTAL***	***EIS***	***NEIS***	***TOTAL***	***EIS***	***NEIS***	***TOTAL***	***EIS***	***NEIS***
EU-27	54747.1	39216.5	15530.6	32393.9	-716.9	33110.8	13255.7	5264.3	7991.4	12060.6	4874.4	7186.2
Canada	7572.4	4960.9	2611.5	7572.4	4960.9	2611.5	2530	517.8	2012.2	2299.6	489.8	1809.8
Japan	5590.5	4412	1178.5	5590.5	4412	1178.5	2024.1	1435.6	588.5	1840.2	1308.2	532
Former Soviet Union	0	0	0	0	0	0	-13099.3	-7802.1	-5297.2	-11537	-6856.5	-4680.5
Pacific OECD	3213.8	2393.4	820.4	3213.8	2393.4	820.4	3213.8	2393.4	820.4	1602.2	517.3	1084.9
United States	2002.7	1725.3	277.4	2002.7	1725.3	277.4	2002.7	1725.3	277.4	1686.7	5140.6	-3453.9

Table 7: Linking ETS under alternative CDM options: Compliance costs by region, sector and scenario (in million €2005)

	ETS_CDM [EU]			***ETS_CDM [EU^{+}]***			***ETS_CDM [EU^{++}]***			***ETS_SUP***		
										[EU]	***[EU^{+}]***	***[EU^{++}]***
	TOTAL	***EIS***	***NEIS***	***TOTAL***	***EIS***	***NEIS***	***TOTAL***	***EIS***	***NEIS***	***TOTAL***	***TOTAL***	***TOTAL***
EU-27	354317.3	2160.6	352156.7	353168.5	1011.8	352156.7	354624.9	2468.2	352156.7	355732.9	353168.5	354624.9
Canada	7572.4	4960.9	2611.5	22295.2	116.7	22178.5	22451.4	272.9	22178.5	7572.4	22295.2	22451.4
Japan	5590.5	4412	1178.5	2656	250.8	2405.2	3028.6	623.4	2405.2	5590.5	2656	3028.6
Former Soviet Union	0	0	0	-943.9	-943.9	0	-2668.7	-2668.7	0	0	-943.9	-2668.7
Pacific OECD	3213.8	2393.4	820.4	3213.8	2393.4	820.4	8588.9	259.3	8329.6	3213.8	3213.8	8588.9
United States	2002.7	1725.3	277.4	2002.7	1725.3	277.4	3062.6	3062.6	0	2002.7	2002.7	3062.6
	PARALLEL_CDM [EU]			***PARALLEL_CDM [EU^{+}]***			***PARALLEL_CDM [EU^{++}]***			***PARALLEL_SUP***		
										[EU]	***[EU^{+}]***	***[EU^{++}]***
	TOTAL	***EIS***	***NEIS***	***TOTAL***	***EIS***	***NEIS***	***TOTAL***	***EIS***	***NEIS***	***TOTAL***	***TOTAL***	***TOTAL***
EU-27	9138.4	3834.1	5304.3	5091.6	2227.2	2864.4	6646.7	2864.5	3782.2	8903.8	5091.6	6646.7
Canada	7572.4	4960.9	2611.5	970.1	248.1	722	1265.8	312.6	953.2	7572.4	970.1	1265.8
Japan	5590.5	4412	1178.5	778.5	560.4	218.1	1014.9	728.6	286.3	5590.5	778.5	1014.9
Former Soviet Union	0	0	0	-4035.6	-2351.1	-1684.5	-5498.7	-3222.7	-2276	0	-4035.6	-5498.7
Pacific OECD	3213.8	2393.4	820.4	3213.8	2393.4	820.4	872.2	301.9	570.3	3213.8	3213.8	872.2
United States	2002.7	1725.3	277.4	2002.7	1725.3	277.4	1846.8	3488.7	-1641.9	2002.7	2002.7	1846.8
	JOINT_CDM [EU]			***JOINT_CDM [EU^{+}]***			***JOINT_CDM [EU^{++}]***			***JOINT_SUP***		
										[EU]	***[EU^{+}]***	***[EU^{++}]***
	TOTAL	***EIS***	***NEIS***	***TOTAL***	***EIS***	***NEIS***	***TOTAL***	***EIS***	***NEIS***	***TOTAL***	***TOTAL***	***TOTAL***
EU-27	9138.4	3834.1	5304.3	5091.6	2227.2	2864.4	6646.7	2864.5	3782.2	10279.7	5091.6	6646.7
Canada	7572.4	4960.9	2611.5	970.1	248.1	722	1265.8	312.6	953.2	7572.4	970.1	1265.8
Japan	5590.5	4412	1178.5	778.5	560.4	218.1	1014.9	728.6	286.3	5590.5	778.5	1014.9
Former Soviet Union	0	0	0	-4035.6	-2351.1	-1684.5	-5498.7	-3222.7	-2276	0	-4035.6	-5498.7
Pacific OECD	3213.8	2393.4	820.4	3213.8	2393.4	820.4	872.2	301.9	570.3	3213.8	3213.8	872.2
United States	2002.7	1725.3	277.4	2002.7	1725.3	277.4	1846.8	3488.7	-1641.9	2002.7	2002.7	1846.8

6.2 The presence of Kyoto trading

In the presence of a post-Kyoto agreement that enables international emission trading at the country level, linking the European ETS has very different implications. Table 6 shows the respective simulation results by scenarios *PARALLEL* and *JOINT*. Focusing first on parallel ETS and Kyoto trading regimes, it shows that already in the absence of linking, the European Union faces efficiency improvements through government trading: Scenario *PARALLEL [EU]* induces drastically lower adjustment costs than *ETS [EU]*, although total costs in the parallel setting are still higher than under efficient domestic action. Kyoto trading serves as a compensation mechanism, largely alleviating the inefficiencies of the EU ETS through parallel international trading among the formerly burdened non-energy-intensive sectors excluded from the scheme. Furthermore, linking the European ETS to emerging non-EU schemes in the presence of Kyoto trading leads to a much greater fall in compliance costs – by linking to Canada, Japan and the Former Soviet Union (yielding regional scenario EU^{+}) total EU compliance costs can be reduced by more than 60 percent. The isolated economic impacts from linking the European ETS are indeed similar to the case of absent Kyoto trading, yielding the same economic impacts for EIS at a permit price of 5.6 € per ton of CO_2. However, it is NEIS that benefit from increased compensation through international Kyoto trading of the same countries – at a permit price of 47.6 €, which is drastically lower than NEIS marginal abatement costs under domestic action. A further enlargement of ETS and Kyoto trading to Australia and the USA (yielding regional scenario EU^{++}) yields increased benefits from a larger emission market for NEIS, decreasing the permit price to 16.5 € and cutting EU compliance costs by half. Also for non-EU regions parallel trading regimes would result beneficial: All regions except of the Former Soviet Union (revenues from permit sales decrease by almost 50 percent) face lower compliance costs when linking to the European scheme and trading parallely at the country level. However, emission markets are still segmented – and where-flexibility still restricted – as international trading is feasible only between the same sectors of the linked economies.

A joint emission trading regime interconnecting energy-intensive companies and national governments is de facto equivalent to full where-flexibility, establishing international trading activities between all regions and sectors. Table 6 shows that in the absence of linking, only an interconnected trading system (*JOINT [EU]*) implies efficiency gains for Europe as compared to cost-efficient domestic action. EU compliance costs amount to less than 50 percent of a parallel system and to less than five percent of *ETS* trading. Linking the EU ETS in a *JOINT* trading system enables the participating energy-intensive companies not only to trade internationally among each other, but also with governments of the participating countries. Hereby, also an enlarged trading system causes a much stronger fall in EU compliance costs than under *ETS* or *PARALLEL* trading, since now all sectors can benefit jointly from extended trading activities. Here, the cost decrease is most substantial moving from *EU* to *EU*$^{+}$, as the dominant emission permit exporter Former Soviet Union is able to supply more excess permits and decrease the international permit price from 69.6 to 14 €. Consequently, also all non-EU regions benefit substantially from enlarged joint emission trading except of the Former Soviet Union, which due to a lower market price generates smaller revenues. Of all three trading regimes, this region benefits most from parallel trading (with all sectors trading at relatively high permit prices), followed by joint and ETS trading.

6.3 The role of the Clean Development Mechanism

Generating emission credits in developing countries via CDM projects may serve a substitute for emission permits traded between industrial countries under the future climate policy regimes presented in the last section. Table 7 shows that the impact of the CDM crucially depends on the underlying trading regime: While under linked ETS trading only energy-intensive sectors may import CDM permits, under a parallel or joint regime both EIS and NEIS may participate in project-based emission crediting through national governments. As a consequence, in the context of an ETS regime unlimited CDM access only slightly reduces total compliance costs for participating regions (see scenarios *ETS_CDM [EU*$^{+}$*]* to *[EU*$^{++}$*]*). This holds true although the CDM significantly lowers the permit price for the energy-intensive part of the economy, e.g. within the EU scheme from 30.5 to 4.7 € per ton of CO_2.

By contrast, in a *PARALLEL* trading regime the CDM reduces adjustment costs by almost 90 percent for the European scheme (see *PARALLEL_CDM [EU]*) as compared to this scenario in the absence of the CDM. In this setting of coexisting trading regimes the uniform permit price amounts to 9.1 €. Compliance costs are in particular lowered for the formerly burdened NEIS who now enjoy access to project-based credits, while the CDM induces even higher adjustment costs than under *ETS_CDM* due to increased CER demand and price for EU energy-intensive industries. This leads to a more even cost distribution between sectors and lower aggregate compliance costs than under *NOTRADE*. The additional efficiency via the CDM under a parallel regime reflect a stronger compensation of non-energy-intensive industries by abatement options of entire CDM host countries, which are less costly than abatement options of NEIS in (industrialized) Kyoto countries.

Furthermore, Table 7 shows that the economic effects of the CDM under a *JOINT* trading regime are for all regions identical to those of a parallel setting: As both EIS and NEIS of trading regions have access to the international pool of project-based credits, the CDM de facto interconnects the two sectors internationally and – due to a lower CER price than the world market price for emission permits – induces full where-flexibility and identical outcomes in both trading regimes. While all regions are generally benefiting from demanding CDM credits, the Former Soviet Union is discriminated by trading activities with developing countries, generating smaller revenues from emission permit sales due to decreased demand and price.

Comparing regional scenarios involving the CDM shows that the economic impacts of enlarged trading schemes generally diminish in the presence of the CDM and can even be reversed: Under *PARALLEL_CDM* and *JOINT_CDM* trading, moving from *EU* to EU^{+} still cuts European compliance costs by almost half (dropping the permit price from 9.1 to 4.8 €) and benefiting permit buyers Canada and Japan. However, further enlarging trading activities to EU^{++} causes efficiency losses by driving the permit price up to 6.4 Euros. This effect is due to an increased demand for emission permits and CERs by linking to Australia and the USA. These two regions do however benefit from joining an EU^{++} regime despite the increased permit price, due to higher marginal abatement costs under *NOTRADE*.

As one climate policy objective of the European Union is to achieve a major fraction of emission abatement within its emission trading scheme, strong substitution patterns in favor of the CDM put supplementarity considerations – i.e. restrictions on CER imports – on the political agenda of the linking process. Table 7 shows that only for the principal permit importer European Union, and only in the absence of linking ETS the alternative supplementarity scenarios laid out in section 5 have impacts on the emission market. First, in the European ETS a restriction of CER imports of EU energy-intensive industries to eight percent of allocated EIS emissions only slightly increases total EU compliance costs (see scenario *ETS_SUP [EU]*). Due to the already minor contribution of unlimited CDM under ETS trading, this result holds despite a permit price increase from 4.7 to 19.3 €.

A supplementarity criterion in a parallel trading regime would restrict EIS imports from the CDM similarly to ETS trading, while NEIS may import a maximum of 50 percent of the downscaled NEIS reduction commitment. Total EU compliance costs may then result even *lower* as under unlimited CDM access: The (binding) import restriction in EIS again induces only a minor cost increase in these sectors of the EU, but the lower EIS demand decreases the CER price enough (from 9.1 to 7.6 €) to transfer relatively larger cost savings to NEIS, for which the 50 percent import limit is not strict enough to be binding.

By contrast, in a joint emission trading regime EU adjustment costs are more than ten percent higher when only 50 percent of the *national* emission reduction commitment may be imported by all sectors via the CDM: Limiting the access to low-cost emission reductions from developing countries reduces potential cost savings from project-based crediting in particular for non-energy-intensive EU industries (facing a uniform permit price of 26.4 €). Unlike the economic effects for Europe, for all non-EU regions the application of the various supplementarity criterions does not change the economic impacts of CDM access, as the respective thresholds of CDM imports are not reached under unlimited CDM access (see e.g. total compliance costs under *PARALLEL_CDM [*EU^{++}*]* versus *PARALLEL_SUP [*EU^{++}*]*).

6.4 The case of no "Hot Air" allocation

The simulation results presented in the previous sections implicitly assume an international climate policy regime in which excess emission permits of the Former Soviet Union ("Hot Air") are allocated for free to the respective national installations. This situation would imply a subsidy for EIS since allocated permits could directly be exported to other ETS regions. It is however not unambiguous whether such a strategy will prevail in the future: On the one hand, excess allocation could be prevented by potential international competitiveness distortions between companies arising from linking to the European scheme. On the other, incentives for strategic behaviour of the Former Soviet Union as a quasi monopolist on the emission market could also restrict permit allocation to installations.[16]

For this reason an alternative setting is introduced which assumes that no *excess* permits will be allocated to installations of the Former Soviet Union. In this case, the region is assigned an emission reduction target versus 1990 levels that resembles its BAU emissions in 2020 (here: 23.3 percent) and a fulfilment factor equal to one.

Table 9 and Table 10 in the Appendix present the corresponding regional compliance costs. It shows that the previous findings are generally robust to the existence of "Hot Air" from the Former Soviet Union. In the absence of allocated excess permits in each scenario involving the Former Soviet Union all other regions face higher compliance costs due to a lower supply

[16] The present paper abstracts from such strategic behavior. For a quantitative analysis of near-term implications of emissions market power by the Former Soviet Union see Böhringer et al. (2006).

of the Former Soviet Union and an increased permit price. However, the higher adjustment costs for permit demanders do not necessarily imply larger revenues from permit sales: Only under *ETS* and *PARALLEL* trading regimes and regional constellation *[EU$^+$]* the lack of excess permits results beneficial for the Former Soviet Union – in all other scenarios the higher market price cannot compensate for the lower amount of permits exports.

7 Conclusions

Linkage of the EU Greenhouse Gas Emission Trading Scheme (ETS) to emerging schemes beyond Europe is a central strategic issue of current EU climate policy. At present, non-European countries like Canada, Japan or Australia are contemplating the set up of domestic ETS with the intention of linking up to the European scheme – enabling companies outside the EU to trade emissions with European firms. From 2008 on, company trading among linked schemes would however overlap with trading among countries, as the Kyoto Protocol facilitates international government trading of greenhouse gas emissions at the country level. Moreover, both companies and governments may undertake project-based emission reductions in developing countries via the Clean Development Mechanism (CDM).

The present paper assesses the economic impacts of linking the EU ETS in the presence of a post-Kyoto agreement in 2020. Based on a numerical multi-country, multi-sector partial equilibrium model of the world carbon market the economic impacts of overlapping climate policies are assessed quantitatively. The model covers explicit marginal abatement cost functions for the year 2020 calibrated to energy-system data, and considers transaction costs as well as investment risk for CDM host countries.

The simulations show that linking the European ETS in the absence of post-Kyoto government trading induces no or only marginal economic benefits for the EU: Total compliance costs decrease not more than one percent in all regional constellations. Since under ETS trading where-flexibility is restricted to energy-intensive sectors that are assigned generous initial emissions, the major compliance burden is carried by sectors not covered by linked ETS, i.e. non-energy-intensive industries. These non-trading segments of the economy are not able to benefit from an enlarged trading scheme. Moreover, the economic impacts for non-EU countries from linking to the European scheme are very heterogeneous: Linking to Canada, Japan and the Former Soviet Union implies drastic compliance costs for Canada due to domestic inefficiencies, while Japan is benefiting and the Former Soviet Union is even net-benefiting from joining the EU scheme. A further linking process to Australia and the USA is not beneficial for any participant except for the Former Soviet Union which benefits from the increased demand and price for its excess emission permits (“Hot Air”).

In the presence of parallel government trading under a post-Kyoto agreement, international emission trading is not only feasible among energy-intensive sectors of linked ETS, but also among non-energy-intensive industries of the same countries. Linking the European ETS to non-EU schemes then leads to a much stronger fall in adjustment costs: By linking to Canada, Japan and the Former Soviet Union total EU compliance costs can be reduced by more than 60 percent. Here, the non-energy-intensive sectors benefit from increased compensation through international government trading of the same countries. A further ETS enlargement to Australia and the USA yields increased benefits from a larger emission market, especially for non-energy-intensive sectors, further cutting EU compliance costs by half. Also for non-EU regions these parallel trading regimes would result beneficial. However, emission markets are still segmented – and where-flexibility still restricted – as international trading is feasible only between the same sectors of the linked economies.

A joint emission trading regime interconnecting energy-intensive companies and national governments is de facto equivalent to full where-flexibility, establishing international trading activities between all regions and sectors. Via a joint regime, the formerly segmented markets can be interconnected, providing large efficiency gains: Linking the EU ETS in a joint trading system causes an even stronger fall in EU compliance costs than under a parallel regime, since now all sectors can benefit jointly from extended trading activities. Here, the cost decrease is most substantial when linking to Canada, Japan and the Former Soviet Union, as the latter region is able to decrease the international permit price by supplying excess permits to a large extent.

The CDM cannot alleviate the inefficiencies of linked ETS, since also project-based crediting is restricted to energy-intensive industries of ETS. By contrast, in a parallel trading regime government access to low-cost abatement options of developing countries induces large efficiency gains. Here, the CDM provides additional cost savings of almost 90 percent for the European scheme, compensating non-energy-intensive industries. By providing access to project-based crediting for both energy-intensive and non-energy-intensive sectors, it establishes an indirect link between the two segments of the economy and assures full where-flexibility. Due to this provision of an international credit pool for all sectors the CDM levels out the economic impacts under parallel and joint trading regimes. The restriction of CDM activities via a supplementarity criterion does not significantly decrease the economic benefits from project-based crediting, as the respective thresholds of CDM imports are not yet reached under unlimited CDM access.

This paper laid out the efficiency implications of internationally linked emission trading schemes, as well as alternative country-level compensation mechanisms for the current inefficiencies of schemes. In the long run however, uncertainties about future post-Kyoto agreements and the exhaustion of low-cost abatement options of developing countries raise concerns about the availability of such mechanisms. Moreover, given the large number of participants, it is company-based trading that provides a fertile ground for developing a competitive market for emissions. Considering the potential for efficiency improvements of future emission trading schemes – such as stricter emission allocation to covered installations or enlarged sectoral scope – linking ETS beyond Europe may become not only a fall-back option for a lacking international agreement, but a vital option of future climate policy on a global level.

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Appendix A

A.1 Algebraic Model Summary

This appendix provides an algebraic summary of the equilibrium conditions for a simple partial equilibrium model designed to investigate the economic implications of emission allocation and emission trading in a multi-sector, multi-region framework. Emission mitigation options are captured through marginal abatement cost functions that are differentiated by sectors and regions.

Cast as a planning problem, the model corresponds to a nonlinear program that seeks a cost-minimizing abatement scheme subject to initial emission allocation and institutional restrictions for emission trading between sectors and regions. The nonlinear optimization problem can be interpreted as a market equilibrium problem where prices and quantities are defined using duality theory. In this case, a system of (weak) inequalities and complementary slackness conditions replace the minimization operator yielding a so-called mixed complementarity problem (see e.g. Rutherford 1995).[17]

Two classes of conditions characterize the (competitive) equilibrium for the model: zero profit conditions and market clearance conditions. The former class determines activity levels (quantities) and the latter determines prices. The economic equilibrium features complementarity between equilibrium variables and equilibrium conditions: activities will be operated as long as they break even, positive market prices imply market clearance – otherwise commodities are in excess supply and the respective prices fall to zero.[18]

Numerically, the algebraic MCP formulation of the model is implemented in GAMS (Brooke et al. 1987) using PATH (Dirkse and Ferris 1995) as a solver. Below, the GAMS code is presented to replicate the results reported in the paper. The GAMS file and the EXCEL reporting sheet can be downloaded from the web-site (http://brw.zew.de/simac/).

In the algebraic exposition of equilibrium conditions, *i* is used as an index for sectors and *r* as an index for regions. Table 8 explains the notations for variables and parameters.

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[17] The MCP formulation provides a general format for economic equilibrium problems that may not be easily studied in an optimization context. Only if the complementarity problem is "integrable" (see Takayma and Judge (1971)), the solution corresponds to the first-order conditions for a (primal or dual) programming problem. Taxes, income effects, spillovers and other externalities, however, interfere with the skew symmetry property which characterizes first order conditions for nonlinear programs.

[18] In this context, the term „*mixed complementarity problem*" (MCP) is straightforward: „*mixed*" indicates that the mathematical formulation is based on weak inequalities that may include a mixture of equalities and inequalities; „*complementarity*" refers to complementary slackness between system variables and system conditions.

Table 8: Variables and parameters

Variables: Activity levels	
D_{ir}	Emission abatement by sector *i* in region *r*
MD_{ir}	Imports of emission permits by sector *i* in region *r* from domestic market
XD_{ir}	Exports of emission permits by sector *i* in region *r* to domestic market
M_{ir}	Imports of emission permits by sector *i* in region *r* from international market
X_{ir}	Exports of emission permits by sector *i* in region *r* to international market
$MCDM_{ir}$	Imports of Certified Emission Reductions (CERs) by sector *i* in region *r* from CDM world market
$XCDM_{ir}$	Exports of CERs by sector *i* in region *r* to CDM world market
Variables: Price levels	
P_{ir}	Marginal abatement cost by sector *i* in region *r*
PD_r	Price of domestically tradable permits in region *r*
PFX	Price of internationally tradable permits
$PCDM$	Price of CERs from CDM world market
$PLIM_r$	Shadow price of CER import restriction
Parameters	
$\text{target}_{\text{ir}}$	Effective carbon emission reduction requirement for sector *i* in region *r*
$a_{1,ir}, a_{2,ir}, a_{3,ir}$	Coefficients of marginal abatement cost function for sector *i* in region *r*
$\text{mlimit}_{\text{ir}}$	Upper limit on CER imports by sector *i* in region *r* from CDM world market (Suppplementarity criterion)

Zero Profit Conditions[19]

1. Abatement by sector *i* in region *r* ($\perp D_{ir}$):

$$a_{1,ir} \cdot D_{ir} + a_{2,ir} \cdot D_{ir}^2 + a_{3,ir} \cdot D_{ir}^3 \geq P_{ir}$$

2. Permit imports by sector *i* in region *r* from domestic market ($\perp MD_{ir}$)

$$PD_r \geq P_{ir}$$

[19] The variable associated with each equilibrium condition is added in brackets and denoted with an orthogonality symbol ($\perp$).

3. Permit exports by sector *i* in region *r* to domestic market ($\perp XD_{ir}$)

$$P_{ir} \geq PD_r$$

4. Permit imports by sector *i* in region *r* from international market ($\perp M_{ir}$)

$$PFX \geq P_{ir}$$

5. Permit exports by sector *i* in region *r* to international market ($\perp X_{ir}$)

$$P_{ir} \geq PFX$$

6. CER imports by sector *i* in region *r* from CDM world market ($\perp MCDM_{ir}$)

$$PCDM + PLIM_r \geq P_{ir}$$

7. CER exports by sector i in region r to CDM world market **(**$\perp XCDM_{ir}$**)**

$$P_{ir} \geq PCDM$$

Market Clearance Conditions

8. Market clearance for abatement by sector *i* in region *r* ($\perp P_{ir}$):

$$D_{ir} + M_{ir} + MD_{ir} + MCDM_{ir} \geq \text{target}_{\text{ir}} + X_{ir} + XD_{ir} + XCDM_{ir}$$

9. Market clearance for domestically tradable permits ($\perp PD_r$):

$$\sum_i XD_{ir} \geq \sum_i MD_{ir}$$

10. Market clearance for internationally tradable permits ($\perp PFX$):

$$\sum_i X_{ir} \geq \sum_i M_{ir}$$

11. Market clearance for CERs ($\perp PCDM$):

$$\sum_i XCDM_{ir} \geq \sum_i MCDM_{ir}$$

12. CER import restriction for supplementarity ($\perp PLIM_r$):

$$\text{mlimit}_{\text{ir}} \geq \sum_i MCDM_{ir}$$

A.2 Simulation results: Abscence of „Hot Air“

Table 9: Trading regimes in the abscense of “Hot Air”: Compliance costs by region, sector and scenario (in million €2005)

	NOTRADE			***ETS [EU]***			***ETS [EU^{+}]***			***ETS [EU^{++}]***		
	TOTAL	***EIS***	***NEIS***	***TOTAL***	***EIS***	***NEIS***	***TOTAL***	***EIS***	***NEIS***	***TOTAL***	***EIS***	***NEIS***
EU-27	54747.1	39216.5	15530.6	359401.6	7244.9	352156.7	358283	6126.3	352156.7	358142.5	5985.8	352156.7
Canada	7572.4	4960.9	2611.5	7572.4	4960.9	2611.5	22745.5	567	22178.5	22739.1	560.6	22178.5
Japan	5590.5	4412	1178.5	5590.5	4412	1178.5	4158.8	1753.6	2405.2	4102.2	1697	2405.2
Former Soviet Union	0	0	0	0	0	0	-2977	-2977	0	-2781.4	-2781.4	0
Pacific OECD	3213.8	2393.4	820.4	3213.8	2393.4	820.4	3213.8	2393.4	820.4	8949.5	619.9	8329.6
United States	2002.7	1725.3	277.4	2002.7	1725.3	277.4	2002.7	1725.3	277.4	5387.2	5387.2	0

	NOTRADE			***PARALLEL [EU]***			***PARALLEL [EU^{+}]***			***PARALLEL [EU^{++}]***		
	TOTAL	***EIS***	***NEIS***	***TOTAL***	***EIS***	***NEIS***	***TOTAL***	***EIS***	***NEIS***	***TOTAL***	***EIS***	***NEIS***
EU-27	54747.1	39216.5	15530.6	74195	7244.9	66950.1	49003.4	6126.3	42877.1	24980.9	5985.8	18995.1
Canada	7572.4	4960.9	2611.5	7572.4	4960.9	2611.5	11533	567	10966	5338.6	560.6	4778
Japan	5590.5	4412	1178.5	5590.5	4412	1178.5	4087.5	1753.6	2333.9	2997.2	1697	1300.2
Former Soviet Union	0	0	0	0	0	0	-25702.8	-2977	-22725.8	-6747.4	-2781.4	-3966
Pacific OECD	3213.8	2393.4	820.4	3213.8	2393.4	820.4	3213.8	2393.4	820.4	3429.3	619.9	2809.4
United States	2002.7	1725.3	277.4	2002.7	1725.3	277.4	2002.7	1725.3	277.4	-7430.4	5387.2	-12817.6

	NOTRADE			***JOINT [EU]***			***JOINT [EU^{+}]***			***JOINT [EU^{++}]***		
	TOTAL	***EIS***	***NEIS***	***TOTAL***	***EIS***	***NEIS***	***TOTAL***	***EIS***	***NEIS***	***TOTAL***	***EIS***	***NEIS***
EU-27	54747.1	39216.5	15530.6	32393.9	-716.9	33110.8	25739	7117.8	18621.2	18269.3	6605	11664.3
Canada	7572.4	4960.9	2611.5	7572.4	4960.9	2611.5	5102.1	418.3	4683.8	3515.9	580.9	2935
Japan	5590.5	4412	1178.5	5590.5	4412	1178.5	4060.4	2782.4	1278	2810.2	1971.4	838.8
Former Soviet Union	0	0	0	0	0	0	-12492.3	-8680	-3812.3	-5341.6	-3814.5	-1527.1
Pacific OECD	3213.8	2393.4	820.4	3213.8	2393.4	820.4	3213.8	2393.4	820.4	2402.7	646.9	1755.8
United States	2002.7	1725.3	277.4	2002.7	1725.3	277.4	2002.7	1725.3	277.4	-1377.7	5012.5	-6390.2

Table 10: CDM options in the abscense of "Hot Air": Compliance costs by region, sector and scenario (in million €2005)

	ETS_CDM [EU]			***ETS_CDM*** $[EU^{+}]$			***ETS_CDM*** $[EU^{++}]$			***ETS_SUP***		
										[EU]	$[EU^{+}]$	$[EU^{++}]$
	TOTAL	***EIS***	***NEIS***	***TOTAL***	***EIS***	***NEIS***	***TOTAL***	***EIS***	***NEIS***	***TOTAL***	***TOTAL***	***TOTAL***
EU-27	354317.3	2160.6	352156.7	354418.6	2261.9	352156.7	355456.1	3299.4	352156.7	355732.9	354838.6	355575.7
Canada	7572.4	4960.9	2611.5	22430.2	251.7	22178.5	22533.1	354.6	22178.5	7572.4	22461.9	22530.2
Japan	5590.5	4412	1178.5	2974.7	569.5	2405.2	3251.8	846.6	2405.2	5590.5	3099.7	3305.5
Former Soviet Union	0	0	0	-344	-344	0	-719.3	-719.3	0	0	-1123.9	-1447.9
Pacific OECD	3213.8	2393.4	820.4	3213.8	2393.4	820.4	8678.5	348.9	8329.6	3213.8	3213.8	8694.8
United States	2002.7	1725.3	277.4	2002.7	1725.3	277.4	3926.3	3926.3	0	2002.7	2002.7	3800.8
	PARALLEL_CDM [EU]			***PARALLEL_CDM*** $[EU^{+}]$			***PARALLEL_CDM*** $[EU^{++}]$			***PARALLEL_SUP***		
										[EU]	$[EU^{+}]$	$[EU^{++}]$
	TOTAL	***EIS***	***NEIS***	***TOTAL***	***EIS***	***NEIS***	***TOTAL***	***EIS***	***NEIS***	***TOTAL***	***TOTAL***	***TOTAL***
EU-27	9138.4	3834.1	5304.3	9483.3	3962.7	5520.6	9869.2	4104.7	5764.5	8903.8	9483.3	9869.2
Canada	7572.4	4960.9	2611.5	1805.9	415.1	1390.8	1879.6	427.4	1452.2	7572.4	1805.9	1879.6
Japan	5590.5	4412	1178.5	1446.1	1033	413.1	1505	1074.3	430.7	5590.5	1446.1	1505
Former Soviet Union	0	0	0	-1411.1	-1047.6	-363.5	-1523.6	-1128.8	-394.8	0	-1411.1	-1523.6
Pacific OECD	3213.8	2393.4	820.4	3213.8	2393.4	820.4	1305.9	435.8	870.1	3213.8	3213.8	1305.9
United States	2002.7	1725.3	277.4	2002.7	1725.3	277.4	1977.2	4633.2	-2656	2002.7	2002.7	1977.2
	JOINT_CDM [EU]			***JOINT_CDM*** $[EU^{+}]$			***JOINT_CDM*** $[EU^{++}]$			***JOINT_SUP***		
										[EU]	$[EU^{+}]$	$[EU^{++}]$
	TOTAL	***EIS***	***NEIS***	***TOTAL***	***EIS***	***NEIS***	***TOTAL***	***EIS***	***NEIS***	***TOTAL***	***TOTAL***	***TOTAL***
EU-27	9138.4	3834.1	5304.3	9483.3	3962.7	5520.6	9869.2	4104.7	5764.5	10279.7	9483.3	9869.2
Canada	7572.4	4960.9	2611.5	1805.9	415.1	1390.8	1879.6	427.4	1452.2	7572.4	1805.9	1879.6
Japan	5590.5	4412	1178.5	1446.1	1033	413.1	1505	1074.3	430.7	5590.5	1446.1	1505
Former Soviet Union	0	0	0	-1411.1	-1047.6	-363.5	-1523.6	-1128.8	-394.8	0	-1411.1	-1523.6
Pacific OECD	3213.8	2393.4	820.4	3213.8	2393.4	820.4	1305.9	435.8	870.1	3213.8	3213.8	1305.9
United States	2002.7	1725.3	277.4	2002.7	1725.3	277.4	1977.2	4633.2	-2656	2002.7	2002.7	1977.2