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Market Power in International Emissions Trading: The Impacts of U.S.Withdrawal from the Kyoto Protocol

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Nontechnical Summary

This paper investigates the implications of U.S. withdrawal from the Kyoto Protocol on environmental effectiveness, economic efficiency, and the distribution of compliance costs for remaining Annex-B countries taking into consideration the monopoly power by the Former Soviet Union (FSU) on international emission permit markets. Based on a multi-region partial equilibrium framework of marginal carbon abatement cost curves, we find that U.S. withdrawal considerably alters the environmental and economic implications of FSU market power in permit trade. Under U.S. compliance, monopolistic permit by FSU has no impact on environmental effectiveness as compared to a competitive trading system. Aggregate emissions of Annex-B regions fall by 10 % below business-as-usual emission levels. Excess costs of market power amount to 40 % of total compliance costs under competitive permit markets. Under U.S. withdrawal, monopolistic permit supply on behalf of the Former Soviet Union will assure some environmental effects of the Kyoto Protocol, with aggregate Annex-B emissions (including U.S.) falling by 3 % vis-à-vis the business-as-usual emission level. For competitive permit trade, environmental effectiveness would be reduced to zero since the U.S. withdrawal implies an excess supply of permits driving permit prices down to zero. Efficiency losses from monopoly behavior by FSU under U.S. withdrawal double total compliance costs compared to a competitive permit market system which achieves the same environmental target. Given FSU monopoly power, U.S. withdrawal provides some cost reduction to complying non-U.S. OECD countries because reduced overall permit demand drives down the permit price. On the other hand, FSU and its competitive fringe EEC must bear a larger decline in revenues from permit sales.

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Abstract

This paper investigates the implications of U.S. withdrawal on environmental effectiveness, economic efficiency, and the distribution of compliance costs taking into account market power of the Former Soviet Union (FSU) on emission permit markets. While exercise of market power on behalf of FSU under U.S. compliance has no environmental impact as compared to competitive permit trade, it prevents the Kyoto Protocol from boiling down to business-as-usual after U.S. withdrawal. Non-compliance of the U.S. increases the efficiency losses from FSU market power and reduces the compliance costs of remaining OECD countries but these gains must be weighted against a dramatic loss in overall environmental effectiveness. Clearly, the big losers from U.S. withdrawal are FSU and its competitive fringe (Central and Eastern Europe) that suffer from a huge decline in permit sales revenues.

JEL classification: D58, Q43, Q58

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1. Introduction

The Kyoto Protocol, adopted in December 1997, has been celebrated as a breakthrough in international climate policy (Oberthür and Ott 2000). This treaty specifies quantified reduction targets for a basket of six major greenhouse gases (GHG) across industrialized countries as listed in Annex-B of the Protocol. Signatories must verify fulfillment of their duties during the commitment period 2008-2012. In its original version, the Protocol entails a reduction of GHG emissions for Annex-B countries by 5.2 % on average below their aggregate 1990 emission level.[1]

One very contentious issue on the implementation of the Kyoto Protocol has been the degree to which emissions reduction commitments by individual Annex-B countries can be met through additional abatement in other Annex-B countries using tradable emission permits. The claim for unrestricted emissions trading follows from overall cost-efficiency considerations: Total costs of achieving the overall Annex-B abatement target will be lowest when marginal abatement costs across different emission sources are equalized under free competitive trade. However, there have been major concerns that unrestricted Annex-B emissions trading will allow transitional economies of Eastern Europe (EEC) and the former Soviet Union (FSU) to sell "excess" emission rights (i.e. rights that they would not use in the case of strictly domestic abatement). These excess emissions are referred to as "hot air" and stem from the fact that EEC and particularly FSU have been conceded emission entitlements under the Kyoto Protocol that appear to be well in excess of their anticipated emissions (as a result of the economic turndown during the transition to market economies). Under emissions trading, these parties can sell hot air virtually at no costs to itself, providing large economic benefits, especially to FSU (see e.g. Weyant 1999). Obviously, hot air decreases the environmental effectiveness of the Kyoto Protocol vis-à-vis strictly domestic action. With respect to 2010, estimates for hot air from EEC and FSU range up to 500 millions of tons of carbon (MtC), whereas the other signatory countries are expected to reduce their emissions by a total of 800-900 MtC compared to business-as-usual (*BaU*) (Paltsev 2000). Proposals for a ceiling on emission trading have been put forward by the EU in order to reduce hot air and, thus, achieve lower total world emissions as compared to unrestricted emissions trading (UNFCCC 1999). The imposition of supply and demand side restrictions to permit trading

[1] Due to lack of appropriate data for non-CO2 gases, most studies focus on the analysis of CO_2, which is by far the most important greenhouse gas for industrialized countries. The usual approach is to apply reduction targets referring to the basket of six GHG to CO2 only. We proceed in a like manner within the current paper.

under the EU proposal has triggered an extensive analysis on the associated economic and environmental impacts (Baron et al. 1999, Bernstein et al. 1999, Böhringer 2000, Bollen et al. 1999, Criqui et al. 1999, Ellermann and Wing 2000, Paltsev 2000). It has been pointed out that these restrictions have similar effects as market power on behalf of dominant permit buyers (monopoly/oligopoly) or sellers (monopsony/oligopsony)[2]: Permit price manipulation results in additional overall economic costs to achieve the same level of abatement as under perfect competition with a redistribution of permit trade gains from buyers to sellers (in the case of monopoly/oligopoly) or from sellers to buyers (in the case of monopsony/oligopsony). Institutional restrictions to permit trading as lanced by the EU have been supported neither by the FSU (for obvious reasons) nor by the USA, which has strongly opposed any emissions trading restrictions on the exploitation of the full efficiency gains. Without the major polluters USA and FSU, however, the Protocol can not be put into force.[3] Monopolistic supply behavior, on the other hand, seems a realistic assumption given the small number of sellers in the Annex B market, namely EEC and, particularly, the FSU.

This paper investigates the implications of U.S. withdrawal on environmental effectiveness, economic efficiency, and the distribution of compliance costs taking into account the exercise of FSU monopoly power on permit markets. Based on a multi-region partial equilibrium framework of marginal carbon abatement cost curves generated by the POLES world energy model (Criqui et al. 1996), we find that U.S. withdrawal considerably alters the environmental and economic implications of FSU market power in permit trade:

(i) Under U.S. compliance, monopolistic permit by FSU has no impact on environmental effectiveness as compared to a competitive trading system. Aggregate emissions of Annex-B regions fall by 10 % below business-as-usual emission levels. Excess costs of market power amount to 40 % of total compliance costs under competitive permit markets.

[2] As noted in Ellermann and Wing (2000) with respect to demand side restrictions: "Monopsonistic effects require only that demand be restricted, not that the restriction be optimal in any sense. Also, effects occur with price-taking behavior by both buyers and sellers so long as an effective coordinating or restraining mechanism is in place."

[3] The Protocol will not be put into force until it has been ratified by at least 55 countries, and these ratifying countries must have contributed at least 55 percent of the industrialized world's CO_2 emissions (the most important GHG) in 1990.

(ii) Under U.S. withdrawal, monopolistic permit supply on behalf of the Former Soviet Union will assure some environmental effects of the Kyoto Protocol with aggregate Annex-B emissions (including U.S.) falling by 3 % vis-à-vis the business-as-usual emission level. For competitive permit trade, environmental effectiveness would be reduced to zero since the U.S. withdrawal implies an excess supply of permits, driving permit prices down to zero.[4] Efficiency losses from monopoly behavior by FSU in the case of U.S. withdrawal double the total compliance costs compared to a competitive permit market system which achieves the same environmental target.

(iii) Given FSU monopoly power, U.S. withdrawal provides some cost reduction to complying non-U.S. OECD countries because reduced overall permit demand drives down the permit price.[5] On the other hand, FSU and its competitive fringe EEC must bear a larger decline in revenues from permit sales.

The remainder of the paper is organized as follows. Section 2 provides the effective emission constraints for Annex-B regions (including sink credits) and lays out our basic reasoning on the potential for supply-side market power. Section 3 entails a description of the analytical framework to study the effects of non-competitive permit supply behavior under the new provisions of the Kyoto Protocol. Section 4 describes our policy simulations. Section 5 concludes.

2. Emission Constraints and Market Power

A. Emission Constraints

Table 1 lists historical GHG emissions for 1990 and projected emissions for 2010 across Annex-B regions. Furthermore, it contains the *nominal* percentage reduction commitment with respect to 1990 as well as the *effective* percentage reduction commitment with respect to 2010 for both the initial amendments of Kyoto (columns *Old*) and the Bonn updates (columns *New*). The latter are based on preliminary estimates for sink credits by the

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4 Kyoto, thus, would boil down to business-as-usual without any real abatement.

5 Given a decrease in environmental effectiveness by a factor of more than three, one should be cautious about interpreting such a cost reduction as an effective welfare gain.

European Commission as listed in Appendix B. The last column of Table 1 reports the cutback requirements of the *New* regime in absolute terms.[6]

We see that all OECD countries are expected to have substantially higher emissions in 2010[7] since their economic growth is linked to higher fossil fuel consumption. On the other hand, EEC and, in particular, FSU, have emissions well below 1990 levels as a result of a sharp decline in economic activity during the 90ies that will not be offset by the projected economic recovery of these regions between 2000-2010. In short, compliance to the Kyoto Protocol implies a drastic reduction in business-as-usual emissions for OECD countries even under sink credits, whereas the scope of hot air for FSU and EEC increases further.

The official DOE projections for 2010 (DOE 2001), combined with the revised Kyoto targets (*New*), suggest a hot air volume of 302 MtC for FSU and 59 MtC for EEC, respectively. Accounting for the U.S. withdrawal from the Protocol, the figures on absolute cutback requirements in Table 1 indicate an excess supply of hot air of 78 MtC. If emission rights were fully tradable across Annex-B regions, competitive permit markets would drive down the international permit price to zero such that no emission reduction at all would occur with respect to business-as-usual.[8]

Paltsev (2000) has noted that, due to the variability of growth numbers in the gross domestic product for FSU, the projected amount of hot air may vary to some extent across different data sources. Lower estimates for hot air may prevent an excess supply of permits and thus competitive permit prices from falling to zero in the case of U.S. withdrawal. However, our simulations on supply-side restrictions in section 4 confirm robustness of quantitative results with respect to larger deductions in hot air. The reason is that monopolistic permit supply will be smaller than the lower bound estimates for hot air in any case.

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6 The aggregation of individual Annex-B countries is based on the data available from the POLES model.

7 In our comparative-static analysis, we refer to the commitment period in terms of a representative target year 2010.

8 It has been agreed that the use of emissions trading "shall be supplemental to domestic action and domestic action shall thus constitute a significant element of the effort made by each Party .... to meet its quantified emission limitation and reduction commitments ..." (UNFCCC 2001). The undefined term "significant" gives sufficient leeway for comprehensive trading. The restrictive position by the EU with respect to the permissible scope of emissions trading between industrialized countries has not been held up since the Bonn conference. There are no concrete caps on the share of emissions reductions a country can meet through the

Table 1: Baseline emissions, percentage reduction, absolute cutbacks

Region	Baseline Emissions (MtC)[a]		Nominal Reduction (% wrt 1990)[b]		Effective Reduction (% wrt 2010)		Absolute Cutback (MtC wrt 2010)	
	1990	2010	Old	New	Old	New	Old	New
AUN	88	130	-6.8	-10.2	27.7	25.4	36	33
CAN	126	165	6.0	-7.9	28.2	17.6	47	29
EUR	930	1040	7.8	5.2	17.5	15.2	182	158
JPN	269	330	6.0	0.8	23.4	19.1	77	63
EEC	279	209	7.1	3.9	-24.0	-28.3	-50	-59
FSU	853	593	0	-4.9	-43.8	-50.9	-260	-302
Total US out[c]	2545	2467	4.3	0	1.3	-3.2	32	-78
USA	1345	1809	7.0	3.2	30.9	28.0	558	507
Total US in[d]	3890	4276	5.2	1.1	13.8	10.0	590	429

Key: AUN – Australia and New Zealand, CAN – Canada, EUR - OECD Europe (incl. EFTA), JPN – Japan, EEC - Central and Eastern Europe, FSU - Former Soviet Union (incl. Ukraine).

[a] Based on DOE reference case (DOE 2001)
[b] Estimates by the EU Commission based on UNFCC (http://www.unfccc.int)
[c] Annex-B without U.S. compliance
[d] Annex-B with U.S. compliance

B. Market Power

The issue of market power in tradable quota markets has been subject to extensive theoretical and empirical research that includes Hahn (1984), Sartzetakis (1997), Ellerman and Decaux (1998), Ellerman et al. (1998), Misiolek and Elder (1989), Malueg (1990), Westkog (1996 and 2001), Burniaux (1998), and Godby (2000). Either dominant buyers (monopsony or oligopsony) or sellers (monopoly or oligopoly) may be able to exert market power in the permit market or use their market power in the permit market to gain power in the product market. In the following, market power refers only to the capacity to influence the market price of traded permits (so-called "cost minimizing manipulation").

Market power in emissions trading results in reduced demand in the case of a monopsony or reduced supply in the case of a monopoly. A monopsonist may thereby force the permit price below a monopolist above the competitive level. Thus, the extent of competition in a tradable permit market affects the efficiency of international permit trade and

purchase of permits from other industrialized countries, nor are there caps on the amount of permits it can sell.

the degree to which potential cost savings are realized. Permit price manipulations result in additional overall economic costs to achieve the same level of abatement as under perfect competition.

There has been some discussion whether market power on international permit markets will be an issue under the Kyoto Protocol. In general, the likelihood of market power increases if the number of participants is smaller or if the size of some participants is larger than neo-classical firm-to-firm trading with many participants (Woerdman 2000). Article 17 of the Kyoto Protocol creates an intergovernmental emissions trading market next to or instead of firm trading, so it is uncertain whether firms or governments will participate in international emissions trading. In the case of firm-to-firm trading, the scope for market power seems rather limited. However, it seem very unlikely that the FSU, as the dominant supplier of emission rights[9], will give up on market power by leaving permit trade to its domestic firms (whose entitlements with carbon rights are unclear anyway). On the demand side, competitive behavior seems to be the appropriate assumption. The reason is that either firms of OECD countries may be allowed to engage in emissions trading directly[10], or - under the assumption of Party-to-Party trading - coordination of several individual OECD countries within a demand cartel seems rather difficult.

Figure 1 illustrates the effects of supply-side restrictions accounting for the excess supply of hot air. Under perfect competition, unrestricted (see index "u" in Figure 1) hot air supply of EEC and FSU exceed aggregate permit demand by non-U.S. OECD countries; the permit market price will drop to zero (P_u) and the quantity of hot air permits traded equals the total abatement requirement of non-U.S. regions (Q_u). Consequently, there will be no domestic emissions abatement of permit importers (here: non-U.S. OECD countries) with respect to business-as-usual emission levels $\left(\bar{e}\right)$, and total revenues for permit exporting countries (here: EEC and FSU) equal zero. Quantity restrictions S_r *(*see index "r" in Figure 1), which reduce the supply of hot air below the total abatement requirement Q_u, drive up the market price of permits by ΔP from P_u to P_r. Total permit trade is, then, reduced from Q_u to Q_r and effective total emission abatement amounts to ΔQ. Apart from increased environmental

9 FSU holds 84 % of total hot air, which exceeds market demand for any given price level (see Table 1 and Figure 2).

10 See e.g. the plans of the EU commission to implement an EU internal trading system starting in 2005 with firm-to-firm trading across energy-intensive industries (see Böhringer 2001).

effectiveness, the exercise of monopoly power entails a redistribution of the gains from permit trade from buyers to sellers and a loss of economic efficiency, because marginal abatement costs (C') are no longer equalized across regions. In comparison to the competitive outcome, permit exporters receive the rectangle *HIK0* as income from permit sales. Hot air exporters benefit from further supply restrictions as long as the gains from higher prices are greater than the loss of revenues from a lower level of permits sold. Due to the higher price of permits, an importing country increases domestic abatement (a) and covers its remaining abatement requirements to its Kyoto emission target (k) through permit imports (q). Its costs of compliance increase to the area *LMNT*.

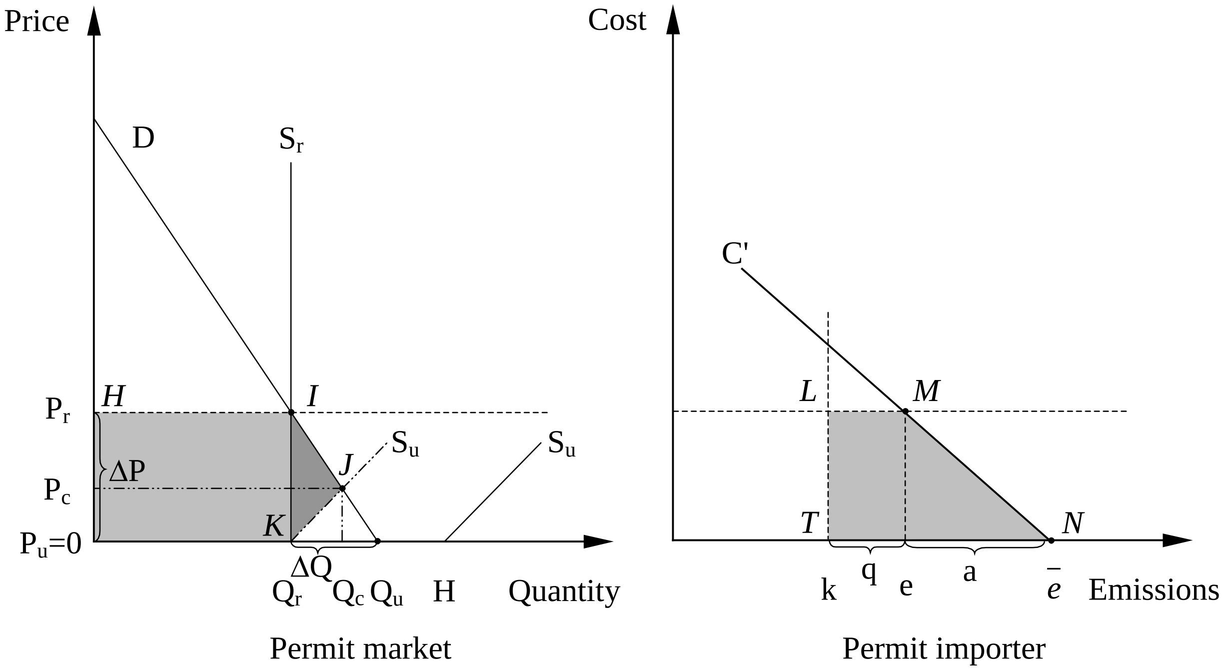

Figure 1 Effects of supply side restrictions accounting for hot air

The existence of hot air complicates the usual textbook illustration of efficiency losses emerging from market power in tradable quota markets. In fact, the possibility of selling hot air changes the environmental effectiveness between the competitive solution vis-à-vis the non-competitive solution. While – in our case – hot air in competitive markets reduces environmental effectiveness to zero, supply-side restrictions below Q_u imply a real reduction in emissions. The concise measurement of efficiency loss from market power must then refer to the same emission abatement. In Figure 1, the triangle *IJK* visualizes the induced efficiency loss: The same effective abatement ΔQ emerging from monopolistic supply could have been achieved at lower overall costs in a competitive setting (see index “c” in Figure 1) if the hot air supplier had also undertaken some real abatement (Q_c-Q_r). The market price of permits would then fall to P_c.

Reference to the same target allows us to abstract from the benefit-side of emission abatement, which would otherwise require the use of rather uncertain and broad-ranged estimates for the external cost of GHG emissions. One should be aware that market power in the presence of negative environmental externalities may increase total welfare (economic efficiency) in contrast to the competitive solution as long as the loss from non-equalization of marginal abatement costs is more than offset by the benefits from reduced environmental damages at the margin.

3. Analytical Framework

The analysis of non-competitive supply behavior in section 4 below is based on marginal abatement cost curves for different Annex-B regions (see Appendix A for the algebraic exposition of the model). These curves represent the marginal cost of reducing carbon emissions by different amounts within an economy. Marginal costs of abatement may vary considerably across countries due to differences in carbon intensity, initial energy price levels, and the ease of carbon substitution possibilities. For the empirical specification of regional marginal abatement costs curves across regions *i*, we adopt a constant elasticity function of the form:

$$C_i'\left(\overline{e_i} - e_i\right) = \alpha_i \cdot \left(\overline{e_i} - e_i\right)^{\beta_i}$$

where C' is the marginal cost of reducing carbon emissions in country *i*, $\overline{e_i}$ are the business-as-usual emissions, e_i are the actual emissions, i.e. $a_i = \overline{e_i} - e_i$ denotes the level of abatement. In order to determine the coefficients α and β, we employ a least-square procedure based on a sufficiently large number of discrete observations for marginal abatement costs (or carbon taxes) and the induced emission reduction in each region. These values are generated by the world energy system model POLES (Criqui et. al. 1996), which embodies a detailed bottom-up description of regional energy markets and world-energy trade. Table 2 lists the least-square estimates for the coefficients of marginal abatement cost curves across regions.

Table 2 Coefficients of marginal abatement cost curve approximations

Coefficients	AUN	CAN	EEC	EUR	FSU	JPN	USA
α	0.675	1.567	0.316	0.114	0.046	0.718	0.020
β	1.442	1.379	1.388	1.369	1.482	1.338	1.427

Figure 2 illustrates the implied marginal abatement cost curves for those Annex-B regions that face binding carbon constraints and are willing to comply with the Kyoto Protocol. As noted above, this set of region compromises all OECD countries except for the U.S. The carbon taxes that the different regions would have to impose in order to reach their Kyoto commitment through strictly domestic action are indicated on the cost curves. We use the marginal abatement costs curves for the derivation of the aggregate permit demand curve under the *New* targets of the Kyoto Protocol. A region will demand permits as long as the market price of permits is lower than its marginal abatement costs. Conversely, it supplies permits as long as the market price is above its marginal costs of abatement. The aggregate demand curve, as depicted by Figure 2, is then obtained by simply adding up the demanded and supplied quantities of all regions at each market price. If the market price is equal to zero (as in the case of competitive permit markets), the aggregate demand amounts to 284 MtC, which is the sum of emission abatement requirements across all non-U.S. OECD regions. As the price increases, aggregate demand diminishes. When the market price reaches 105 USD/tC, AUN switches from being a permit supplier to being a permit demander, since the international permit price exceeds its marginal abatement costs associated with purely domestic compliance to the Kyoto Protocol. The same happens at a price of 117 USD/tC for EUR. At a price of 131 USD/tC, the amount of permits supplied by AUN (5 MtC) and EUR (13 MtC) just equals the demand by CAN (4 MtC) and JPN (14 MtC), resulting in an aggregate demand of zero.

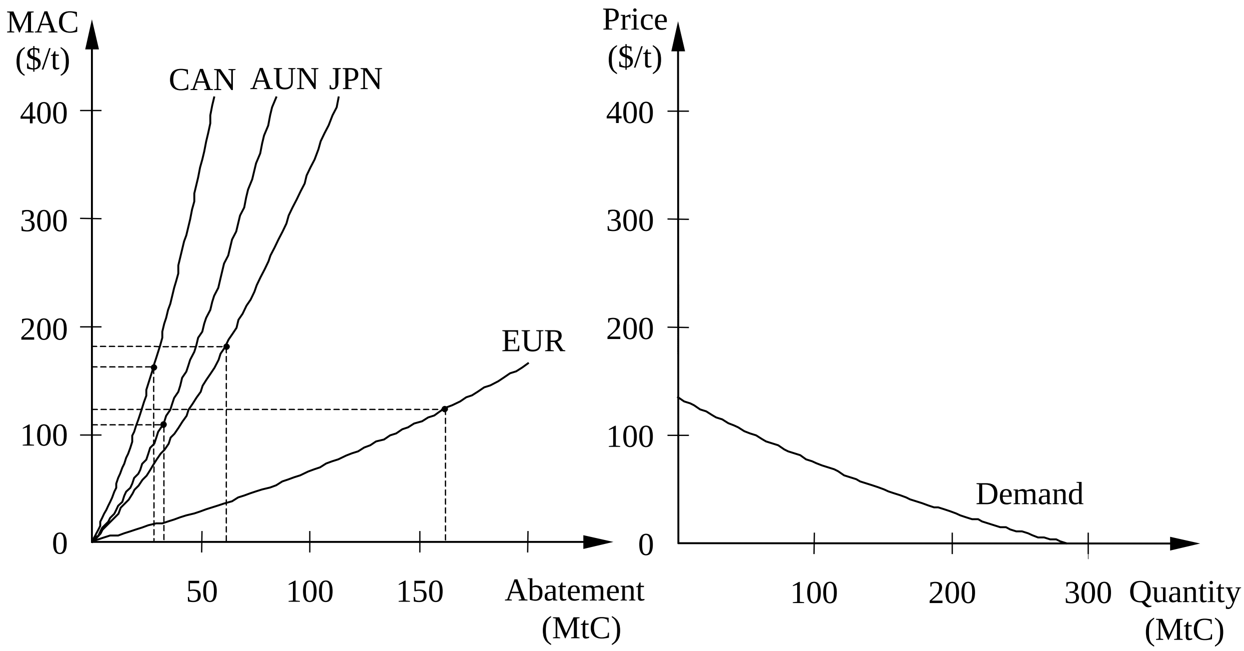

Figure 2 Marginal abatement cost curves and aggregate demand

4. Policy Simulations

Throughout the exposition in this section, we refer to Annex-B regions as those countries of the Annex-B in the Kyoto Protocol that are willing to ratify. This means that the U.S. is not included unless explicitly specified otherwise. Furthermore, it should be noted that all our results refer to one target year, namely 2010.

A. Scenarios

In our simulations, we first consider the case in which Annex-B countries meet their Kyoto reduction commitment by purely domestic action. Although this scenario is unlikely, it provides a useful reference point for the potential environmental effectiveness of the Kyoto Protocol if hot air is suppressed (see scenario *COMP-2*):

NTR Annex-B countries can trade emission rights as allocated under the Kyoto Protocol only within domestic borders. This is equivalent to a situation in which Annex-B countries apply domestic carbon taxes that are high enough to meet their individual Kyoto commitments. Regions EEC and FSU do not face direct compliance costs, as their emission targets do not become binding but won't be able to sell hot air in this case either.

Considering international emissions trading, we start with the assumption of perfect competitive supply and demand behavior:

TRD All Annex-B countries, including FSU and EEC, are allowed to trade emissions among each other. All regions behave as price takers. There is no market power exercised in the international permit market.

As has been elaborated in section 3, competitive supply behavior on behalf of FSU is neither realistic for the case of U.S. compliance nor for the case of U.S. withdrawal: FSU takes a dominant permit supply position due to its large entitlements with hot air. In the scenario *MONOP*, therefore, we assume monopoly power by the FSU:

MONOP FSU acts as a monopoly whereas all other regions are price takers, i.e. they minimize their permit trading or abatement costs given the permit price set by the FSU. EEC is treated as a competitive fringe (price taker) following the price leadership of the dominant region FSU.[11]

The scenario *COMP-1* is designed to provide information on the efficiency gains from competitive markets as compared to the monopolistic solution warranting the same environmental effectiveness:

COMP-1 Marginal abatement costs across all Annex-B regions are equalized given the overall Annex-B reduction target from scenario *MONOP*. In this case, the individual abatements by the various regions are cost-efficient from an overall point of view.

The final scenario, *COMP-2*, is the complement to the initial *NTR* scenario in the sense that it achieves the same environmental effectiveness under competitive permit trading:

COMP-2 FSU and EEC are only entitled with business-as-usual emissions and no longer dispose of hot air. The aggregate reduction level for Annex-B regions amounts to the emission cutback achieved under *NTR*. Emissions can be fully traded across regions to assure a cost-efficient outcome.

The label *COMP* for the last two scenarios indicates that they incorporate monetary compensation to FSU and EEC up to the revenues from permit sales that occur in the case of monopolistic FSU supply behavior (scenario *MONOP*). After compensation of FSU and EEC, *COMP-1* still provides some efficiency gains from competitive markets to allow for a Pareto-superior solution as compared to the *MONOP* outcome. *COMP-2* delivers information on the

[11] FSU knows how much EE supplies at any given price and adjusts the residual demand curve accordingly.

magnitude and distribution of compliance costs across Annex-B regions if FSU and EEC are only entitled with their business-as-usual emissions in 2010. Once again, compensation to FSU and EEC for the *MONOP* revenues would be required. In a nutshell: The scenario *COMP-2* provides the lowest aggregate costs for non-U.S. OECD countries to achieve the *NTR* environmental effectiveness (including monetary compensations to FSU and EEC).

The three final scenarios *US-NTR*, *US-TRD*, and *US-MONOP* consider U.S. compliance for alternative assumptions on the scope of emissions trading and the underlying market structure. U.S. compliance is obviously not a realistic policy option given the current status of climate policy. Yet, these scenarios provide the necessary information on how U.S. withdrawal (as captured by the preceding scenarios) changes economic costs and environmental effectiveness vis-à-vis U.S. compliance:

US-NTR All Annex-B regions – including the U.S. - meet their reduction target by domestic action only.

US-TRD Emission entitlements can be traded on perfectly competitive markets across all Annex-B regions.

US-MONOP Emission are freely tradable across all Annex-B regions. FSU exerts monopoly power on international permit markets.

B. Results

Table 3 summarizes the economic and environmental effects across all scenarios that assume non-compliance of the U.S. We begin the interpretation of results for the *NTR* case. Without permit trading, each Annex-B country has to meet its reduction target exclusively by domestic action. The associated marginal abatement costs are listed in Note "c" of Table 3. Notice that the order in marginal abatement costs across OECD countries does not necessarily reflect the order of magnitude of percentage reduction requirements. The relative cutback requirement is only one determinant of marginal and inframarginal[12] abatement costs. Other major factors affecting marginal abatement costs include the energy/carbon intensity of the respective economies, initial energy prices[13], and the ease of carbon substitution in production and consumption. EEC and FSU do not face any binding abatement requirements. Therefore,

[12] The areas under the marginal abatement cost curves in Figure 2 reflect the total costs of compliance for the *NTR* case as listed in Table 3.

their marginal costs of abatement are zero. In absolute terms, compliance costs for OECD countries sum up to 16.2 bn USD with EUR facing the highest compliance costs. However, if we adopt a meaningful relative cost measure (here: costs as percentage of projected GDP in 2010), EUR bears by far the smallest abatement burden. Compliance costs are rather small across OECD countries, ranging from 0.07 % GDP loss for EUR up to 0.2 % for AUN and CAN. Obviously, the real emission reduction under *NTR* for Annex-B countries must be equal to the *New* effective reduction commitments under the Kyoto Protocol as listed in Table 1. Total emission reduction with respect to *BaU* amounts to 284 MtC or 6.6 % of aggregate *BaU* emissions across all Annex-B countries, including the U.S.

Under competitive Annex-B emissions trading (scenario *TRD*), the permit price equals zero, since the amount of hot air exceeds the total amount of the emission reduction requirements. Consequently, the total costs as well as country-specific costs for meeting the *New* Kyoto targets without participation of the U.S. are zero. Total gains from trade as compared to the NTR scenario, hence, amount to 16.2 bn USD, i.e. the total of *NTR* compliance costs. However, there is no emission reduction at all with respect to *BaU*. In short, Kyoto boils down to business-as-usual; Annex-B emissions in 2010 remain unchanged.

Under monopoly power, FSU reduces the hot air supply to maximize its profits given the reaction of EEC as a competitive fringe. The monopolistic profit of FSU amounts to 3 bn USD with a hot air supply of 94 MtC at a market price of 32 USD. The fringe supplier EEC delivers emission permits of 87 MtC to the market composed of 59 MtC hot air and 35 MtC from domestic abatement. EEC benefits from implementation of the Kyoto Protocol with a net revenue of 2.4 bn USD under *MONOP*. All OECD regions face substantially lower compliance costs under MONOP as compared to the *NTR* case, since their *NTR* marginal abatement costs are much higher than the monopolistic permit price. As a consequence, it is much cheaper for OECD countries to reduce their domestic abatement efforts (see rows *Real emission reduction* in Table 3) and pay for fictive (in the case of hot air) or effective emission abatement in FSU and EEC. However, the huge cost reduction under *MONOP* vis-à-vis *NTR* is not only due to cost savings from permit trading but also due to a substantial relaxation of the overall emission constraint. Environmental effectiveness drops by more than a half from 6.6 % to 3 %. The monopoly case entails efficiency losses because marginal abatement costs

[13] For example, higher initial energy prices due to prevailing taxes require - ceteris paribus - higher carbon taxes in order to reach the same relative cutback in energy demand.

across all Annex-B regions are not equalized. In fact, FSU has marginal abatement costs of zero and does not abate any real emissions.

Scenario *COMP-1* reveals the efficiency gains from competitive permit trade as compared to the *MONOP* case (keeping the same environmental effectiveness). Marginal abatement costs drop by a half, and total efficiency gains amount to roughly 1 bn USD. Marginal abatement costs are now equalized across all trading partners, and real emission reduction in Table 3 indicates the efficient abatement share for each region under overall cost-effectiveness considerations. With regard to permit trade, emission exports reported for FSU and EEC now reflect real abatement; the additional row in Table 3, "hot air", denotes the total feasible amount of hot air that can be sold by FSU and EEC in the competitive setting. Note, that this amount is the same as under *MONOP*, but an overall cost-efficient abatement now requires a (substantial) cutback of real emissions in FSU. Of course, FSU will only accept the *COMP-1* abatement policy when it is at least fully compensated up to its *MONOP* profits. Likewise, approval by OECD countries and EEC implies that no country is worse off as compared to the *MONOP* case. Given the gains in overall compliance costs, these requirements can be met, while nearly one 1 bn USD can additionally be distributed across all trading partners. It is not appropriate to speculate at this point on a specific distribution mechanism.

The results for the final scenario COMP-2 in Table 3 summarize the implications that would surface if Annex-B countries were to achieve the same total emission reduction as for the *NTR* case. Total compliance for OECD countries decreases from 16.2 bn USD to 9.8 bn USD. As expected, all OECD countries would be better off than under *NTR* but undergo higher costs than in the *MONOP* case. Interestingly, *COMP-2* would not require additional compensation of the FSU; FSU profits slightly more from competitive permit trading under *COMP-2* (i.e. without hot air and *NTR* environmental effectiveness) than from monopolistic pricing under *MONOP*. The reason for this is that the increase in the permit price under *COMP-2* not only compensates FSU for the undertaken domestic abatement, but remaining profits are even higher than the profits from hot air sales under *MONOP*. EEC, however, is worse off, since its revenues from permit trade are not high enough to cover both domestic abatement costs and the profits occurring in the *MONOP* case. Hence, EEC must be considered a candidate for compensation up to its *MONOP* profits. The question remains whether OECD countries would accept the overall increase in total costs from 7.2 bn USD to

11.2 bn USD (including compensating transfers to EEC) and how the distribution of these costs should look.

Table 3: Summary of results without participation of USA

	NTR	TRD	MONOP	COMP-1	COMP-2
Absolute cost of compliance (bn USD)					
AUN	1.4	0	0.8	0.4	1.0
CAN	2.0	0	0.8	0.4	1.1
EEC	0	0	-2.4	-1.1	-1.0
EUR	7.8	0	3.9	2.2	5.3
FSU	0	0	-3.0	-2.0	-3.1
JPN	5.0	0	1.7	0.9	2.4
Total	16.2	0	1.8	0.9	5.6
Relative cost of compliance (% of business-as-usual GDP in 2010)					
AUN	0.209	0	0.116	0.065	0.154
CAN	0.208	0	0.080	0.043	0.111
EEC	0	0	-0.403	-0.184	-0.174
EUR	0.067	0	0.034	0.019	0.046
FSU	0	0	-0.351	-0.231	-0.363
JPN	0.104	0	0.036	0.019	0.050
Total [a]	0.083	0	0.009	0.004	0.029
Real emission reduction (% from business-as-usual in 2010)					
AUN	25.4	0	11.2	6.9	14.8
CAN	17.6	0	5.4	3.3	7.3
EEC	0	0	13.4	8.1	17.9
EUR	15.2	0	5.9	3.6	8.0
FSU	0	0	0	8.7	18.4
JPN	19.1	0	5.2	3.1	7.0
Total [b]	6.6	0	3.0	3.0	6.6
Total real emission reduction (MtC)					
	284	0	130	130	284
Market price (USD/tC)					
	- [c]	0	32	16	48
Permit trade (MtC) [d]					
AUN	-	0	18	24	14
CAN	-	0	20	24	17
EEC	-	0	-87	-17	-37
EUR	-	0	97	121	77
FSU	-	0	-94	-52	-109
JPN	-	0	46	53	40
Hot air				-153	

[a] Percentage change with respect to business-as-usual GDP of Annex-B in 2010 except for the U.S.
[b] Percentage change with respect to total Annex-B emissions in 2010 under *BaU* including U.S. emissions.
[c] MAC without trade: 105 USD/tC for AUN, 163 USD/tC for CAN, 117 USD/tC for EUR, 184 USD/tC for JPN.
[d] Positive values indicate permit imports, negative values indicate permit exports.

Table 4 completes our analysis of alternative abatement policy scenarios. It provides a perspective on how U.S. compliance (or, in turn, U.S. withdrawal, if we make the reference to Table 3) affects environmental effectiveness and the magnitude, as well as the distribution of compliance costs. For the scenario *US-NTR*, compliance costs of non-U.S. Annex-B countries must be the same as under the *NTR* scenario in our partial analytical framework. In absolute as well as relative terms, the U.S. bears the highest compliance costs. The importance of U.S. compliance for international climate policy becomes evident from the implied change in environmental effectiveness: Real emission reduction of Annex-B countries triples compared to the *NTR* case under U.S. withdrawal. Competitive international permit trade under *US-TRD* accommodates a major cutback in total compliance costs while the real emission reduction vis-à-vis business-as-usual amounts still to 10 % (compared to 18.5 % for *US-NTR* and only 6.6 % for *NTR*). In contrast to our results for the case of U.S. withdrawal, we see that monopoly power by FSU has no impact on environmental effectiveness; the aggregate emission cutback under *US-TRD* and *US-MONOP* are the same. The reason is that in both cases the total amount of permits supplied by FSU (and EEC) exceeds the total stock in hot air. Given the same environmental impact, we can directly read off the efficiency losses induced by *US-MONOP* vis-à-vis *US-TRD*: Monopolistic supply by FSU drives up the permit price to 51 USD, which increases compliance costs by 40 % as compared to competitive permit trading (in which the permit price is only 37 USD).[14]

Cross-comparison between scenarios *MONOP* and *US-MONOP* indicates that non-U.S. OECD countries face smaller compliance costs after U.S. withdrawal considering FSU market power. The reason for this is the fall in the emission permit price implied by a reduced permit demand after U.S. withdrawal. However, the reduction in compliance costs must be weighted against a substantial loss in environmental effectiveness (from 10% to 3% emission reduction). FSU and its competitive fringe EEC face a drastic decline in revenues from permit sales, since the permit price declines from 51 USD under *US-MONOP* to 32 USD under *MONOP*.

[14] We omit an additional scenario *US-COMP* (like *COMP-1*) to identify the efficiency losses from market power, since the latter would be (almost) identical to the scenario *US-TRD*.

Table 4: Summary of results with participation of USA

	US-NTR	US-TRD	US-MONOP
Absolute cost of compliance (bn USD)			
AUN	1.4	0.9	1.1
CAN	2.0	0.9	1.1
EEC	0	-2.8	-4.2
EUR	7.8	4.4	5.6
FSU	0	-13.2	-15.6
JPN	5.0	1.9	2.5
USA	30.3	14.5	18.6
Total	46.5	6.5	9.1
Relative cost of compliance (% of business-as-usual GDP in 2010)			
AUN	0.209	0.128	0.160
CAN	0.208	0.090	0.117
EEC	0	-0.474	-0.699
EUR	0.067	0.037	0.048
FSU	0	-1.522	-1.803
JPN	0.104	0.040	0.053
USA	0.230	0.110	0.142
Total [a]	0.142	0.020	0.028
Real emission reduction (% from business-as-usual in 2010)			
AUN	25.4	12.3	15.5
CAN	17.6	6.0	7.6
EEC	0	14.8	18.7
EUR	15.2	6.6	8.3
FSU	0	15.4	0.3
JPN	19.1	5.8	7.4
USA	28.0	10.7	13.5
Total [b]	18.5	10.0	10.0
Total real emission reduction (MtC)			
	790	429	429
Market price (USD/tC)			
	- [c]	37	51
Permit trade (MtC) [d]			
AUN	-	17	13
CAN	-	19	16
EEC	-	-90	-98
EUR	-	90	72
FSU	-	-393	-304
JPN	-	44	39
USA	-	313	262

[a] Percentage change with respect to business-as-usual GDP of Annex-B in 2010 including the U.S.
[b] Percentage change with respect to total Annex-B emissions in 2010 under *BaU* including U.S. emissions.
[c] Marginal abatement cost in region without trade are 105 USD/tC for AUN, 163 USD/tC for CAN, 117 USD/tC for EUR, 184 USD/tC for JPN and 145 USD/tC for USA.
[d] Positive values indicate permit imports, negative values indicate permit exports.

Figure 3 summarizes the concrete results of our policy simulations. Without U.S. compliance, the residual demand of competitive OECD countries (all of them facing binding emission constraints) is given by the curve D. Under competitive permit trading *TRD*, FSU supplies hot air in excess of market demand, which results in a market equilibrium at point *H*. If the FSU exercises monopoly power (*MONOP*), it sells hot air permits until the marginal revenues of permit sales (MR) are equal to the marginal costs of abatement, which are zero in our case (point *I*). Monopoly power by the FSU, thus, increases the international permit price, and initiates real emission reduction. Point *J* reflects the scenario *COMP-1*, which achieves the *same* emission reduction as under *MONOP* in a cost efficient way, since cheap reduction possibilities in FSU are exploited (to a level where marginal abatement costs are equalized across all regions). With U.S. participation, the residual demand faced by FSU is depicted by the curve D_{US}. In this case, the competitive permit market equilibrium (*US-TRD*) is given by point *K* whereas point *L* captures the situation of FSU monopoly power (*US-MONOP*). Note that monopolistic behavior under U.S. participation does not affect environmental effectiveness, since the optimal monopolistic permit supply by FSU is larger than its amount of hot air.

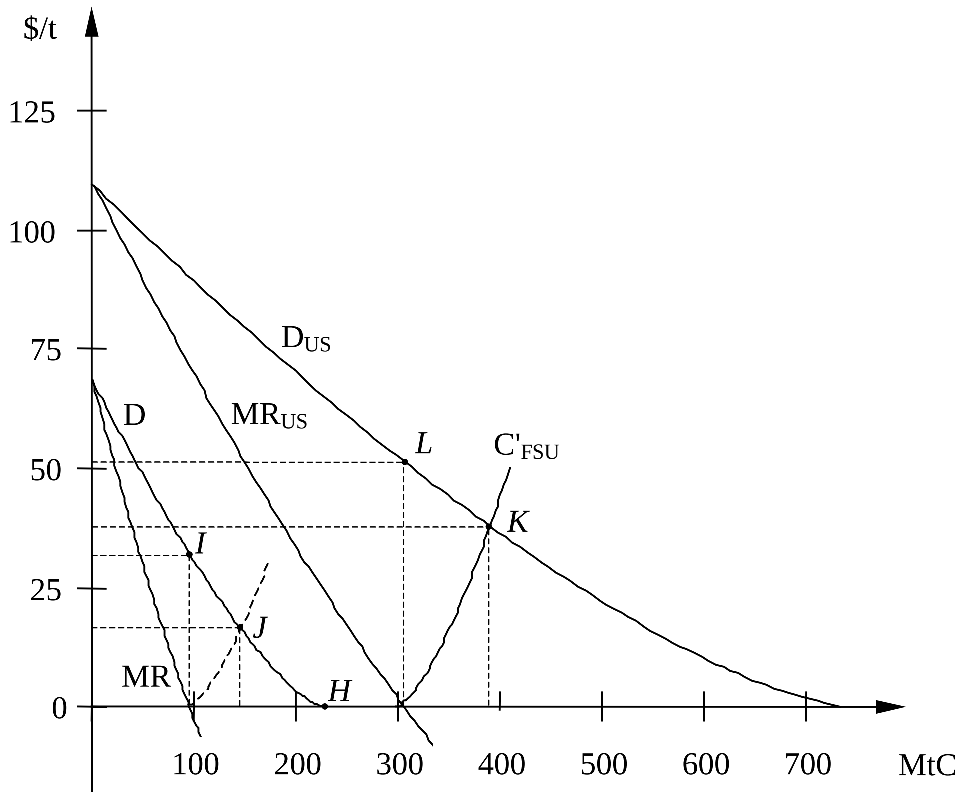

Figure 3 Graphical exposition of results

5. Conclusions

This paper has laid out that the implications of FSU market power on environmental effectiveness and compliance costs differ substantially when comparing U.S. compliance to U.S. withdrawal. While exercise of market power on behalf of FSU under U.S. compliance has no environmental impact as compared to competitive permit trade, it prevents the Kyoto Protocol from boiling down to business-as-usual after U.S. withdrawal. Efficiency losses from FSU market power increase considerably (in relative terms) if the U.S. is not going to comply. U.S. withdrawal reduces the compliance costs of remaining OECD countries costs, but these gains must be weighed against a dramatic loss in overall environmental effectiveness. Clearly, the big losers from U.S. withdrawal are FSU and its competitive fringe EEC that suffer from a huge decline in permit sales revenues.

Sensitivity analysis with respect to alternative baseline projections confirm the robustness of our qualitative findings, although the concrete quantitative values, particularly at the single country level, may alter considerably for diverging assumptions on future economic growth and baseline emissions.[15]

There are several aspects that warrant further investigation of the issues treated in this paper. First, our analysis does not cover a further commitment period after 2012, which might influence the behavior of Parties in the first commitment period, e.g. through strategic banking of emission permits. Second, we have not considered the possibility of lowering market power by opening up emission trading to non-Annex B countries via the Clean Development Mechanism (CDM). Third, our analysis is a partial equilibrium approach, since it does not consider spillover effects of carbon abatement policies or monopolistic pricing to other markets. For instance, abating countries do not take into account the effects of carbon reduction efforts on international prices and therefore its terms of trade. It would be interesting – also from a methodological point of view – to compare the partial equilibrium results with respective general equilibrium calculations in order to identify and quantify potential sources of divergence.

[15] For the sake of brevity, we do not report the sensitivity analysis on different baseline projections, i.e. lower or higher growth and emission projections as compared to our central case provided by DOE (DOE 2001).

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Appendix A: Algebraic model description

This section provides an algebraic summary of the partial equilibrium model for permit trade underlying the simulations in section 4. We begin with the model formulation for a competitive system of permit trade without the occurrence of hot air. Second, we show how hot air can be accounted for. Finally, we lay out the set-up for the case of monopolistic permit supply.

A1. Competitive permit trading

Under competitive permit trading, all countries i are price takers. Each country minimizes its compliance costs to some exogenous target level k_i. Compliance costs equal the sum of abatement costs and the costs of buying carbon permits; in the case of permit sales, the second term becomes negative, which means that the country minimizes the cost of abatement minus the income from selling permits. Costs are minimized subject to the constraint that a country meets its exogenous reduction target, in other words: a country's initial endowment of permits plus the amount of permits bought or sold on the market (q_i) may not exceed the emission target level k_i:

$$\min_{q_i} \; C_i\left(\overline{e_i} - e_i\right) + P \cdot q_i \qquad (1)$$

$$s.t. \quad e_i = k_i + q_i \,,$$

where

C_i	denotes the abatement cost function for reducing carbon emissions,
$\overline{e_i}$	stands for the business-as-usual emissions,
e_i	are the actual emissions, and
P	is the permit price taken as exogenous.

The first order condition for the cost minimization problem is given by:

$$C_i^{'}\left(\overline{e_i} - e_i\right) = P \,. \qquad (2)$$

In the optimum, the price taking countries abate emissions up to a level where their marginal abatement costs (C') equal the permit price. Total costs of reducing emissions to the overall target level $K = \sum_i k_i$ are minimized, since all opportunities for exploiting cost differences in abatement across countries are taken.

A.2 Accounting for hot air

A country with hot air (*h_i*) minimizes costs of abatement minus income from selling permits (q_i<0):

$$\min_{q_i} C_i\left(h_i + \overline{e_i} - e_i\right) + P \cdot q_i \tag{3}$$

$$s.t. \quad e_i = k_i + q_i \, .$$

The amount of hot air equals the difference between the emission target and the business-as-usual emissions:

$$k_i = h_i + \overline{e_i} \, . \tag{4}$$

The first order condition yields:

$$C_i^{'}\left(h_i + \overline{e_i} - e_i\right) = P \, . \tag{5}$$

The existence of hot air does not change the cost-efficiency property of unrestricted competitive permit trading since marginal abatement costs are still equalized. However, hot air sold on the permit market does not imply any effective (real) emission reduction in the hot air countries. The occurrence of traded hot air, therefore, results in an increase of overall emission compared to a situation without international permit trade.

A.3 Monopolistic permit supply

Monopolistic permit supply is characterized as a situation where one country (denoted "m") - in our case the hot air country FSU - has supply power in the permit market while all other countries, denoted as fringe "f", behave as price takers. The fringe countries, thus, minimize their compliance costs given the permit price set by the monopolist. They emit carbon until the marginal costs of abatement equal the permit price:

$$C_f^{'}\left(h_f + \overline{e_f} - e_f\right) = P \, . \tag{5'}$$

The aggregate permit demand of the fringe, which is in total a net importer of permits, is:

$$Q_F\left(P\right) = \sum_f q_f\left(P\right). \tag{6}$$

The monopolist sets its permit supply (q_m<0) to minimize abatement costs minus income from permit sales:

$$\min_{q_m} C_m\left(h_m + \overline{e_m} - e_m\right) + P \cdot q_m \tag{7}$$

$$s.t. \quad e_m = k_m + q_m$$
$$P = P\left(Q_F\right)$$

where P is the inverse demand function of the fringe countries. As illustrated in Figure 3, the first order condition of the cost minimization problem indicates that the monopolist sets marginal abatement costs equal to marginal revenue:

$$C_m^{'}\left(h_m + \overline{e_m} - e_m\right) = P - P^{'}\left(Q_F\right) \cdot q_m \,, \tag{8}$$

Marginal abatement costs are accordingly not equalized between the fringe countries (Equation 5') and the monopolist (Equation 8), resulting in overall efficiency losses due to market power.

Appendix B: GHG Emission Reduction Targets for Annex-B countries

	Label[a]	Original Kyoto Targets (*OLD*)[b] (% of 1990 GHG emissions)	Revised Targets (*NEW*)[c] (% of 1990 GHG emissions)
Australia	AUN	108	110.7
Austria	EUR	87	92.9
Belgium	EUR	92.5	93.8
Bulgaria	EEC	92	95.2
Canada	CAN	94	107.9
Croatia	EEC	95	95
Czech Republic	EEC	92	94.1
Denmark	EUR	79	81.1
Estonia	FSU	92	94.7
Finland	EUR	100	107.8
France	EUR	100	103.9
Germany	EUR	79	80.7
Greece	EUR	125	133.1
Hungary	EEC	94	97.8
Iceland	EUR	110	118
Ireland	EUR	113	116.2
Italy	EUR	93.5	95.3
Japan	JPN	94	99.2
Latvia	FSU	92	98
Liechtenstein	EUR	92	107.9
Lithuania	EUR	92	96.5
Luxembourg	EUR	72	79.6
Monaco	EUR	92	93
Netherlands	EUR	94	95.2
New Zealand	AUN	100	107
Norway	EUR	101	105.3
Poland	EEC	94	96.5
Portugal	EUR	127	130.7
Romania	EEC	92	96.2
Russian Federation	FSU	100	105.7
Slovakia	EEC	92	96.3
Slovenia	EEC	92	100.4
Spain	EUR	115	118.9
Sweden	EUR	104	109.5
Switzerland	EUR	92	96.6
Ukraine	FSU	100	102.4
United Kingdom	EUR	87.5	88.8
United States	USA	93	96.8

[a] Label of aggregate model region which includes the respective Annex-B country

[b] UNFCCC (1997)

[c] Estimates by the European Commission accounting for sink credits based on UNFCCC (2001)