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Abstract

Since January 1st the European Union has launched an EU-internal emissions trading scheme (EU ETS) for emission-intensive installations as the central pillar to comply with the Kyoto Protocol. The EU ETS may be linked at some time to a Kyoto emissions market where greenhouse gas emission allowances of signatory Kyoto countries can be traded. In this paper we investigate the implications of Russian market power for environmental effectiveness and regional compliance costs to the Kyoto Protocol taking into account potential linkages between the Kyoto emissions market and the EU ETS. We find that Russia may have incentives to join the EU ETS as long as the latter remains separated from the Kyoto international emissions market. In this case, Russia can exert monopolistic price discrimination between two separated markets thereby maximizing revenues from hot air sales. The EU will be able to substantially reduce compliance costs when it does not restrain itself to EU-internal emission regulation schemes. However, part of the gains from extra-EU emissions trading will come at the expense of environmental effectiveness as (more) hot air will be drawn in.

JEL classification: D42, Q25

Keywords: market power, hot air, climate policy

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Non-Technical Summary

Under the Kyoto Protocol Russia has been granted much more emission rights than it is presumed to need for its business-as-usual economic development. The substantial amount of excess emission rights – often referred to as *hot air* – will enable Russia to behave strategically on the international carbon emissions trading market by rationing permit supply. Based on numerical simulations with a simple multi-sector, multi-region (partial equilibrium) model of carbon abatement and emissions trading, we investigate the implications of Russian market power for environmental effectiveness and regional compliance costs to the Kyoto Protocol taking into account potential linkages between the Kyoto emissions market and the recently created EU-internal emissions market. We find that Russia may have incentives to join the EU ETS as long as the latter remains separated from the Kyoto international emissions market. In this case, Russia can exert monopolistic price discrimination between two separated markets thereby maximizing revenues from hot air sales. The EU will be able to substantially reduce compliance costs when it does not restrain itself to EU-internal emission regulation schemes. However, part of the gains from extra-EU emissions trading will come at the expense of environmental effectiveness as (more) hot air will be drawn in.

1. Introduction

On February 16th 2005 the Kyoto Protocol entered into force upon prior ratification by Russia. Despite the withdrawal of the United States – the world's major emitter of anthropogenic greenhouse gases – the Kyoto Protocol is often praised as a milestone in international climate policy because (i) it is the first regime to impose binding greenhouse gas emission limits on industrialized countries and (ii) it builds on flexible mechanisms to facilitate efficient implementation of emission abatement requirements. In January 2005, i.e. shortly before the coming-into-force of the Kyoto Protocol, the European Union started off an EU-internal emissions trading scheme (EU ETS) as the central pillar of European climate policy to comply with the Kyoto Protocol.

Against this background, we investigate the strategic climate policy options for Russia emerging from its role as dominant permit supplier on international emission markets: Russia has been granted much more emission rights under the Kyoto Protocol than it is expected to need for its business-as-usual economic development. Note, that this point has been made before in the literature (see the next section for a review). The innovative contribution of the present paper consists of the consideration of the EU ETS under Russian market power within the framework of the Kyoto Protocol. The potential market differentiation between the EU ETS and the Kyoto international emissions market may have considerable implications for Russia. How should the country ration its excess emission rights – often referred to as *hot air* – in order to maximize national revenues when taking into account potential linkages between the Kyoto emissions market and the EU ETS? What are the implications of Russia's strategic policy options for regional compliance costs and environmental effectiveness of the Kyoto Protocol?

Based on numerical analysis with a model of carbon abatement possibilities by regions and sectors we find that Russia may have incentives to join the EU ETS as long as the latter remains separated from the Kyoto international emissions market. In this case, Russia can exert monopolistic price discrimination between two separated markets thereby maximizing revenues from hot air sales. The EU will be able to substantially reduce compliance costs when it does not restrain itself to EU-internal emission regulation schemes. However, part of the gains from extra-EU emissions trading will come at the expense of environmental effectiveness as (more) hot air will be drawn in.

The remainder of the paper is organized as follows. Section 2 sets the stage by describing the current institutional framework of international climate policy and laying out different strategic climate policy options for Russia; it furthermore summarizes the main insights of the relevant previous literature. Section 3 presents the analytical framework which is used for numerical simulations of selected climate policy scenarios based on empirical and projected data. Section 4 motivates the policy scenarios under investigation. Section 5 discusses simulation results. Section 6 concludes.

2. International Climate Policy: What is at Stake?

Within the Kyoto Protocol to the Framework Convention on Climate Change the industrialized countries (so-called Annex B countries) committed themselves to reduce their emissions for the period 2008 to 2012 by specific amounts relative to 1990. Based on experts' projections of future emission trajectories, these commitments imply effective cutbacks from business-as-usual (BaU) for most signatory Kyoto parties. However, some countries – most notably Russia – are expected to have BaU emissions that fall substantially short of the national emission budgets as granted under the Kyoto Protocol. These excess emission rights – commonly referred to as *hot air* – have generated some discussion in the literature (see, e.g., Bernard et al. (2003), Böhringer (2000), Klepper and Peterson (2005), Michaelowa and Koch (1999), Paltsev (2000)). The main insight of this literature is that the supply of hot air will lower the international permit price significantly. However, the results depend on the assumptions regarding the strategic behavior on the supply side as well as on the strength of terms of trade effects. According to the data used in the present study (EU (2003) and DOE (2005)), the Russian hot air amounts to 615 $MtCO_2$.

The Kyoto Protocol allows for flexible instruments which may be used by signatory parties to reduce their compliance costs: International Emissions Trading (IET) between industrialized countries as well as project-based Joint Implementation (JI) and the Clean Development Mechanism (CDM) with hosts either in industrialized (JI) countries or developing countries (CDM). Among these instruments, IET may be used to generate income from sales of hot air. Independent from the meanwhile legally binding status of the Kyoto Protocol, the EU has pushed forward an EU-internal emissions trading system for energy-intensive sectors – the so-called EU ETS – as a key market-based instrument to implement its Burden Sharing Agreement (EU (1999)). The latter defines national emission reduction targets across EU Member States in consistency with the aggregate

EU commitment under the Kyoto Protocol. Energy-intensive sectors (installations) which are covered by the EU ETS (in the following DIR sectors) are able to trade permits among each other. However, the current EU ETS implies a hybrid regulation scheme as other sectors (in the following NDIR), such as households or transport, are not covered and therefore require complementary regulation in each EU Member State to comply with the national targets as prescribed by the Burden Sharing Agreement. The carbon emission sources in the EU are therefore subject to different regulatory regimes that are not directly linked to each other via flexible instruments. This segmentation of the EU carbon market induces efficiency losses from restricted "where-flexibility": Although marginal abatement costs across DIR sectors within the EU will be equalized, they might differ substantially from the marginal abatement costs in the NDIR sectors of each EU Member State. In fact, the excess costs can be substantial if the NDIR sectors would be regulated by purely domestic policies only (see, e.g., Böhringer et al. (2005), Klepper and Peterson (2004)). Note, however, that EU governments may use international emissions trading at the governmental level to equalize at least marginal abatement costs across all NDIR sectors.

In assessing the institutional climate policy background, it should be noted that there are two important differences between the emissions market under the EU ETS and the IET established under the Kyoto Protocol. Firstly, under the Kyoto IET countries themselves are trading emissions while the EU ETS is strictly firm (installation) based. Secondly, the Kyoto Protocol covers the aggregated emissions of a country while the EU ETS is restricted to the energy-intensive DIR sectors and covers only roughly half of the total EU emissions. These differences between EU ETS and Kyoto IET are of critical importance for Russia's strategic options in international climate policy. Given larger amounts of hot air, Russia may act as a dominant player on the IET market, thereby rationing hot air supply to maximize its own profit. By focusing on Russia in this study we neglect possible strategic options for the remaining countries of the Former Soviet Union (i.e. without Russia and the Baltic States). However, taking into account that this region (in the following denoted as "XSU") comprises 11 heterogeneous countries with different policy interests the assumption of non-strategic behavior for the XSU region seems to be justified.[1]

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[1] The XSU region disposes of 334 MtCO_2 hot air. According to the GTAP classification this region comprises Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Tajikistan,

In our subsequent analysis, we focus on *three* possible future climate policy regimes. *Firstly* – as envisaged by the Kyoto Protocol – there is the option of IET for all signatory countries (including the EU). If emission markets were competitive, previous research on the Kyoto Protocol suggested that hot air will drive down environmental effectiveness and compliance costs eventually to zero (see e.g. Böhringer (2002)). Monopolistic rationing of hot air on behalf of Russia may, however, ensure positive marginal abatement costs, and thus some effective emission reduction (see e.g. Böhringer and Löschel (2003)). *Secondly*, there is the possibility that the EU will continue to implement its Kyoto target internally: The EU ETS applies to DIR sectors within the EU and Member States use an emissions trading similar to the Kyoto IET for their NDIR sectors within the EU only. At the same time all other signatory Kyoto parties join the IET market with Russia maximizing revenues through monopolistic supply of hot air. In this setting, it may be possible that EU Member States make use of the Kyoto IET on the global market for their NDIR sectors while the EU ETS for DIR sectors remains separated. *Thirdly*, one may imagine a regime where Russia leans towards – or possibly joins – the EU ETS (which is separated from the Kyoto market) and at the same time takes part in the Kyoto IET and maximizes hot air revenues there. In this case, Russia has an interest to avoid a fragmentation of its hot air supply to the EU ETS, as hot air permits issued to Russian DIR firms would dilute its market power. Thus, one might consider a situation where Russia manages a pooling of its EU ETS permit supply:[2] Price discrimination on both – the EU ETS market as well as the IET Kyoto market – might then be an attractive option for Russia to maximize revenues from hot air sales.

3. Analytical Framework

We investigate the implications of Russian market power under different assumptions of market linkages with a simple multi-sector, multi-region model of carbon abatement and emissions trading.[3] The partial equilibrium model is based on marginal abatement cost curves for the DIR and NDIR sectors across signatory countries of the Kyoto Protocol: Marginal costs of abatement vary considerably across countries and sectors due to

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Turkmenistan, Ukraine, and Uzbekistan. Given the UNFCCC data on CO_2 emissions (UNFCCC (2006)) Ukraine (47%), Kazakhstan (20%) and Uzbekistan (11%) hold the largest shares of CO_2 emissions among the members of the XSU region.

[2] Article 28 of the EU ETS Directive (Directive 2003/87/EC) concedes this option. See Golub and Strukova (2004) for a similar reasoning.

[3] For a detailed description of the model see http://brw.zew.de/simac.

differences in carbon intensity, initial energy price levels, or the ease of carbon substitution possibilities.

In order to obtain country-specific marginal abatement cost curves for the DIR and NDIR sectors, we make use of the PACE model - a standard multi-region, multi-sector CGE model (for a detailed algebraic exposition see Böhringer (2002)) which is based on the most recent consistent accounts of national production and consumption and bilateral trade and energy flows for the year 2001 (as provided by the GTAP 6 database).[4] We perform a sequence of carbon tax scenarios for each region relevant to our analysis where we impose uniform carbon taxes (starting from 0 to 100 \$US per ton of carbon). We thereby generate a large number of marginal abatement costs, i.e., carbon taxes, and the associated carbon emission reductions in DIR and NDIR sectors.

The discrete data can be fitted to continuous marginal abatement cost curves by an ordinary least-square approach. For the empirical specification of sectoral marginal abatement costs curves across regions *i* we adopt a polynomial of third degree:

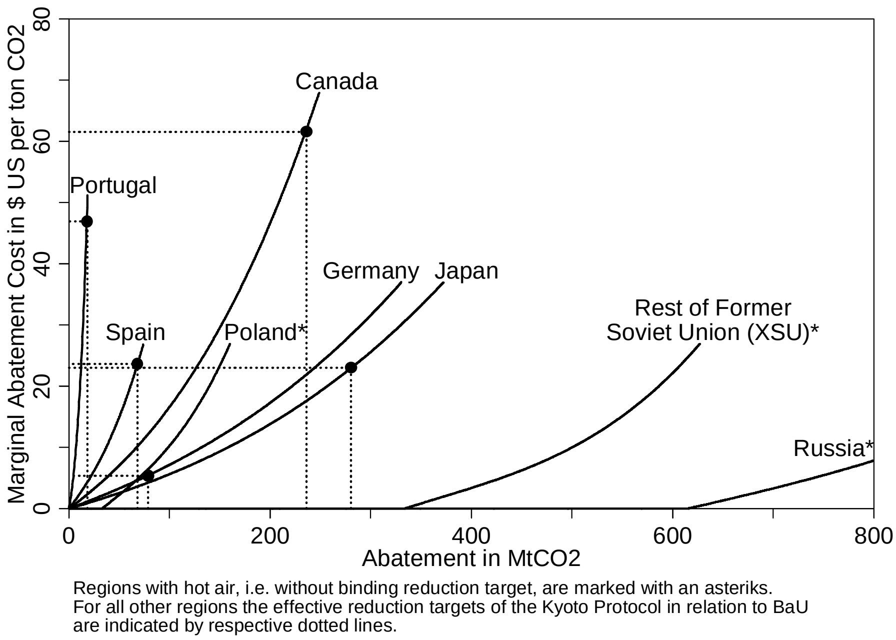
$$p = -\frac{\partial C_i}{\partial e_i} = \alpha_{1,i} \cdot (\bar{e}_i - e_i) + \alpha_{2,i} \cdot (\bar{e}_i - e_i)^2 + \alpha_{3,i} \cdot (\bar{e}_i - e_i)^3$$

where $-\frac{\partial C_i}{\partial e_i}$ is the marginal cost of reducing carbon emissions in country *i*, $\bar{e}_i$ are the BaU emissions, and e_i are the actual emissions, i.e. $a_i = \bar{e}_i - e_i$ denotes the level of abatement.

Table 6 in the Appendix provides a summary of the least-square estimates for the coefficients $\alpha_{1,i}$, $\alpha_{2,i}$ and $\alpha_{3,i}$ of marginal abatement cost curves. As an illustration the marginal abatement costs for selected regions are depicted in Figure 1.[5] The differences in the marginal costs corresponding to the country-specific reduction target in the Kyoto Protocol are substantial. Obviously, there exists a large potential for aggregate cost savings by equalizing marginal abatement cost via trading of emission permits.

[4] See Dimaranan and McDougall (2006) for the GTAP 6 database.
[5] Note that the marginal abatement costs in Figure 1 and Table 4 are defined in \$US per ton of CO_2 while the coefficients in Table 6 refer to marginal costs in \$US per ton of carbon.

Figure 1: Marginal Abatement Costs for Selected Regions



4. Policy Scenarios

In our quantitative simulations, we distinguish two important dimensions of the near-term international climate policy regime: (i) the linkage between the Kyoto IET and the EU ETS (respectively the NDIR sectors of the EU), and (ii) the ability of Russia to exert market power.

We specify six policy scenarios to illustrate what is at stake in international climate policy during the first commitment period of the Kyoto Protocol:

NTr: All Annex B countries achieve their reduction target domestically. 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.

Kyoto-C: All Annex B countries are allowed to trade emission permits among each other. All regions behave as price takers, i.e., perfect competition in the international permit market is assumed.

Kyoto: This scenario is the same as *Kyoto-C* but with market power by Russia on the supply side, i.e., Russia is able to ration its hot air and to choose the profit maximizing price for its permits.

EU-Closed: This scenario considers an intra-EU implementation of Kyoto targets. DIR sectors take part in the EU ETS and the EU member states may only exchange permits for their NDIR sectors between each other, i.e. there is no linkage between the Kyoto IET and the EU ETS and the NDIR sectors. As in scenario *Kyoto* Russia has market power in the IET.

EU-NDIR-Tr: This scenario is the same as *EU-Closed*, but the EU member states are now able to cover permit demand for their NDIR sectors from the Kyoto market. That implies a link between both markets and therefore additional demand on the Kyoto market compared to *EU-Closed*.

EU-RUS: This scenario is the same as *EU-NDIR-Tr*, but Russia is now able to take part as a dominant supplier with market power in the separated EU ETS, i.e. there is now a linkage between the EU ETS and the Kyoto IET via Russia. As before, Russia has market power in the Kyoto IET, i.e. the country acts as monopolist on two separated permit markets.

Table 1 summarizes briefly the central features of our six climate policy scenarios. Note that the first three scenarios – *NTr*, *Kyoto-C*, and *Kyoto* – have been discussed in the previous literature (see e.g. Böhringer and Löschel (2003)) and are reconsidered for the sake of comparison and benchmarking.

Table 1: Policy Scenarios

	Market linkage: Kyoto IET with		Russian market power in		
	EU ETS	EU NDIR	Kyoto IET	EU NDIR	EU ETS
NTr	-	-	-	-	-
Kyoto-C	yes	yes	no	-	-
Kyoto	yes	yes	yes	-	-
EU-Closed	no	no	yes	no	No
EU-NDIR-Tr	no	yes	yes	yes	No
EU-RUS	yes	yes	yes	yes	Yes

5. Simulation Results

Our analysis focuses on the total compliance costs (see Table 2) and the emission reduction in per cent of BaU emissions (see Table 3). We begin the interpretation of results with 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 Table 4 and visualized for selected regions in Figure 1. Compliance to the Kyoto Protocol without trade induces substantial adjustment cost, which amount to more than 11000 m $US. The highest costs are borne by Canada and Japan.

Table 2: Compliance Costs in m $US (2001)

	NTr	*Kyoto-C*	*Kyoto*	*EU-Closed*	*EU-NDIR-Tr*	*EU-RUS*
Russia	0	0	-511	-179	-560	-634
XSU*	0	0	-733	-684	-1100	-1100
Canada	5713	0	474	444	681	681
Japan	2670	0	539	507	760	760
European Union	2810	0	516	1339	659	628
Austria	90	0	24	111	33	31
Belgium	17	0	16	103	27	34
Germany	205	0	129	454	171	164
Denmark	15	0	8	-3	8	4
Spain	675	0	132	632	179	169
Finland	0	0	-7	-68	-12	-12
France	318	0	98	427	135	130
United Kingdom	24	0	24	-141	22	17
Greece	89	0	31	154	43	41
Ireland	207	0	25	136	35	35
Italy	280	0	104	659	157	167
Netherlands	55	0	47	293	72	80
Portugal	326	0	36	199	51	50
Sweden	1	0	0	-19	-1	0
Baltic States	0	0	-83	-550	-122	-123
Czech Republic	0	0	-98	-679	-145	-144
Hungary	0	0	-7	-77	-12	-12
Poland	0	0	-86	-726	-134	-137
Slovakia	0	0	-16	-111	-23	-22
Rest of Europe	510	0	138	548	178	159
All	11193	0	284	1427	440	334

* Rest of Former Soviet Union (without Russia and the Baltic States).

There are two major determinants in our partial equilibrium framework for the country-specific compliance cost. Firstly, the effective reduction requirement a country has to fulfill as compared to its reference emission level (here: BaU emissions in 2010). The column *NTr* in Table 3 indicates the effective reduction requirement for each region under the Kyoto Protocol. The higher the effective reduction requirement the higher are ceteris paribus the associated compliance costs. Secondly, the ease of carbon abatement is captured by the shape of the marginal abatement cost curves. The steeper the marginal abatement costs the more costly a given reduction becomes ceteris paribus. Japan and Canada stand out for rather high costs due to high effective reduction targets as well as difficulties to substitute away from carbon. Countries committed under the Kyoto regime with zero compliance costs under *NTr* do not face a binding emission target, i.e. they typically dispose of hot air. Countries with hot air mainly comprise the new EU accession states (Baltic States, Czech Republic, Hungary, Poland, Slovakia) as well as Russia and the XSU region. In total, emission reduction under *NTr* amounts to 11% vis-à-vis the BaU for all countries complying to Kyoto.

Table 3: Emission Reduction in per cent of BaU Emissions (2010)

	NTr	*Kyoto-C*	*Kyoto*	*EU-Closed*	*EU-NDIR-Tr*	*EU-RUS*
Russia	0	0	0	0	0	0
XSU*	0	0	3.8	3.6	5.7	5.7
Canada	34.7	0	2.4	2.3	3.4	3.4
Japan	23.2	0	3.4	3.2	4.8	4.8
European Union	10.9	0	4.2	8.0	4.6	3.1
Austria	21.0	0	3.7	8.0	4.1	2.9
Belgium	12.4	0	11.8	17.6	12.6	6.9
Germany	9.5	0	3.9	7.5	4.3	3.0
Denmark	10.5	0	3.8	6.1	4.1	2.6
Spain	22.5	0	3.1	6.0	3.4	2.3
Finland	0	0	5.9	9.0	6.3	4.0
France	12.9	0	2.5	6.9	2.9	2.3
United Kingdom	4.1	0	3.8	8.8	4.3	3.2
Greece	15.8	0	3.2	5.3	3.4	2.2
Ireland	27.8	0	4.1	7.3	4.4	3.2
Italy	13.5	0	3.1	6.0	3.4	2.3
Netherlands	17.4	0	9.3	14.1	9.9	5.5
Portugal	27.1	0	3.1	5.3	3.4	2.4
Sweden	2.5	0	5.0	9.1	5.5	3.7
Baltic States	0	0	3.7	7.8	4.2	3.0
Czech Republic	0	0	8.4	14.4	9.1	5.9
Hungary	0	0	4.3	8.9	4.8	3.3
Poland	0	0	5.5	10.8	6.2	4.3
Slovakia	0	0	9.7	13.7	10.2	5.8
Rest of Europe	14.6	0	2.5	4.5	2.7	1.8
All	11.0	0	3.1	4.8	3.8	3.0

* Rest of Former Soviet Union (without Russia and the Baltic States).

Under competitive Annex B emissions trading (scenario *Kyoto-C*), the permit price equals zero, since the amount of hot air exceeds the total amount of the emission reduction requirements. Consequently, the total as well as country-specific compliance costs for meeting the Kyoto targets are zero, i.e. total gains from trade amount to about 11000 m $US. However, there is no emission reduction at all with respect to BaU, i.e. Kyoto boils down to business-as-usual. Annex B emissions in 2010 remain unchanged. Therefore, this scenario reproduces insights from earlier analysis in the literature (see, e.g., Böhringer (2002), Klepper and Peterson (2005)).

Under monopoly power in scenario *Kyoto*, Russia exerts market power by rationing hot air to maximize net revenues. Russia sells 246 $MtCO_2$, i.e. 40% of its hot air (see Table 5). Although environmental effectiveness is no longer zero, total emission reduction amounts to only 3.1% of aggregate BaU emissions, i.e. the environmental effectiveness falls by more than 70% as compared to purely domestic Kyoto implementation. The CO_2 value per ton amounts to 2.1 $US (see Table 4). Compared to *NTr*, the scenario *Kyoto* is on the one hand more cost-efficient since – except for Russia with marginal abatement costs of zero – marginal values of carbon dioxide across all competitive regions are equalized. On the other hand, rationing of hot air by Russia induces some excess costs as compared to a truly competitive situation.[6] The monopolistic profit of Russia amounts to 511 m $US. Note, that in our simulations all other hot air regions such as XSU are assumed to fully supply their hot air. This “free ride” on the monopoly price caused by Russian strategic behavior leads to net gains of about 733 m $US for XSU which are in this case higher than those for Russia. At this point, it is left to future studies to examine potential collusion between different countries supplying hot air.[7]

[6] See Böhringer and Löschel (2003) and Klepper and Peterson (2005) for a detailed discussion of market power in international emissions trading under the existence of hot air.

[7] As noted in the introduction, we do not consider collusive behavior of Russia with XSU as a realistic policy option, since XSU consists of 11 politically heterogeneous countries. See Löschel and Zhang (2002) for an approach to model strategic behavior of two regions in international climate policy.

Table 4: Marginal Abatement Cost in $US (2001) per ton CO_2

	NTr	*Kyoto-C*	*Kyoto*	*EU-Closed*		*EU-NDIR-Tr*		*EU-RUS*	
				NDIR	DIR	NDIR	DIR	NDIR	DIR
Russia	0	0	0	0	0	0	0	0	0
XSU*	0	0	2.1	1.9	1.9	3.0	3.0	3.0	3.0
Canada	61.5	0	2.1	1.9	1.9	3.0	3.0	3.0	3.0
Japan	23.0	0	2.1	1.9	1.9	3.0	3.0	3.0	3.0
European Union**	0-46.9	0	2.1	13.2	2.1	3.0	2.1	3.0	1.2

* Rest of Former Soviet Union (without Russia and the Baltic States).

** Austria: 16.1, Belgium: 2.1, Germany: 5.4, Denmark: 6.5, Spain: 23.6, Finland: 0, France: 13.3, United Kingdom: 2.3, Greece: 11.0, Ireland: 43.6, Italy: 10.7, Netherlands: 3.1, Portugal: 46.9, Sweden: 1.1, Baltic States, Czech Republic, Hungary, Poland, Slovakia: 0, Rest of Europe: 15.9.

For scenario *EU-Closed* which captures the hybrid regulation scheme under the EU ETS in Europe we obtain three carbon markets. Firstly, the EU ETS market that applies to emission-intensive DIR sectors within the EU. Secondly, the carbon market within the EU for NDIR sectors which – in this scenario – are not eligible for international emissions trading and thirdly, the carbon market for all non-EU Kyoto parties. Due to the withdrawal of the EU from the international emissions trading market the price for permits is lower compared to scenario *Kyoto*. Canada and Japan, the two remaining actors on the demand side in this scenario, are the beneficiaries of the price decrease. Russia is now able to sell only 92 $MtCO_2$ of its hot air, i.e. the Russian profits decrease considerably compared to scenario *Kyoto*. Compliance costs for the EU amount to about 1300 m $US and are substantially higher than under scenario *Kyoto*. Aggregate emission reduction for all Kyoto parties amounts to 4.8% due to higher abatement efforts by the EU.

In the scenario *EU-NDIR-Tr* the EU Member States are able to cover permit demand for their NDIR sectors also from the Kyoto market. Because of the additional demand the permit price on the Kyoto market increases compared to scenario *EU-Closed* from 1.9 to 3.0 $US per ton CO_2. The Kyoto market access is quite profitable for EU member states as they reduce the total compliance costs compared to *EU-Closed* by 680 m $US, i.e. roughly by 50% compared to *EU-Closed*. These savings correspond to a decline of marginal abatement costs for the EU NDIR sectors from 13.2 to 3.0 $US per ton CO_2. However, due to the increased amount of Russian hot air sold, the environmental effectiveness is diminished if the NDIR sectors are allowed to trade on the international market. Russia now sells 185 $MtCO_2$ hot air instead of only 92 $MtCO_2$ in scenario *EU-Closed*.

Table 5: Hot Air Supply by Russia

		Kyoto	*EU-Closed*	*EU-NDIR-Tr*	*EU-RUS*
in $MtCO_2$	Kyoto market	246	92	185	185
in $MtCO_2$	EU ETS	--	--	--	65
in % of total hot air	Share	40	15	30	41

Under scenario *EU-RUS*, Russia can sell hot air either to the Kyoto market or to the DIR sectors within the EU ETS. In order to maximize net revenues from selling in both markets, Russia realizes a higher price (3.0 $US) in the Kyoto market than in the EU ETS (1.2 $US). This indicates that the (point) elasticity of demand in the Kyoto market is lower than in the EU ETS (see Appendix). From the Russian point of view, this price discrimination is favorable as Russian profits increase from scenario *EU-NDIR-Tr* to *EU-RUS* by about 70 m $US respectively 13%. Therefore, our results indicate that Russia indeed has an incentive to join the EU ETS as the country is then able to realize market power in two separated permit markets. The use of hot air for the DIR sectors is also profitable from the European perspective, since the EU compliance costs are further reduced compared to a situation where the EU ETS is not linked to the Kyoto market. However, from an environmental point of view the Russian participation on the EU ETS leads to a further deterioration because of the higher amount of hot air which flows into the EU (additional 65 $MtCO_2$ compared to *EU-NDIR-Tr*) and the corresponding lower permit price in the EU ETS which reduces total abatement in this market.

6. Conclusions

Our simulation shows that the market design of the future international permit trading regime has a strong influence on the economic and environmental effects of the Kyoto Protocol. In particular, we identify two elements of the market structure – the linkage of different permit markets and the strategic behavior of Russia – which seem important for an evaluation of any future regime. Given a competitive market, Russian hot air is sufficient to make the Kyoto constraint non-binding. However, because of its large amount of hot air Russia is the dominant supplier of permits in any future permit market and may exert market power, i.e. influence the permit price. Note, that this point has been made before in the literature. The innovative contribution of this paper consists of the consideration of the EU ETS under Russian market power within the framework of the Kyoto Protocol.

We find that Russia will have incentives to join the EU ETS if the latter is separated from the Kyoto international emissions market. In this case, Russia can exert monopolistic price discrimination between two separated markets thereby maximizing revenues from hot air sales. The EU will be able to substantially reduce compliance costs if it does not restrain itself to EU-internal emission regulation schemes. However, part of the gains from extra-EU emissions trading will come at the expense of environmental effectiveness as (more) hot air will be drawn in.

Finally, the allocation of permits between DIR and NDIR sectors within the EU critically influences Russia's potential gains from joining the EU trading scheme. The possible price discrimination by Russia due to the separation of the Kyoto market and the EU ETS may therefore have implications for the future design of national allocation plans in Europe. This detail of the interaction between institutional framework and market structure in international climate policy remains a topic for future research.

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Appendix: Algebraic Model Formulation

This section provides an algebraic summary of the partial equilibrium model for permit trade underlying the simulations above. 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. Third, we lay out the set-up for the case of monopolistic permit supply in one market and – finally – in two separated markets.

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 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 ($q_i > 0$) or sold ($q_i < 0$) on the market may not exceed the emission target k_i:

$$\min_{q_i} C_i\left(\bar{e}_i - e_i\right) + P \cdot q_i$$

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

where

C_i	denotes the abatement cost function for reducing carbon emissions,
$\bar{e}_i$	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 conditions for the cost minimization problem is given by

$$C_i^{'}\left(\bar{e}_i - e_i\right) = P \ .$$

In the optimum, the price taking countries abate emissions up to a level where their marginal abatement costs ($C_i^{'}$) 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 ($q_i < 0$):

$$\min_{q_i} C_i\left(h_i + \bar{e}_i - e_i\right) + P \cdot q_i$$

$$\text{s.t.} \qquad e_i = k_i + q_i .$$

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

$$k_i = h_i + \bar{e}_i .$$

The first order condition yields:

$$C_i^{'}\left(h_i + \bar{e}_i - e_i\right) = P .$$

The existence of hot air does not change the costs-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 trading.

Monopolistic permit supply in one market

Monopolistic permit supply is characterized as a situation where one country (denoted “m”) – in our case the hot air country Russia – 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 abatement costs equal the permit price of the market, i.e.

$$C_f^{'}\left(h_f + \bar{e}_f - e_f\right) = P .$$

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

$$Q_F(P) = \sum_f q_f(P).$$

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

$$\min_{q_m} C_m(h_m + \bar{e}_m - e_m) + P \cdot q_m$$

$$\text{s.t.} \qquad e_m = k_m + q_m$$

$$P = P(Q_F)$$

where P is the inverse demand function of the fringe countries. The first order conditions of the costs minimization problem indicate that the monopolist sets marginal abatement costs equal to marginal revenue:

$$C_m^{'}(h_m + \bar{e}_m - e_m) = P - P^{'}(Q_F) \cdot q_m .$$

Marginal abatement costs are accordingly not equalized between the fringe countries and the monopolists, resulting in overall efficiency losses due to market power.

Monopolistic permit supply in two markets

Monopolistic permit supply in scenario *EU-RUS* is characterized as a situation where one country (denoted "m") – in our case the hot air country Russia – has supply power in two separated permit markets.[8] All other countries, denoted as fringe "f1" in market 1 and "f2" in market 2 behave as price takers. The fringe countries minimize their compliance costs given the permit price set by the monopolist. They emit carbon until the marginal abatement costs equal the permit price of the corresponding market, i.e.

$$C_{f1}^{'}(h_{f1} + \bar{e}_{f1} - e_{f1}) = P_1 \qquad \text{and} \qquad C_{f2}^{'}(h_{f2} + \bar{e}_{f2} - e_{f2}) = P_2 .$$

The aggregate demand of the fringe in both markets, which are in total net importers of permits, is

$$Q_{F1}(P_1) = \sum_{f1} q_{f1}(P_1) \quad \text{and} \qquad Q_{F2}(P_2) = \sum_{f2} q_{f2}(P_2).$$

The monopolist sets its permit supply in both markets ($q_{m1} < 0$ and $q_{m2} < 0$) to minimize abatement costs minus income from permit sales:

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[8] See Varian (1989).

$$\min_{q_{m1}, q_{m2}} C_m\left(h_m + \bar{e}_m - e_m\right) + P_1 \cdot q_{m1} + P_2 \cdot q_{m2}$$

$$\begin{aligned} \text{s.t.} \qquad & e_m = k_m + q_m \\ & q_m = q_{m1} + q_{m2} \\ & P_1 = P_1\left(Q_{F1}\right) \\ & P_2 = P_2\left(Q_{F2}\right), \end{aligned}$$

where P_1 and P_2 are the inverse demand functions of the fringe countries in market 1 and 2. The first order conditions of the costs minimization problem indicate that the monopolist sets marginal abatement costs equal to marginal revenue in both markets:

$$C_m^{'}\left(h_m + \bar{e}_m - e_m\right) = P_1 - P_1^{'}\left(Q_{F1}\right) \cdot q_{m1} \quad \text{and} \quad C_m^{'}\left(h_m + \bar{e}_m - e_m\right) = P_2 - P_2^{'}\left(Q_{F2}\right) \cdot q_{m2} \, .$$

Let $|\varepsilon_1|$ and $|\varepsilon_2|$ be the elasticity of demand in market 1 and 2, we can write these expressions as

$$C_m^{'}\left(h_m + \bar{e}_m - e_m\right) = P_1 \cdot \left[1 - \frac{1}{|\varepsilon_1|}\right] \quad \text{and} \quad C_m^{'}\left(h_m + \bar{e}_m - e_m\right) = P_2 \cdot \left[1 - \frac{1}{|\varepsilon_2|}\right].$$

It follows that $P_1 > P_2$ if and only if $|\varepsilon_1| < |\varepsilon_2|$. Hence, the market with the more inelastic demand – the market that is less price sensitive – is charged the higher price.

Table 6: Coefficients for Marginal Abatement Curves

	DIR sectors			NDIR sectors		
	$\alpha_{1,i}$	$\alpha_{2,i}$	$\alpha_{3,i}$	$\alpha_{1,i}$	$\alpha_{2,i}$	$\alpha_{3,i}$
RUS	0.6034	-0.0008	0.0001	3.9461	-0.0244	0.0011
XSU	1.1282	-0.0204	0.0006	2.3060	0.0243	0.0012
CAN	2.6176	0.0386	0.0019	4.3542	0.0953	0.0007
JPN	0.7733	0.0040	0.0001	3.9321	0.0527	0.0004
AUT	16.4489	1.0866	0.8126	44.8074	10.0505	2.0624
BEL	3.3541	-0.3797	0.0242	17.0792	1.9634	0.2285
DEU	1.0853	0.0043	0.0001	3.4134	0.1617	-0.0019
DNK	18.6304	-1.6119	3.2171	95.9893	115.7542	-33.8785
FIN	10.2283	0.1559	0.3571	72.2584	28.4968	14.0868
FRA	4.4582	0.0898	0.0108	6.5645	0.2509	0.0005
GBR	1.9926	0.0273	0.0010	4.2733	0.1158	0.0021
GRC	9.7133	-0.1708	0.0748	58.5566	8.8027	2.7891
IRL	10.3267	15.2168	4.9583	83.8419	25.5878	6.9464
ITA	2.4653	0.0412	0.0016	10.7892	0.3566	0.0110
NLD	2.4859	-0.1555	0.0031	16.1308	0.5764	0.0952
PRT	17.5205	2.0198	1.9669	26.8714	122.9196	-42.7560
ESP	3.5267	0.0676	0.0092	14.8199	0.6169	0.0198
SWE	13.0939	-1.0617	1.0209	49.3104	18.7495	3.3653
BAL	30.2165	-10.4277	6.1301	59.0840	21.4185	43.1309
CZE	4.2692	-0.2478	0.0320	18.7241	-1.0535	1.5116
HUN	13.3728	-0.2222	1.0389	42.8616	5.6833	2.9371
POL	2.3028	-0.0033	0.0021	7.1590	0.1783	0.0517
SVK	9.2117	-2.3174	0.7331	72.9121	24.0981	11.4548
XEU	2.7258	-0.0073	0.0042	12.2751	0.5652	0.0290

RUS: Russia, XSU: Rest of Former Soviet Union (without Russia and the Baltic States), CAN: Canada, JPN: Japan, AUT: Austria, BEL: Belgium, DNK: Denmark, FIN: Finland, FRA: France, DEU: Germany, GBR: United Kingdom, GRC: Greece, IRL: Ireland, ITA: Italy, NLD: Netherlands, PRT: Portugal, ESP: Spain, SWE: Sweden, BAL: Baltic States, CZE: Czech Republic, HUN: Hungary, POL: Poland, SVK: Slovakia, XEU: Rest of Europe.