Cooling down hot air: a global CGE analysis of post-Kyoto carbon abatement strategies

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Abstract

The Kyoto Protocol marks a break through in global warming mitigation policies as it sets legally binding emissions targets for major emitting regions. However, realization of the Protocol depends on the clarification of several issues, one of which is the permissible scope of international emissions trading between signatory countries. Unrestricted trade produces hot air when signatory countries, whose Kyoto targets are well above their business as usual emissions, trade in larger amounts of "abundant" emission rights. Concerns on hot air motivated proposals for caps on emissions trading by the EU. These caps are strictly refused by the USA and other non-European industrialized countries who want to exploit the full efficiency gains from trade. In this paper we show that there are "cooling down" strategies which can reconcile both positions. International permit trade provides enough efficiency gains to make all signatory countries better off than they would be without permit trade while mitigating hot air. In other words, part of the efficiency gains from free trade could be used to pay for higher abatement targets of signatory countries which assure the same environmental effectiveness as compared to strictly domestic action or restricted permit trade. © 2000 Elsevier Science Ltd. All rights reserved.

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1. Introduction

The Kyoto Protocol constitutes a milestone in global warming mitigation policies. For the first time, major emitting regions the so-called Annex B countries committed themselves to legally binding quantified greenhouse gas emissions limitation and reduction objectives. However, national parliaments of several Annex B countries joined within the so-called UMBRELLA group[1] have put acceptance of the Kyoto Protocol under condition that emissions trading among signatory countries can be used as a flexible mechanism to meet national reduction targets. This stipulation has a clear economic rationale. Emissions trading allows to exploit differentials in marginal costs of emissions reduction across countries which may significantly reduce the total costs of meeting accumulated reduction targets as compared to strictly domestic policy measures. Nevertheless, the scope and institutional design of tradable permit systems is highly disputed among signatory parties. Opponents of emissions trading systems, such as the EU and its associates[2], refer to potential loopholes. International trade in permit rights may lead to an effective increase of global emissions when signatory countries whose baseline emissions are below their Kyoto entitlements sell large amounts of their abundant emission rights. This phenomenon has been referred to as *hot air* (Herold, 1998; Greenpeace, 1998). It is particularly relevant for the Russian Federation and Ukraine where projected emissions for the Kyoto budget period are well below the assigned amount of emission rights due to the breakdown of domestic economies.

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[1] The key protagonists of free emissions trading include the USA, Japan, Australia, Canada, Iceland, New Zealand, Norway, Ukraine and the Russian Federation.

[2] EU associates include Czech Republic, Slovakia, Croatia, Lettland, Switzerland, Slovenia, Poland and Bulgaria.

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In order to mitigate hot air, the EU and its associates stress the principle of supplementarity and call for restrictive ceilings on the amount of tradable emissions (Baron *et al.*, 1999).[3] The UMBRELLA group, on the other hand, is not willing to forego potential efficiency losses from trade restrictions and has already indicated strong resistance to any ceiling plans. As the realization of the Kyoto Protocol depends crucially on the ratification by the UMBRELLA group — in particular the US — a solution to the hot air issue seems to be rather crucial for an effective climate protection policy.

In this paper we analyze alternative ways to mitigate hot air without giving up efficiency gains from trade in emission rights. The key idea is that signatory countries, under a system of internationally tradable permits, adopt more stringent emission reduction targets as imposed by the Kyoto Protocol to offset hot air which is excluded by strictly domestic abatement policies. We show that this strategy of *cooling down* hot air provides a cost-effective, Pareto-superior solution to all signatory countries as compared to abatement policies which partially or fully restrict international trade in emission rights. Our quantitative analysis is based on a large-scale CGE model of the world economy.

The remainder of the paper is as follows. In Section 2 we provide some background information on the post-Kyoto climate change policy discussions. In Section 3 we lay out the modeling framework and baseline parameterization. In Section 4 we present our scenarios and discuss the computational results. In Section 5 we summarize and conclude.

2. Policy background

The Kyoto Protocol to the *United Framework Convention on Climate Change* (UNFCCC, 1997) fixes legally binding quantified greenhouse gas emissions limitation and reduction objectives (QELROs) for Annex B parties. On average, Annex B parties have committed themselves to reduce greenhouse gas emissions by 5.2% from 1990 levels in the budget period 2008-2012. Table 1 indicates the commitments for the industrialized countries or regions as represented in our modeling framework.

The developing countries have refused, so far, any abatement commitment, mainly because they fear negative effects of emissions limitation on their economic development. Also, before committing themselves to reduction targets, they demand primary action by the developed world with large historical emissions.

Table 1
Quantified emissions limits under the Kyoto Protocol (Baron et al., 1999)

Annex B country or region	Commitments (in % of base year emissions)
United States of America	93
Canada	94
European Union (incl. EU associates)	91.9
Japan	94
Former Soviet Union (Russian Federation and Ukraine)	100
Other OECD (Australia and New Zealand)	107.3

During the Kyoto conference the UMBRELLA group declared agreement on emissions trading as an indispensable element of any protocol. Due to their pressure, emissions trading between signatory countries is now one of the flexible mechanisms[4] introduced by the Kyoto Protocol. The rules for emissions trading are vague, though, and remain to be defined.[5] With respect to the scope of tradable permits the Kyoto Protocol states that any trading shall be "supplemental" to domestic action for the purpose of meeting the obligations. The principle of supplementarity was inserted mainly due to concerns of the European Union on hot air. Hot air increases the effective emissions associated with the Kyoto Protocol as parties with actual emissions below target levels can trade their abundant emission rights. This will be particularly relevant for the Russian Federation and Ukraine where projected emissions are well below the Kyoto entitlements as the consequence of a severe economic decline after transformation to market economies.[6] Estimates of hot air range between an amount of 500-650 million tons of CO_2 which corresponds to 70-90% of the total Annex B reduction commitment (Herold, 1998).

In May 1999 the EU Council of Ministers issued a concrete proposal with restrictive caps on the share of emissions reductions a country might obtain through the use of the Kyoto Protocol's flexible mechanisms (Baron et al., 1999). This proposal faces stiff resistance, however, by the UMBRELLA group, in particular the USA, which prefer no limits to emissions trading at all (Loy, 1999).

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[3] Other critical aspects of emissions trading which we do not further discuss here include the certification, verification and the monitoring of emission reduction as well as the establishment of credible compliance mechanisms.

[4] Other mechanisms of cooperative implementation include the clean development mechanism (CDM) and joint implementation (JI).

[5] Unresolved issues are, inter alia, the time when trading might start, the definition of participants and gases that might be traded, the establishment of the rules and procedures for trading, the institutional set-up and the regulations regarding monitoring, verification and ultimately enforcement of the rules.

[6] Another moral justification for supplementarity has been to limit the possibility for countries to "buy themselves out" of their obligations. Clearly, this argument contradicts basic principles of welfare economics.

Table 2
Overview of sectors and countries/regions (Data base: GTAP 4, McDougall, 1997)

Sectors		Regions	
COL	Coal	USA	United States
CRU	Crude oil	CAN	Canada
GAS	Natural gas	EUR	Europe
ROP	Refined oil products	JPN	Japan
ELE	Electricity	OOE	Other OECD (Australia and New Zealand)
EIS	Energy-intensive sectors	FSU	Former Soviet Union
Y	Manufactures and services	CHN	China
		IND	India
		ASI	Other Asia
		MPC	Mexico and OPEC
		ROW	Rest of World

The policy background as described above reveals the need for strategies that reconcile both positions, i.e. mitigate hot air but at the same time exploit the efficiency gains from tradable emission permits. In our simulations below we show that it is indeed possible to cool down hot air and nevertheless make all signatory countries better off through emissions trading.

3. Analytical framework and baseline calibration

For our analysis we use a 7-sector, 11-region general equilibrium model of the world economy. The choice of sectors captures key dimensions in the analysis of carbon abatement such as differences in carbon intensities and the scope for substitutability across energy goods and carbon-intensive non-energy goods. The regional aggregation covers the Annex-B parties as well as major non-Annex-B regions, which are central to the greenhouse gas issue. Table 2 summarizes the sectors and regions incorporated in our model. We provide an algebraic documentation of the model in the appendix.

The economic effects of the Kyoto Protocol depend crucially on the extent to which QELROs bind the economies in the budget period. In other words, the magnitude and distribution of costs associated with the implementation of future emission constraints depend on the Business-as-Usual (*BAU*) projections for GDP, fuel prices, energy efficiency improvements, etc. In our comparative-static framework we infer the BAU structure of the model's regions for 2010 using most recent projections on the economic development. We then measure the costs of abatement relative to that baseline. As a starting point for our forward projection we use the GTAP 4 database (McDougall, 1997) and OECD/IEA energy statistics (IEA, 1996) for 1995 which is the most recent year for which a complete set of statistics is available.[7] We use the reconciliated benchmark data for this year to calibrate parameters of the CES functional forms from a given set of quantities and prices (given exogenous elasticities). In a second step we do the forward calibration of the 1995 economies to 2010 incorporating exogenous information by the US Department of Energy (DOE, 1998) for GDP growth, energy demand and future energy prices. The fossil fuel production functions are finally calibrated to be consistent with exogenous price elasticities of supply.

A typical shortcoming of the comparative-static approach is the rudimentary representation of how policy interference affects investment decisions. In our abatement scenarios we keep investment at the *BAU* level and ignore potentially important impacts of carbon abatement on the level and pattern of investment across countries. Our analytical framework provides rather conservative estimates of the cost of abatement because we would expect that carbon emission limits will reduce the return to capital and result in lower overall investment and GDP growth (see e.g. Böhringer and Rutherford, 2000).

4. Policy scenarios and numerical results

4.1. *Policy scenarios*

The two initial simulations address the question to what extent international permit trade between Annex B countries produces hot air as compared to strictly domestic abatement:

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[7] See Babiker and Rutherford (1997) for the assembly and reconciliation of these data sources.

(*NTR*) Annex B countries can trade emission rights as allocated by the Kyoto Protocol only within domestic borders. There is no international trade in permit rights.

(*HOT*) Emissions trading among Annex B countries assures that the Kyoto targets are met in a more cost-efficient way than with *NTR*. However, permit trade produces higher emission levels (hot air) when countries that do not make full use of their emission budget under *NTR* sell off abundant emission rights in the international market.

We then investigate the efficiency implications of two alternative strategies that achieve the same global emission level as *NTR* while allowing for unrestricted trade in permits. We endogenously adjust emissions of OECD regions (USA, CAN, EUR, JPN, OOE) to keep global emission equal to the *NTR* emission level. This means that OECD countries commit themselves to the global emission target associated with *NTR* rather than just complying with specific Kyoto targets. We distinguish two variants for endogenously scaling OECD emissions entitlements[8] to cool down hot air emerging from permit trade:

(*UNI_NTR*) QELROs of OECD countries are uniformly scaled across OECD countries to assure that global emissions do not exceed the *NTR* emission level.

(*EQU_NTR*) QELROs of OECD countries are endogenously scaled (i) to assure that the *NTR* emission level is kept, and (ii) to equalize the welfare gains from permit trade across OECD countries in percentage Hicksian equivalent variation of *NTR* income.

How does the endogenous benefit sharing rule work? We cardinalize utility based on a homothetic separable social welfare function $W = \sum_r W_r$ where W_r is the welfare index of region r. The welfare impact on region r is measured by changes in $W_r = U_r^{1-\rho}/(1-\rho)$ where the parameter ρ reflects the degree of aversion to inequality in utilities and U_r is a linearly homogeneous consumption welfare index (Atkinson, 1970; Boadway and Bruce, 1984, Layard and Walters, 1978). In the simulations with endogenous benefit sharing we impose that

$$W_r^{1-\rho}/(1-\rho) - \bar{W}_r^{1-\rho}/(1-\rho) = \Delta W^{OECD}$$

and determine allocations of emission rights for OECD countries endogenously such that the efficiency gains from trade are shared "equally" across trading partners. $\bar{W}_r$ is the reference welfare level of region r for the *NTR* reference scenario. We set ρ equal to 1 which implies that efficiency gains from trade for the OECD country group are distributed to equalize the percentage Hicksian equivalent variation in income of OECD countries with respect to their *NTR* income levels.[9]

The final set of three policy simulations deals with the EU proposal for emission ceilings. First, we investigate the efficiency and emission implications of caps on permit trade as suggested by the EU Council of Environment (Baron et al., 1999):

(*CAP*) Purchases or sales of emissions by Annex B countries may not exceed 5% of the weighted average of base year emissions and the assigned Kyoto emission budget.

We then quantify the potential efficiency gains from full trade while achieving the same level of global emissions as with *CAP* using our two alternative scaling procedures:

(*UNI_CAP*) QELROs of OECD countries are uniformly scaled across OECD countries to assure that global emissions do not exceed the CAP emission level.

(*EQU_CAP*) QELROs of OECD countries are endogenously scaled (i) to assure that the *CAP* emission level is kept, and (ii) to equalize the welfare gains from permit trade across OECD countries in percentage Hicksian equivalent variation of *CAP* income.

Our comparative-static model measures the costs of implementing Kyoto as compared to a Business-as-Usual reference point (*BAU*) in 2010 where no abatement requirements exist.

For all abatement simulations we assume that revenues from permit sales accrue lump-sum to the representative agent in each region. In our exposition of results marginal abatement costs can be interpreted as the price of emission permits which are either traded domestically (*NTR*) or internationally (other cases).

4.2. Results

4.2.1. Emission reduction requirements and marginal abatement costs under NTR

To understand the potential for efficiency gains from permit trade we first investigate the differences in marginal abatement costs across Annex B countries for the scenario *NTR* where permits are not tradable at the international level. Table 3 reports the marginal abatement costs associated with the implementation of the Kyoto targets through strictly domestic action. There are large differences in marginal abatement costs across

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[8] The alternative assumption is to include also the Former Soviet Union into the scaling mechanism (see Table 5).

[9] Note that when $\rho = 1$, W_r takes on the form $\ln U_r$.

Table 3
Effective emission cutback requirements and marginal abatement costs in 2010

	Cutback requirement[a]	Marginal abatement costs[b]
CAN	27.48	62.65
EUR	10.72	19.02
JPN	25.99	81.65
OOE	15.63	20.41
USA	27.47	43.55
FSU	– 48.33	—

[a] In % from *BAU*.
[b] In $US per ton of CO_2.

Annex B countries indicating substantial efficiency gains from permit trade. Marginal abatement costs range between zero for FSU and 82 $US per metric ton of CO_2 for JPN. The magnitude of marginal costs depends inter alia on the level of abatement. The further out we are on the abatement cost curve the more costly it gets — ceteris paribus — to substitute away from carbon in production and consumption. Table 3 summarizes the abatement levels for the various Annex B countries. Note that the Kyoto targets which appear modest with respect to 1990 emission levels translate into much higher *effective* cutback requirements for OECD countries with respect to their *BAU* emission levels in 2010. OOE, for example, is allowed to *increase* emissions by 7% over 1990 levels under the Kyoto Protocol; nevertheless, this implies an obligatory *decrease* of more than 15% in its *BAU* emissions by 2010. Apart from the abatement level the marginal abatement costs depend on differences in carbon intensity for different sectors across countries. These differences explain, for example, why JPN faces much higher marginal abatement costs as compared to USA in order to achieve an almost identical relative cutback of carbon emissions. JPN uses relatively little carbon in sectors with low-cost substitution possibilities, in particular electricity generation (due to nuclear power). As a consequence JPN has to cut back relatively more emissions in other sectors such as traffic where abatement comes more costly.

Table 3 also reveals that FSU is far off from facing a binding carbon constraint. While FSU has committed to stabilize its emissions in the budget period at 1990 emission levels, its *BAU* emissions in 2010 are far below the Kyoto target. The main reason for the drop in emissions to below 1990 levels is the decline in economic activity (particularly in emission-intensive industries) after the transformation of FSU to market economies. Having no abatement costs at all under *NTR* we can safely project that FSU will be a seller of permit rights in a tradable permit system for Annex B countries.

4.2.2. Unrestricted trade in permits: efficiency gains, hot air and cooling down strategies

Table 4 summarizes the changes in key economic indicators when we move from the *NTR* to policies which allow for unrestricted trade in permits among Annex B countries.

First of all, we see that Annex B trade in permits produces hot air with global carbon emissions increasing by 489 million tons of CO_2 as compared to *NTR* (see the difference between global emissions under *NTR* and *HOT* in Table 4A.). FSU sells a large amount of its formerly abundant emission rights and takes over domestic abatement. The pattern of permit trade is determined by the location of marginal abatement costs under *NTR* with respect to the equalized marginal abatement costs for tradable permits. Countries whose marginal abatement costs under *NTR* are below the uniform permit price will sell permits and abate more emissions. In turn, countries whose marginal abatement costs are above the uniform permit price rate will buy permits and abate less emissions. FSU is the sole seller of permit rights under *HOT* whereas the other Annex B countries are buyers. Nearly all Annex B countries benefit substantially from trade in permits. The one exception is EUR whose small welfare losses under *NTR* increase slightly due to negative terms of trade effects. The overall efficiency gains from permit trade are the composition of gains from equalized marginal abatement costs through trade *and* from a relaxation of the global emission constraint due to hot air. To measure the gains from international trade in permits as compared to the *NTR* scenario properly we have to fix the environmental target, i.e. global emission, at the *NTR* level. We do this in scenarios *EQU_NTR* and *UNI_NTR* where we endogenously scale the permit allocations of OECD countries to meet the *NTR* global emission level.

Efficiency gains from international trade provide the rationale for *cooling down* strategies: On average OECD countries should be willing to accept stricter abatement targets to mitigate hot air because they will nevertheless do significantly better than under *NTR*. However, at the single country level this general proposition might not work out due to negative terms of trade effects (see e.g. EUR in Table 4B.). We may have to scale permit allocations in a differentiated way to produce a Pareto-superior outcome for all trading partners. Scenario *EQU_NTR* reports such a scaling which assures that all OECD countries benefit equally in terms of HEV with respect to NTR. Cooling down hot air further increases the welfare gains for FSU which are already substantial under *HOT*. Permit prices under *UNI_NTR* and *EQU_NTR* go up implying larger revenues from permit sales for FSU.

The magnitude of benefits from trade for OECD countries and FSU will change significantly depending on whether FSU is included in the *trade-for-higher-targets* deal or not. If FSU is included, a major part of its gains

Table 4
Environmental and economic implications of alternative abatement strategies

	BAU	*NTR*	*HOT*	*UNI_NTR*	*EQU_NTR*
A. Global emissions (in billion tons of CO_2)					
	30.19	28.51	29.03	28.51	28.51
B. Welfare changes (in % HEV of BAU income)					
OECD		– 0.24	– 0.11	– 0.22	– 0.21
ANNEX B		– 0.25	– 0.04	– 0.09	– 0.09
NON ANNEX B	–	– 0.08	– 0.05	– 0.06	– 0.06
GLOBAL		– 0.20	– 0.04	– 0.08	– 0.08
CAN		– 0.87	– 0.45	– 0.76	– 0.85
EUR	—	– 0.01	– 0.03	– 0.08	0.01
JPN		– 0.30	– 0.05	– 0.11	– 0.28
OOE		– 0.65	– 0.38	– 0.61	– 0.63
USA		– 0.40	– 0.21	– 0.37	– 0.38
FSU		– 0.99	4.08	6.82	6.82
ASI	–	0.13	0.08	0.13	0.12
CHN	–	0.20	0.07	0.11	0.11
IND		0.27	0.11	0.17	0.17
MPC		– 0.94	– 0.46	– 0.68	– 0.68
ROW		– 0.01	– 0.01	– 0.01	
C. Marginal abatement costs (in $US per ton of CO_2)					
CAN		62.65	12.6	19.97	19.98
EUR		19.02	12.6	19.97	19.98
JPN		81.65	12.6	19.97	19.98
OOE	–	20.41	12.6	19.97	19.98
USA		43.55	12.6	19.97	19.98
FSU			12.6	19.97	19.98
D. Effective cut back requirement (wrt to 1990 emissions levels)					
CAN		0.94	0.94	0.87	0.81
EUR		0.92	0.92	0.85	0.96
JPN		0.94	0.94	0.87	0.52
OOE		1.07	1.07	1.00	0.98
USA		0.93	0.93	0.86	0.86
FSU		1.00	1.00	0.93	1.00

from permit sales will be re-distributed among OECD countries (see Table 5).

We see that abatement policies in the developed world produce non-negligible spill-overs to non-abating developing countries. In our static framework emission constraints for Annex B countries improve welfare for most developing countries except for fossil fuel exporters MPC and ROW. Secondary welfare changes in developing countries are directly related to terms of trade effects, i.e. changes in international market prices.[10]

The fall in fossil fuel prices due to reduced demands plays a major role for the magnitude and the sign of welfare changes from terms of trade effects. Regions which are net importers of fossil fuels gain, whereas regions which export fossil fuels lose.

In non-fossil fuel markets, where traded goods are differentiated by origin, developed countries are able to pass on part of their domestic abatement costs to non-abating developing countries. Apart from higher export prices of developed countries, developing countries might suffer from a *scale* effect as economic activity and hence import demand by developed countries decline. On the other hand, there is an opposite *substitution* effect as developing countries may gain market shares in import

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[10] Böhringer and Rutherford (1999) present a decomposition method that allows to separate terms of trade effects on different markets.

demand of trading partners because their exports become more competitive as compared to abating Annex B countries. Trade in permits appears to be welfare decreasing for most of the developing countries (except for MPC). The results that (i) abatement in Annex B countries produces welfare gains for most developing countries, and (ii) Annex B permit trade decreases those gains for most developing countries should be noted with some caution. Dynamic analysis (see e.g. Böhringer and Rutherford, 2000) which accounts for the negative impact of abatement on investment and hence future capital stocks, i.e. future consumption possibilities, indicates that welfare losses from abatement in developed countries are potentially underestimated in our static framework. As a consequence the negative spill-overs through international markets may dominate the positive spill-overs for developing countries, reversing some of our qualitative results.

Table 5
Environmental and economic implications of alternative abatement strategies

	Welfare[a]	Marginal costs[b]	Abatement[c]
CAN	– 0.69	19.77	0.92
EUR	0.17	19.77	1.13
JPN	– 0.12	19.77	0.83
OOE	– 0.47	19.77	1.09
USA	– 0.21	19.77	0.98
FSU	– 0.81	19.77	0.51
ASI	0.13		—
CHN	0.12	—	—
IND	0.18		—
MPC	– 0.76	—	—
ROW	– 0.02	—	—

[a] In HEV of BAU income.
[b] In $US per ton of CO_2.
[c] With respect to 1990 emission levels.

Table 6
Environmental and economic implications of EU cap strategy

	NTR	*HOT*	*CAP*	*UNI_CAP*	*EQU_CAP*
A. Global emissions (in billion tons of CO_2)					
	– 28.51	29.03	28.74	28.74	28.74
B. Welfare changes (in %HEV of BAU income)					
OECD	– 0.24	– 0.11	– 0.20	– 0.16	– 0.16
ANNEX B	– 0.25	– 0.04	– 0.17	– 0.06	– 0.06
NON ANNEX B	– 0.08	– 0.05	– 0.07	– 0.06	– 0.06
GLOBAL	– 0.20	– 0.04	– 0.15	– 0.06	– 0.06
CAN	– 0.87	– 0.45	– 0.72	– 0.61	– 0.68
EUR	– 0.01	– 0.03	– 0.03	– 0.05	0.01
JPN	– 0.30	– 0.05	– 0.17	– 0.08	– 0.13
OOE	– 0.65	– 0.38	– 0.58	– 0.50	– 0.54
USA	– 0.40	– 0.21	– 0.36	– 0.30	– 0.32
FSU	– 0.99	4.08	1.31	5.52	5.52
ASI	0.13	0.08	0.11	0.11	0.11
CHN	0.20	0.07	0.15	0.09	0.09
IND	0.27	0.11	0.21	0.14	0.14
MPC	– 0.94	– 0.46	– 0.74	– 0.58	– 0.58
ROW	– 0.01	– 0.01	– 0.02	– 0.01	– 0.01
C. Marginal abatement costs (in $US per ton of CO_2)					
CAN	62.65	12.6	38.90	16.54	16.55
EUR	19.02	12.6	27.86	16.54	16.55
JPN	81.65	12.6	45.18	16.54	16.55
OOE	20.41	12.6	27.86	16.54	16.55
USA	43.55	12.6	27.86	16.54	16.55
FSU		12.6		16.54	16.55
D. Effective cut back requirement (wrt to 1990 emissions levels)					
CAN	0.94	0.94	0.94	0.90	0.85
EUR	0.92	0.92	0.92	0.88	0.96
JPN	0.94	0.94	0.94	0.90	0.77
OOE	1.07	1.07	1.07	1.03	0.99
USA	0.93	0.93	0.93	0.89	0.87
FSU	1.00	1.00	1.00	0.96	1.00

4.2.3. The EU proposal: caps on trade

Apart from the questionable attempt to limit the "buy out" possibilities for Annex B countries the EU proposal for caps on permit sales and purchases aims primarily at mitigating hot air. As can be seen from Table 6 the EU proposal in fact reduces hot air substantially.

However, the ceilings imply a loss in economic efficiency as one cannot exploit lower cost abatement options across Annex B countries to the full extent possible. To materialize the efficiency gains associated with the EU proposal, we apply once again our cooling down strategies, taking the effective global emissions under *CAP* as the reference target, achieving the same level of environmental quality, i.e. emissions, as under *CAP* the efficiency losses of cooling down strategies is significantly below the loss from *CAP*.

5. Conclusions

Only recently, the EU and associated partners have proposed caps on emissions trading to mitigate hot air. These caps are strictly refused on behalf of the USA and other members of the so-called UMBRELLA group who want to exploit the full efficiency gains from trade. In this paper we have shown that there are cooling down strategies which can reconcile both positions. International permit trade provides enough sufficiency gains to make all Annex B countries better off than without permit trade while mitigating hot air. To put it differently, part of the efficiency gains from free trade could be used to pay for higher average abatement targets of signatory countries which assure the same environmental effectiveness as under strictly domestic action (*NTR*) or restricted trade (*CAP*).

Abstracting from lump-sum transfers we have determined initial permit allocations which imply an equitable sharing of efficiency gains across signatory countries.

Of course, our quantitative results will depend crucially on our baseline projections which determine the magnitude of hot air. When GDP (emission) projections for FSU are higher than in our baseline scenario, hot air in the context of the Kyoto Protocol becomes less important.

Yet, beyond the current debate on hot air under the Kyoto Protocol, it should be noted that, more generally, hot air is a problem of defining proper baselines. When regions negotiate emission baseline that lie beyond their *credibly* projected emissions, these regions are primary candidates for producing hot air in tradable permit systems. Obviously, the prospects for trade in permits provide a strong incentive for countries to overstate expected emissions. At the global level this entails the risk of driving up the world-wide emission level. In essence, the debate on hot air or baseline projections then boils down to the central issue of burden sharing. However, as indicated by our simulations, accepting exaggerated claims for emission rights and trying to avoid hot air through caps in trade may trigger significant efficiency losses. The world community will do much better to search for *fair* initial allocations of permits rights based on credible emissions projections that allow for free permit trade. The latter reduces the costs of emission abatement at the global level, while the former addresses the question how costs (cost savings) should be divided up. Our quantitative analysis of post-Kyoto abatement strategies hence provides an illustrative example of issues that are likely to play themselves out at the global level in the future when developing countries will have also to adopt emission constraints.

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Appendix A. Algebraic

This appendix provides an algebraic summary of the equilibrium conditions for our comparative-static model designed to investigate the economic implications of the Kyoto Protocol in 2010 as compared to a Business-as-Usual economic development where no carbon abatement policies apply. Before presenting the algebraic exposition we state our main assumptions and introduce the notation.

Nested separable constant elasticity of substitution (CES) functions characterize the use of inputs in production. All production exhibits non-increasing returns to scale. Goods are produced with capital, labor, energy and material (KLEM).

A representative agent (RA) in each region is endowed with three primary factors: natural resources (used for fossil fuel production), labor and capital. The RA maximizes utility from consumption of an CES composite which combines demands for energy and non-energy commodities. Supplies of labor, capital and natural resources are exogenous. Labor and capital are mobile within domestic borders but cannot move between regions; natural resources are sector specific.

All goods, except for coal and crude oil, are differentiated by region of origin. Constant elasticity of transformation functions (CET) characterize the differentiation of production between production for the domestic markets and the export markets. Regarding imports, nested CES functions characterize the choice between imported and domestic varieties of the same good (Armington). Crude oil and coal are imported and exported as homogeneous products.

Lump sum transfers of the RA finance the exogenous government demands in each region and the government transfers all revenues from carbon permits to the RA.

Table 7
Sets

i	Sectors and goods
j	Aliased with i
r	Regions
s	Aliased with r
EG	All energy goods: Coal, crude oil, refined oil, gas and electricity
FF	Primary fossil fuels: Coal, crude oil and gas
LQ	Liquid fuels: Crude oil, refined oil and gas
d	Demand categories: $Y =$ intermediate, $C =$ household and $I =$ investment

Table 8
Activity variables

Y_{ir}	Production in sector i and region r
E_{ir}	Aggregate energy input in sector i and region r
M_{ir}	Aggregate imports of good i and region r
A_{dir}	Armington aggregate for demand category d of good i in region r
I_r	Aggregate investment in region r
G_r	Aggregate public output in region r
C_r	Aggregate household consumption in region r
E_{Cr}	Aggregate household energy consumption in region r

Table 9
Price variables

p_{ir}	Output price of good i produced in region r for domestic market
p^X_{ir}	Price of aggregate energy in sector i and region r
p^E_{ir}	Price of aggregate energy in sector i and region r
p^M_{ir}	Import price aggregate for good i imported to region r
p^A_{dir}	Price of Armington aggregate for demand category d of good i in region r
p^I_r	Price of investment demand in region r
p^G_r	Price of government demand in region r
p^C_r	Price of aggregate household consumption in region r
p^E_{Cr}	Price of aggregate household energy consumption in region r
w_r	Wage rate in region r
v_r	Price of capital services in region r
q_{ir}	Rent to natural resources in region r ($i \in FF$)
$t^{CO_2}_r$	Price of CO_2 permit in region r

Two classes of conditions characterize the competitive equilibrium for our model: zero profit conditions and market clearance conditions. The former class determines activity levels and the latter determines price levels. In our algebraic exposition, the notation Π^z_{ir} is used to denote the profit function of sector j in region r where z is the name assigned to the associated production activity. Differentiating the profit function with respect to input and output prices provides compensated demand and supply coefficients (Shepard's lemma), which appear subsequently in the market clearance conditions. We use i (aliased with j) as index for commodities (sectors), r (aliased with s) as index for regions and d as index for the demand category ($d = Y$: intermediate demand, $d = C$: private household demand, $d = G$: investment demand, $d = I$: investment demand). The label EG represents the set of energy goods and the label FF denotes the subset of fossil fuels. Tables 7–12 explain the notations for variables and parameters employed within our algebraic exposition.

Table 10
Cost shares

θ^X_{ir}	Share of exports in sector i and region r
θ_{jir}	Share of intermediate good j in sector i and region r ($i \notin FF$)
θ^{KLE}_{ir}	Share of KLE aggregate in sector i and region r ($i \notin FF$)
θ^E_{ir}	Share of energy in the KLE aggregate of sector i and region r ($i \notin FF$)
α^T_{ir}	Share of labor ($T = L$) or capital ($T = K$) in sector i and region r ($i \notin FF$)
θ^Q_{ir}	Share of natural resources in sector i of region r ($i \in FF$)
θ^{FF}_{Tir}	Share of good i ($T = i$) or labor ($T = L$) or capital ($T = K$) in sector i and region r ($i \in FF$)
θ^{COA}_{ir}	Share of coal in energy demand by sector i in region r ($i \notin FF$)
θ^{ELE}_{ir}	Share of electricity in non-coal energy demand by sector i in region r
β_{jir}	Share of fossil fuel j in energy demand by sector i in region r ($i \notin FF$, $j \in LQ$)
θ^M_{isr}	Share of imports of good i from region s to region r
θ^A_{dir}	Share of domestic variety i in Armington aggregate for demand category d in region r
θ^I_{ir}	Share of good i in investment for region r
θ^G_r	Share of good i in government demand in region r
θ^E_{Cr}	Share of energy in aggregate household consumption in region r
γ_{ir}	Share of non-energy good i in non-energy household consumption demand in region r
$\theta^E_{ELE,C,r}$	Share of electricity in aggregate household energy consumption in region r
θ^E_{iCr}	Share of non-electric energy good i in the non-electric household energy consumption in region r

Table 11
Endowments and emissions coefficients

$\bar{L}_r$	Aggregate labor endowment for region r
$\bar{K}_r$	Aggregate capital endowment for region r
$\bar{Q}_{ir}$	Endowment of natural resource i for region r ($i \in FF$)
$\bar{G}_r$	Aggregate government demand in region r
$\bar{I}_r$	Aggregate investment demand in region r
$\bar{B}_r$	Balance of payment surplus in region r (*note*: $\sum_r \bar{B}_r = 0$)
$\overline{\mathrm{CO}}_{2r}$	Endowment of carbon emission rights in region r
a_{dir}^{carb}	Carbon emissions coefficient for fossil fuel i ($i \in FF$) in demand category d of region r

Table 12
Elasticities

η	Transformation between production for the domestic market and production for the export	4
σ_{KLE}	Substitution between energy and value-added in production (except fossil fuels)	0.3
σ_{FF}	Substitution between natural resources and other inputs in fossil fuel production calibrated consistently to exogenous supply elasticities μ_{FF}.	$\mu_{\mathrm{COA}} = 0.5$ $\mu_{\mathrm{CRU}} = 1.0$ $\mu_{\mathrm{GAS}} = 1.0$
σ_{COA}	Substitution between coal and the non-coal energy in production (except fossil fuels)	0.5
σ_{ELE}	Substitution between electricity and the non-coal fossil fuels in production (except fossil fuels)	0.3
σ_M	Substitution between imports from different regions	8
σ_A	Substitution between the import aggregate and the domestic input	4
$\sigma_{ELE,C}$	Substitution between electricity and the non-electric energy in household energy consumption	0.3
σ_{NELE}	Substitution between non-electric	0.5

A.1. Zero profit conditions

1. Production of goods except fossil fuels:

$$\Pi_{ir}^{Y} = (\theta_{ir}^{X} p_{ir}^{X^{1-\eta}} + (1-\theta_{ir}^{X}) p_{ir}^{1-\eta})^{1/(1-\eta)} - \sum_{j \notin EG} \theta_{jir} p_{Yjr}^{A} - \theta_{ir}^{KLE} [\theta_{ir}^{E} p_{ir}^{E^{1-\sigma_{KLE}}} + (1-\theta_{ir}^{E}) (w_r^{\alpha_{jr}^{L}} v_r^{\alpha_{jr}^{K}})^{1-\sigma_{KLE}}]^{1/1-\sigma_{KLE}} = 0, \quad i \notin FF.$$

2. Production of fossil fuels:

$$\Pi_{ir}^{Y} = (\theta_{ir}^{X} p_{ir}^{X^{1-\eta}} + (1-\theta_{ir}^{X}) p_{ir}^{1-\eta})^{1/1-\eta} - \left[\theta_{ir}^{Q} q_{ir}^{1-\sigma_Q} + (1-\theta_{ir}^{Q}) \left(\theta_{Lir}^{FF} w_r + \theta_{Kir}^{FF} v_r + \sum_j \theta_{jir}^{FF} p_{Yjr}^{A}\right)^{1-\sigma_Q}\right]^{1/(1-\sigma_Q)} = 0, \quad i \in FF.$$

3. Sector-specific energy aggregate:

$$\Pi_{ir}^{E} = p_{ir}^{E} - \left\{\theta_{ir}^{COA} p_{\{Y,COA,r\}}^{A^{1-\sigma_{COA}}} + (1-\theta_{ir}^{COA}) \left[\theta_{ir}^{ELE} p_{\{Y,ELE,r\}}^{A^{1-\sigma_{ELE}}} + (1-\theta_{ir}^{ELE}) \times \left(\prod_{j \in LQ} p_{Yjr}^{A^{\beta_{jir}}}\right)^{1-\sigma_{ELE}}\right]^{1-\sigma_{COA}/1-\sigma_{ELE}}\right\}^{1/1-\sigma_{COA}} = 0.$$

4. Armington aggregate:

$$\Pi_{dir}^{A} = p_{dir}^{A} - [(\theta_{dir}^{A} p_{ir}^{1-\sigma_A} + (1-\theta_{dir}^{A}) p_{ir}^{M^{1-\sigma_A}})^{1/1-\sigma_A} + t_r^{\mathrm{CO}_2} a_{dir}^{\mathrm{CO}_2}] = 0.$$

5. Aggregate imports across import regions:

$$\Pi_{ir}^{M} = p_{ir}^{M} - \left(\sum_s \theta_{isr}^{M} p_{is}^{1-\sigma_M}\right)^{1/1-\sigma_M} = 0.$$

6. Investment:

$$\Pi_r^{I} = p_r^{I} - \sum_i \theta_{ir}^{I} p_{Iir}^{A} = 0.$$

7. Public good production:

$$\Pi_r^{G} = p_r^{G} - \sum_i \theta_{ir}^{G} p_{Gir}^{A} = 0.$$

8. Household consumption demand:

$$\Pi_r^{C} = p_r^{C} - \left(\theta_{Cr}^{E} p_{Cr}^{E^{1-\sigma_{EC}}} + (1-\theta_{Cr}^{E}) \times \left[\prod_{i \notin EG} p_{Cir}^{A^{\gamma_{ir}}}\right]^{1-\sigma_{EC}}\right)^{1/1-\sigma_{EC}} = 0.$$

9. Household energy demand:

$$\Pi_{Cr}^{E} = p_{Cr}^{E} - \left\{\theta_{\{ELE,C,r\}}^{E} p_{ELE,r}^{1-\sigma_{ELE,C}} + (1-\theta_{\{ELE,C,r\}}^{E}) \times \left[\left(\sum_{i \in EG\{ELE\}} (\theta_{iCr}^{E} p_{Cir}^{A^{1-\sigma_{NELE}}})\right)^{1/1-\sigma_{NELE}}\right]^{1-\sigma_{ELE,C}}\right\}^{1/1-\sigma_{ELE,C}} = 0.$$

A.2. Market clearance conditions

10. Labor:

$$\bar{L}_r = \sum_i Y_{ir} \frac{\partial \Pi_{ir}^{Y}}{\partial w_r}.$$

11. Capital:

$$\bar{L}_r = \sum_i Y_{ir} \frac{\partial \Pi^Y_{ir}}{\partial w_r}.$$

12. Natural resources:

$$\bar{Q}_{ir} = Y_{ir} \frac{\partial \Pi^Y_{ir}}{\partial q_{ir}}, \quad i \in FF.$$

13. Output for domestic markets:

$$Y_{ir} \frac{\partial \Pi^Y_{ir}}{\partial p_{ir}} = \sum_{dj} A_{djr} \frac{\partial \Pi^A_{djr}}{\partial p_{ir}}.$$

14. Output for export markets:

$$Y_{ir} \frac{\partial \Pi^Y_{ir}}{\partial p^X_{ir}} = \sum_s M_{is} \frac{\partial \Pi^M_{is}}{\partial p^X_{ir}}.$$

15. Sector specific energy aggregate:

$$E_{ir} = Y_{ir} \frac{\partial \Pi^Y_{ir}}{\partial p^E_{ir}}.$$

16. Import aggregate:

$$M_{ir} = \sum_d A_{dir} \frac{\partial \Pi^A_{dir}}{\partial p^M_{ir}}.$$

17. Armington aggregate:

$$A_{dir} = \sum_j Y_{jr} \frac{\partial \Pi^Y_{jr}}{\partial p^A_{dir}} + C_r \frac{\partial \Pi^C_r}{\partial p^A_{dir}} + I_r \frac{\partial \Pi^I_r}{\partial p^A_{dir}} + G_r \frac{\partial \Pi^G_r}{\partial p^A_{dir}}.$$

18. Household consumption:

$$C_r p^C_r = w_r \bar{L}_r + v_r \bar{K}_r + \sum_{j \in FF} q_{jr} \bar{Q}_{jr} + t^{CO_2}_r \overline{CO}_{2r} + p^G_r \bar{G}_r + p^I_r \bar{I}_r + \bar{B}_r.$$

19. Aggregate household energy consumption:

$$E_{Cr} = C_r \frac{\partial \Pi^C_r}{\partial p^E_{Cr}}.$$

20. Government output:

$$\bar{G}_r = G_r.$$

21. Investment:

$$\bar{I}_r = I_r.$$

22. Carbon emissions:

$$\overline{CO}_{2r} = \sum_{di} A_{dir} \frac{\partial \Pi^A_{dir}}{\partial t^{CO_2}_r}.$$

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