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An Analysis of Alternative Emission Trading Strategies of Parties to the Kyoto Protocol*

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Summary: This article analyzes the cost of Canada, Japan, and Western Europe of complying with the Kyoto Protocol and the possible revenues of Eastern Europe, Russia, and Ukraine in a set of scenarios, each of which reflecting one particular pattern of permit trading. One main focus was to investigate how a working Clean Development Mechanism (CDM) scheme may influence the market power of a possible cartel of "hot air" sellers. The results show that the compliance costs are significantly reduced with the availability of CDM and that these cost depend only weakly on the restrictions of the "hot air" supply. The greenhouse gas emission reductions of the trading scenarios are about 40% less than in a domestic measures only scenario. The analysis uses a modified version of the well-known MERGE model (Manne and Richels, 2004).

Zusammenfassung: Dieser Artikel analysiert die Kosten, die Japan, Kanada und Westeuropa infolge der Erfüllung ihrer Verpflichtungen gemäß dem Kyoto-Protokoll entstehen, sowie den möglichen Ertrag, den Osteuropa, Russland und die Ukraine aus dem Verkauf eines Teils ihrer Emissionszertifikate erlösen können. Für die Analyse werden verschiedene Szenarien angenommen, von denen jedes ein bestimmtes Muster des Emissionshandels widerspiegelt. Im Besonderen wurde der Einfluss eines funktionierenden CDM-Systems (Reduktionsgutschriften im Rahmen des „Clean Development Mechanism") auf die Marktdominanz eines möglichen solchen Kartells untersucht. Die Resultate zeigen, dass die Kosten der Erfüllung der Kyoto-Verpflichtungen stark abnehmen, wenn Reduktionsgutschriften im Rahmen des CDM verfügbar sind, und dass diese Kosten nur schwach von (Selbst-) Beschränkungen der Anbieter abhängen. Die Treibhausgasemissionsreduktionen für die Emissionshandelsszenarien sind etwa 40 % geringer als in einem Szenario ohne Emissionshandel. In der Analyse wird das weithin bekannte MERGE-Modell verwendet (Manne und Richels 2004).

1 Introduction

Russia keeps playing a key role in the Kyoto Protocol. After an intense discussion Russia ratified the Kyoto Protocol on 18 November 2004, which subsequently entered into force on 16 February 2005.

Now, after ratification, Russia's expected surplus of emission allowances during the "Kyoto period" 2008–2012 will enable the country to influence the global carbon market by controlling the amount of "hot air" offered to Parties of the Kyoto Protocol facing binding greenhouse gas emission constraints. By holding back permits from the global market, Russia can increase total income from carbon trading and keep the carbon price high.

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Russia's market power will depend on geopolitical factors and on the effectiveness of the Kyoto Protocol's "flexibility mechanisms", most importantly the Clean Development Mechanism (CDM). Especially interesting is if and how the Kyoto Protocol's "flexibility mechanisms" can reduce the possible Russian market dominance. Perhaps the most important political factor will be the rules governing the implementation of the Kyoto Protocol in Europe. Outside Europe, Parties to the Kyoto Protocol are alert to the possibility of a "European bubble" which – so it is feared – would give Europe a competitive advantage by "absorbing" the excess carbon emissions in Eastern European EU member countries or accession countries.

To analyze the importance of each of these factors, we have used a modified version of the MERGE model (Manne and Richels, 2004) to formulate carbon trade regimes that reflect the main possibilities of the global market situations described above.

In Section 2 of this paper, we give a brief description of the MERGE model and its IIASA extensions. In Section 3, we give a brief characterization of a long-term global reference scenario in which we embed our analysis of the First Commitment Period (2008–2012), followed by a presentation the results of analyzing five compliance scenarios, each of them describing one particular carbon trading regime. In Section 4, we draw conclusions from looking at all our scenarios together and compare them with results obtained by other authors.

2 The MERGE Model

2.1 MERGE "in a Nutshell"

The global optimization model MERGE (Manne and Richels, 2004) describes the interaction between macroeconomic production, the energy system (demand and supply), pollutant emissions, and climate change. The model consists of three logical parts: a macroeconomic module, an energy supply part, and a climate module. It combines a top-down description of the economy and energy demand with a bottom-up description of the energy sector.

The *macroeconomic module* defines an inter-temporal utility function of a single representative producer-consumer in each of the model's world regions, which is then maximized by MERGE subject to given constrains. The main variables of this module are the production factors capital stock, available labor, and energy inputs, which together determine the total output of an economy according to a nested CES (constant elasticity of substitution) production function. The optimal quantities of the production factors are determined by their relative prices. The core of the *energy module* is a comparatively simple Reference Energy System (RES) describing the technological options available to supply the energy needed as a production factor. The *climate module* calculates the resulting GHG concentrations and global temperature.

MERGE was designed as an integrated-assessment model (IAM) to study global GHG mitigation scenarios and to conduct cost-benefit analysis.[1] For the given purpose of our analysis, IIASA-ECS amended the original MERGE 5 model. They are described in the following subsection.

2.2 IIASA Extensions of MERGE

In order to be able to model the important players in the Kyoto Protocol, the two MERGE regions CANZ (Canada, Australia, and New Zealand) and EEFSU (Eastern Europe and Former Soviet Union) were split into the four regions Canada, ANZ (Australia and New Zealand), EEU (Eastern Europe) and FSU (Former Soviet Union). The model now includes eleven world regions.[2]

Also, all six "Kyoto gases" are now included in the dynamics determining emission permit trade in the First Commitment period, CH_4 leakages from natural gas pipelines have been included, and the limits on sequestration from forest management as given in the Marrakech Accord were included.

The Clean Development Mechanism (CDM) is one of the Kyoto Protocols "flexible mechanisms", designed to reduce the economic costs (and to thus increase the global efficiency) of greenhouse gas abatement. Equations describing the CDM mechanism and a price-responsive CDM supply were incorporated into the model. As to quantities and prices of CDM projects, we used an interpolation of two supply curves reported by Point Carbon (Tangen et al. 2004). Our interpolation ("Ratification in 2005") and the original 2003 and 2007 curves are shown as the middle curve in Figure 1.

As to model input data, MERGE-I[3] now includes recent information on expected economic growth and energy consumption of the complying regions. In the same spirit, the power sector options of these regions were restricted for the year 2010 (relative to the REF scenario) to avoid the possibilities of unrealistically high build-up rates of power plants. For Japan, we have additionally assumed that no more LNG terminals will be available by 2010 than in the Reference scenario and that therefore natural-gas imports in 2010 must not exceed those given by the Reference scenario (see also Schrattenholzer and Totschnig 2004).

3 Six Scenarios

To analyze the consequences of assuming different geopolitical scenarios guiding the emission trading within the Kyoto Protocol, we think that it is useful to think of three "limiting cases". One limiting case is a Reference scenario (REF) without GHG emission

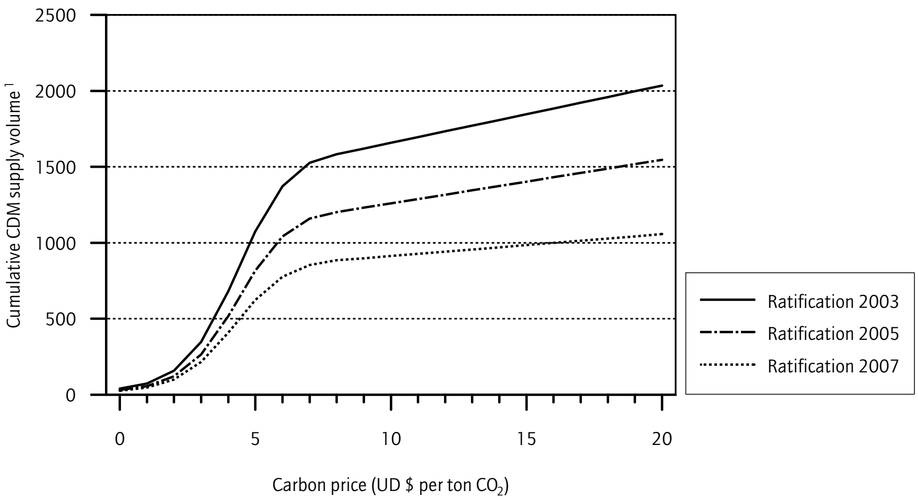
1 The scope of MERGE is thus considerably wider than the minimum required for our task. We nevertheless decided to use MERGE for our research task, mainly for two reasons. First, we think that as a consequence of its world-wide use, MERGE can be regarded as a kind of "language" that is widely understood. Second, we think that it is instructive to see short-time results "embedded" in longer-term scenarios, in particular when talking about climate change.

2 All regions follow the same convention as EIA-USDOE's International Energy Outlook (2004), with the only exception that we included the new Baltic EU members Estonia, Latvia, and Lithuania in EEU (and not in FSU).

3 We use MERGE-I ("I" as in IIASA) to refer the new version of the original model.

Figure 1

CDM Supply Curves as Function of the Carbon Price for three Scenarios of Russian Ratification



1 From today until 2012 in Mt CO_2 equivalent.

Source: Original curves: Tangen et al. (2004); interpolation by the authors.

constraints. GHG abatement costs are calculated relative to this scenario. The second limiting case is an extreme compliance scenario (DOM) in which the "Kyoto limits" are achieved exclusively with domestic measures. Relative to this scenario, benefits of GHG emission trading (including CDM) are calculated. As a third limiting case we defined the "Full Trade" (FT) scenario in which all Parties participate freely in global GHG emission trading. In particular, the full potential of CDM is available on the global market.

Note that in all scenarios including GHG trading (i.e. all scenarios in Table 1 but REF and DOM) it is assumed that sellers of "hot air" cooperate (by limiting the quantities sold) with each other to achieve their maximum revenues[4] in the 2008–2012 period. In this study no banking of emission permits between different time periods is considered.

In order to determine the possible role of the Clean Development Mechanism (CDM) in a carbon market dominated by the carbon sellers, we defined the scenario "Full Trade, no CDM" (FTnCDM). A comparison between this scenario and FT ("Full Trade") quantifies the benefits of CDM in a global GHG emission market with a sellers' cartel.

To calculate the effect of an assumed "European GHG Emission Bubble", the "Divided Market" (DM) scenario stipulates that – as a consequence of an expanding European Un-

4 Maximum revenues of permit selling were determined by a series of model runs with different limits on the selling of "hot air".

Table 1

Overview of Six Scenario Definitions

1. REF	2. DOM	3. FT	4. FTnCDM	5. DM	6. DMnCDM
Business as usual, no policy	Domestic actions only	Full trade, with CDM and sellers cartel	Full trade, sellers cartel, no CDM	Divided market, with CDM, no Ukraine, EU bubble, Japan and Canada emission trade with Russia	Divided market, no CDM, no Ukraine, EU bubble, Japan and Canada emission trade with Russia

Source: This article.

ion – Western Europe and Eastern Europe jointly comply to the total of their respective Kyoto limits (the "bubble"). The international trade of GHG emission rights is thus left to Japan and Canada trading with Russia. To give this scenario the flavor of risk analysis (from the perspective of the non-European Parties to the Kyoto Protocol), Ukraine is assumed not to become eligible to sell on the global GHG emission market. The Clean-Development Mechanism (CDM) is included. Again the effect of including CDM is analyzed by formulating a variant of DM, DMnCDM, which is derived from DM by assuming the non-availability of CDM.

For convenient reference, the definitions of the six scenarios are summarized in Table 1.

Restricting the GHG emissions only for the First Commitment Period of the Kyoto Protocol (2008–2012) would be likely to lead to implausible results. For all scenarios (except REF) we therefore assumed that the GHG emission limits remain at the 2010 levels throughout the time horizon of the model. This is a commonly used assumption for long-term energy models and is usually dubbed as "Kyoto Forever".

3.1 The MERGE Reference Scenario

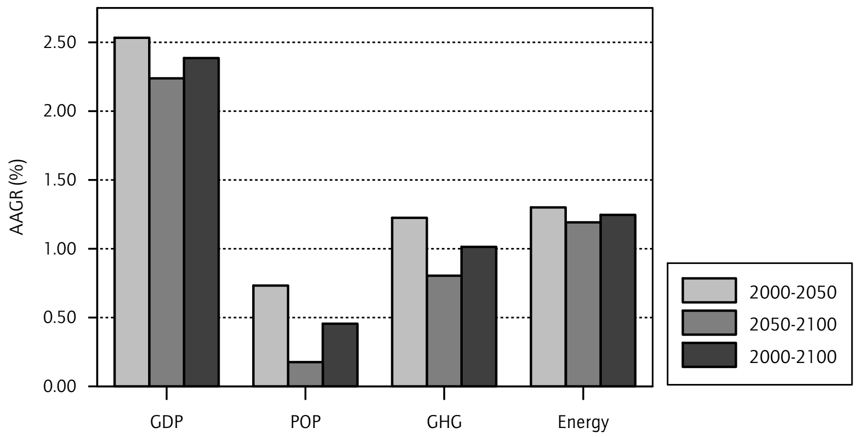
Before presenting the results of the compliance scenarios, we now give a brief characterization of the MERGE Reference scenario (from 2000–2100) as defined by Manne and Richels (2004).

In the original MERGE, population projections from present up to 2020 are taken from the International Energy Outlook 2003 (EIA-USDOE, 2003). For the time after 2020, it has been assumed that the global population grows asymptotically towards 10 billion. The potential economic growth of MERGE's Reference scenario amounts to an average annual growth rate (AAGR) of global GDP over the 21st century of 2.4% percent. Again including recent information into our version of the model, we set the potential annual GDP growth in the model's first time period (2000–2005) to 1% for Japan and to 1.6% for WEU (down from 1.2% and 2.2% respectively).

We summarize the results of the reference scenario by reporting long-term average annual growth rates (AAGRs) in Figure 2.

Figure 2

Long-term Annually Averaged Growth Rates (AAGR) of the World GDP, Population, GHG Emission and Energy Consumption, MERGE Reference Scenario



Source: Manne and Richels (2004).

One way of characterizing the main features of these results from an energy and environmental perspective would be so say that the energy intensity of GDP decreases at an average annual rate of just over 1% while the GHG intensity of energy decreases at an average annual rate of 0.23%.

3.2 The "Domestic Measures Only" (DOM) Scenario

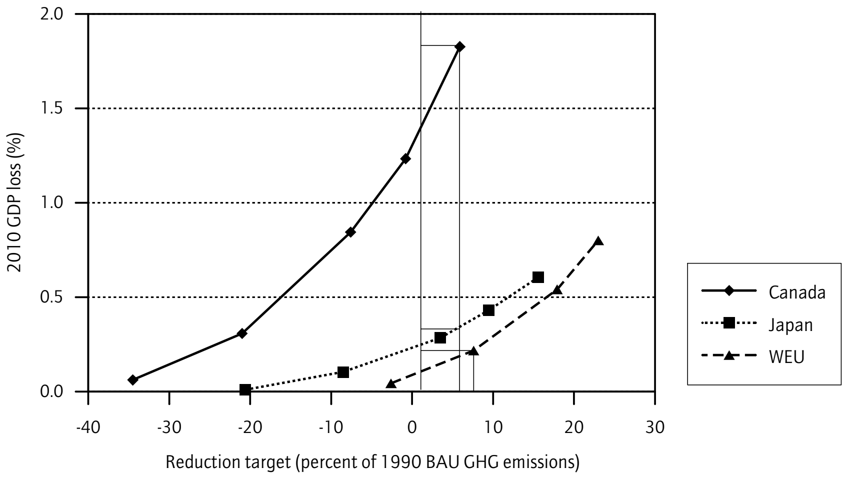
The purpose of the DOM scenario was to measure the maximum cost of compliance. A comparison between DOM and a scenario including GHG emission trading permits the calculation of the effects of emissions trading as defined in the according scenario.

In addition to showing the cost of GHG emission reduction to the "Kyoto target", we show in Figure 3 GDP loss also for different reduction targets to more fully characterize the relation between reduction levels and cost.

The GDP losses resulting from complying with the Kyoto targets with domestic measures only are 1.75% for Canada, 0.31% for Japan and 0.23% for WEU. The most important reason explaining this difference between the abatement cost curves of these three regions is that in the Reference scenario, the GHG emissions in 2010 of Canada, Japan and WEU increase by 35%, 21% and 3% from their respective 1990 values. As a result, Canada's Kyoto limit is the most stringent and its GDP loss is highest. Japan's GHG emissions in the Reference are also high, but its GDP loss is mitigated considerably by the comparatively high allowances for sequestration from forest management as decided at COP-6 in Bonn. The low GHG emission growth of 3% in WEU and the accordingly low marginal abatement costs (see also Table 2) are not surprising given the restructuring of Germany's economy following German unification.

Figure 3

GDP Loss as a Function of the Reduction Target (Relative to 1990 Emissions) for the "Domestic Measures only" Scenario



Scenario for Canada, Japan, and WEU; MERGE-I Runs.
The vertical black lines indicate the Kyoto targets.

Source: Authors' calculations.

Analyzing the results in more detail shows that the reduction of the GHG intensity of the energy system via fuel switching (decarbonization), energy demand reduction, and abatement plus sequestration (forest management and non-CO_2 GHG abatement measures) contribute approximately 30 percent each to the total abatement of GHG emissions in all three regions. "Leakage" (GHG reductions by importing energy-intensive products instead of producing them domestically) contributes 6% (WEU), 11% (Canada) and 16% (Japan) respectively. In all three regions energy demand reductions limit the use of coal for power generation and that of oil in the non-electric sector. As a consequence of the limited speed of change, renewable energy sources play a minor role in 2010.

3.3 The "Full Trade" (FT) Scenario

The "Full Trade" (FT) scenario assumes a global market of GHG emission permits and a full availability of emission reduction according to CDM. In this sense, FT combines economic and environmental efficiency. Recall that for this scenario, it is assumed that Eastern Europe, Russia and Ukraine form a sellers' cartel and that all three choose to sell the same fraction of their assigned GHG emission permits (Assigned Amount Units, AAU) in order to maximize their revenues. This maximization is summarized in Figure 4.

The revenue curves for EEU, Russia and Ukraine are more or less flat for permit export limits between 5% and 15% and have three gentle but noticeable peaks. We chose the middle value of 10% (of the AAUs) for the main variant of the "Full Trade" scenario (and

Table 2

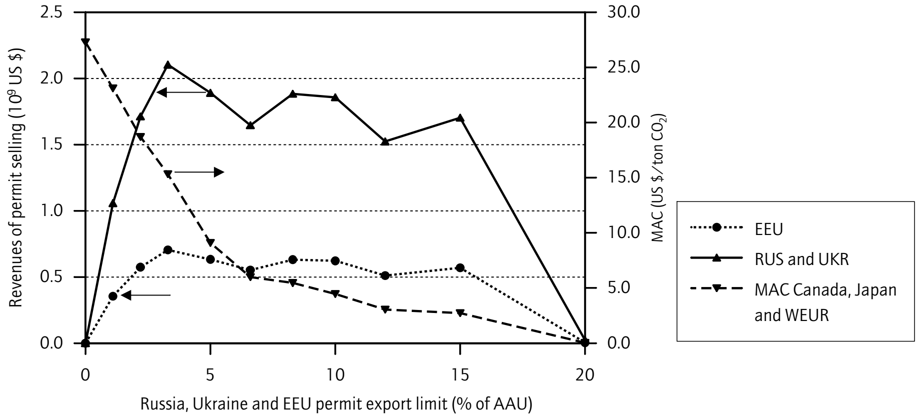
GHG Trade and GDP in Six Scenarios for the Year 2010

Scenario	Region	Permit supply of sellers cartel (% of sellers AAU)	Global GHG reduction (% of REF Emission)	Global GHG Emissions ($GtCO_2$ equ.)	Marginal GHG abatement cost (\$/ton CO_2 equ.)	Net Purchase of AAUs ($MtCO_2$ equ.)	Net Purchase of CERS ($MtCO_2$ equ.)	Expenditures for AAU and CER purchase (bn 2000 USD)	GDP loss (bn 2000 USD)	GDP loss (% of REF GDP)	GDP (tr 2000 USD)
1. REF				39,486							
No Policy	Japan										5.424
	WEUR										12.039
	Canada										1.026
2. DOM			2.0	38,712							
Domestic action only	Japan				62				16.7	0.31	5.407
	WEUR				38				28.1	0.23	12.011
	Canada				95				17.9	1.75	1.008
3. FT		10	1.1	39,063							
Full Trade with CDM , no USA and ANZ, sellers cartel	Japan				4	94	131	1.0	3.5	0.06	5.420
	WEUR				4	264	0	1.2	9.7	0.08	12.029
	Canada				4	197	0	0.9	2.6	0.25	1.023
	Sum					555	131				
4. FTnCDM		6.6	1.3	38,954							
Full trade no CDM, no USA and ANZ, sellers cartel	Japan				26	141		3.6	10.4	0.19	5.413
	WEUR				26	86		2.2	24.2	0.20	12.015
	Canada				26	139		3.6	8.1	0.79	1.018
	Sum					367					
5. DM		10	1.1	39,061							
Divided Market: with CDM, no UKR, EU bubble, JAP, CAN emission trade with RUS cartel	Japan				4	121	105	0.91	3.1	0.06	5.421
	WEUR				3	291	0	0.79	7.5	0.06	12.032
	Canada				4	199	0	0.80	2.3	0.23	1.024
	Sum					611	105				
6. DMnCDM		6.6	1.2	39,003							
Divided Market no CDM, no UKR, EU bubble, JAP, CAN emission trade with RUS cartel	Japan				34	108		3.7	13.0	0.24	5.411
	WEUR				3	301		0.8	11.2	0.09	12.028
	Canada				34	103		3.5	10.1	0.98	1.016
	Sum					512					

Source: Authors' calculations.

Figure 4

Russian plus Ukrainian and EEU Revenues from Selling Different Amounts of GHG Emission Permits and Marginal Abatement Costs (MAC) in Canada, Japan, and WEU, MERGE-I run "Full Trade" Scenario



The marginal abatement costs (MAC) is an important driver for the carbon price.

Source: Authors' calculations.

for the summary in Table 2). Selling 10% of AAUs corresponds to selling about 41% of the Russian plus Ukrainian and 60% of the EEU "hot air".[5]

At the chosen point, also the curve of total expenditures of the permit importers for permits is already in its flat part (see Figure 5).

3.4 The "Full Trade, no CDM" (FTnCDM) Scenario

The "Full Trade, but no CDM" (FTnCDM) scenario is identical to FT with the exception that here, no CDM is allowed. In Figure 6 we again show the permit sellers' revenues as a function of the amount of sold permits.

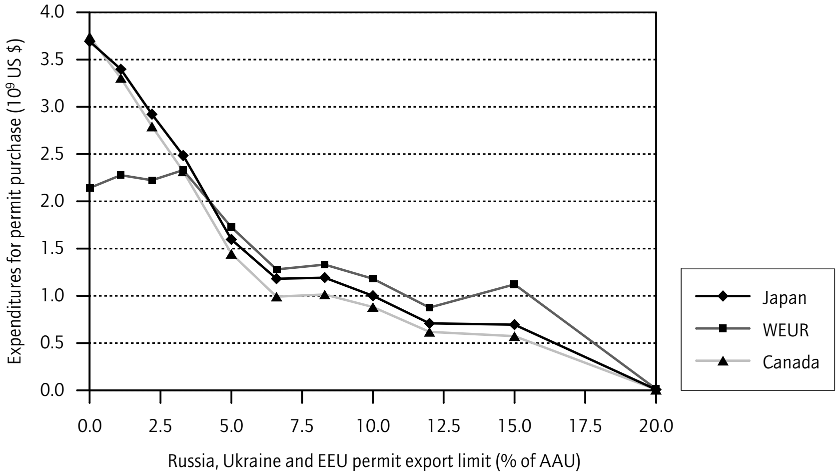
The optimal permit export limit with the highest revenues for the sellers was to sell only 6.6% of their Assigned Amount Units (AAU), which corresponds to selling about 27% of the Russian plus Ukrainian and 39% of the EEU "hot air".

Looking at the impact of different permit export limits from the buyers' perspective, we show, in Figure 7, the costs of permit purchase.

5 The total "hot air" of EEU and FSU (Russia+Ukraine) amount to about 17% and 25% of their respective Assigned Amount Units (AAUs).

Figure 5

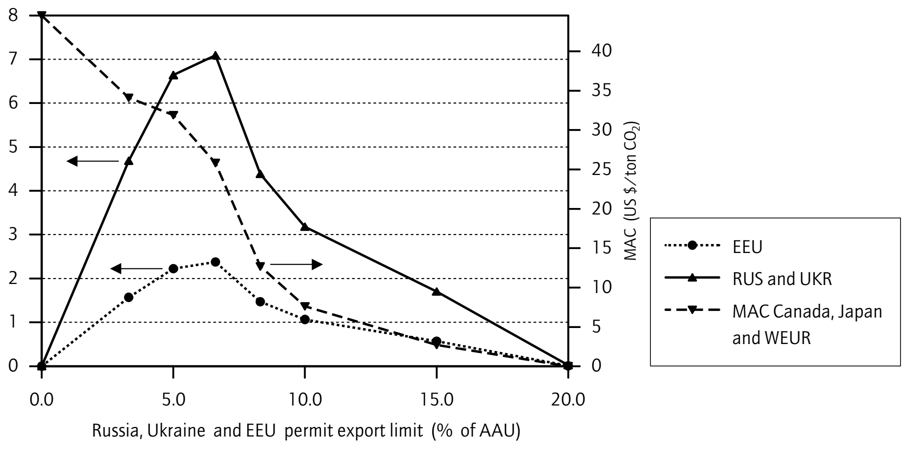
Total Costs for Permit ("hot air" and CDM) Purchasing of Canada, Japan, and WEU at Different Amounts of Sold Permits, "Full Trade" Scenario



Source: Authors' calculations.

Figure 6

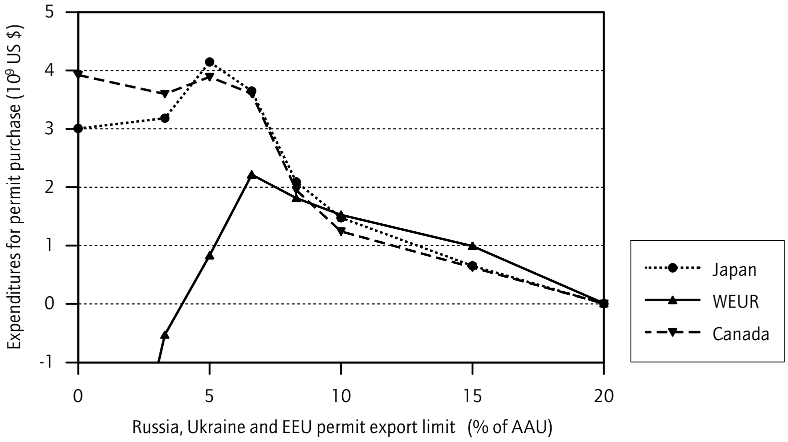
Russian plus Ukrainian and EEU Revenues from Selling Different Amounts of GHG Emission Permits and Marginal Abatement Costs, (MAC) in Canada, Japan, and WEU, "Full Trade, no CDM" Scenario



Source: Authors' calculations.

Figure 7

Total Expenditures for Permit Purchases by Canada, Japan, and WEU at Different Amounts of Sold Permits, "Full Trade, but no CDM" Scenario



Source: Authors' calculations.

Figure 6 and Figure 7 show that without the CDM option the sellers' revenues and the buyers' expenditures strongly depend on the sellers' cartel limitations of the permit exports. The carbon price goes to zero as soon as the exporting regions (Former Soviet Union and Eastern Europe) export more carbon emission entitlements than needed for the compliance of all Parties (18% of their Assigned Amount Units or 81% of EEU+Russian+Ukrainian "hot air"). Note however, that this result rests on the assumed annual GDP growth rates (between 2000 and 2010) of 4.5% for Russia, Ukraine and 4% for EEU. In contrast, at lower values of the permit export limit, the carbon price becomes so high that it is optimal for WEU (the region with the lowest MAC in DOM) to even sell some of its permits and to increase domestic mitigation and that Canada and Japan also increasingly comply by domestic measures. This limits total revenues of the sellers. The GDP losses for the most profitable permit export limit of 6.6% are 0.79% for Canada, 0.19% for Japan and 0.20% for WEU.

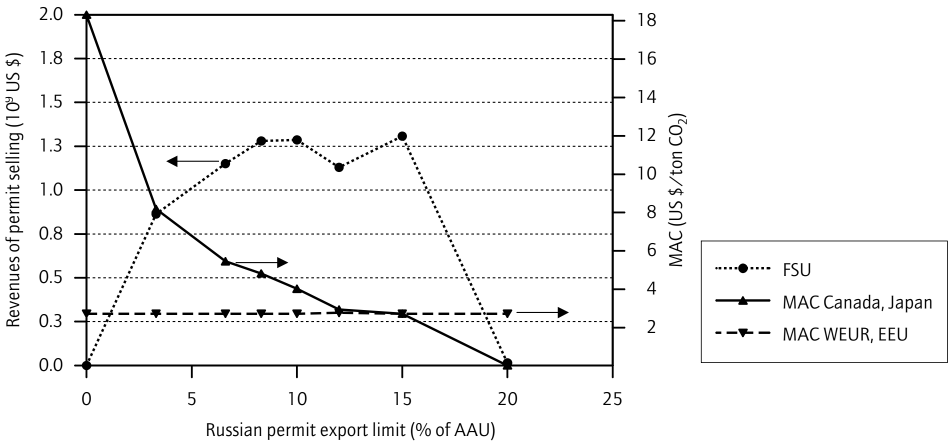
3.5 The "Divided Market" (DM) Scenario

The non-European Parties of the Kyoto Protocol (and European environmentalists) are concerned about the possibility that WEU and EEU jointly comply with their Kyoto targets ("European bubble"). As CDM is included in this scenario, Canada, Europe, and Japan compete for CDM, while Canada and Japan compete for "hot air" from Russia. To make this scenario a "risk analysis" case, Ukraine is assumed to be not eligible for carbon trading.

The determination of Russia's optimal permit export limit is illustrated in Figure 8. The figure clearly shows that Europe is "decoupled" from the effects of Russia varying her

Figure 8

Russian Revenues from Selling Different Amounts of GHG Emission Permits and Marginal Abatement Costs, (MAC) in Canada, Japan, and WEU, "Divided Market" Scenario



Source: Authors' calculations.

Figure 9

Total Costs for Permit ("hot air" and CDM) Purchasing of Canada, Japan, and WEU at Different Amounts of Sold Permits, "Divided Market" ScenarioI

Source: Authors' calculations.

permit export limit. Similar to the “Full Trade” scenario, marginal GHG abatement costs of Canada and Japan approach zero when Russia’s export limits approach 17% of her AAUs (equivalent to 69% of the Russian “hot air”). The revenues curve is flat near 10%, and this is the value chosen for the main variant of the DM scenario (and for the summary in Table 2). Selling 10% of AAUs corresponds to selling about 41% of the Russian “hot air”.

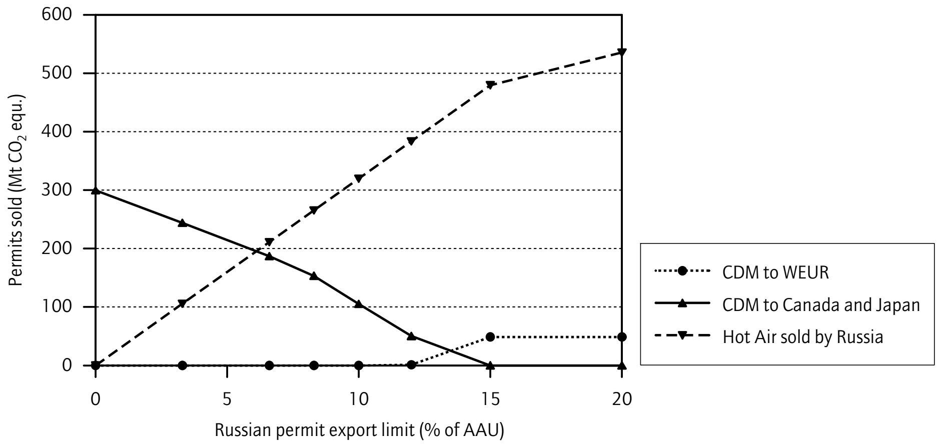
From the buyers’ perspective, the influence of varying Russia’s permit export limit looks as shown in Figure 9. The costs of permit purchase increases for WEU for a permit export limit more than 15%, since WEU then buys CDM credits (which are offered at lower prices at a consequence of Russia’s lower “hot air” prices, which make Canada and Japan buy more “hot air”) in addition to the EEU “hot air” and spares by this expensive domestic mitigation measures.

The share of CDM in total permit purchase strongly depends on the prevailing carbon price. It decreases from a 37% share at a permit export limit of 3.3% to a 6% share when the permit export limit is set at 15% of Russia’s AAUs.

From Figure 10 it can be seen that Russian “hot air” competes with CDM for market shares of emission credits bought by Canada and Japan. The resulting Russian revenues, as seen in Figure 8, are rather stable between selling 6.6% and 15% of their AAUs, due to the declining carbon price.

Figure 10

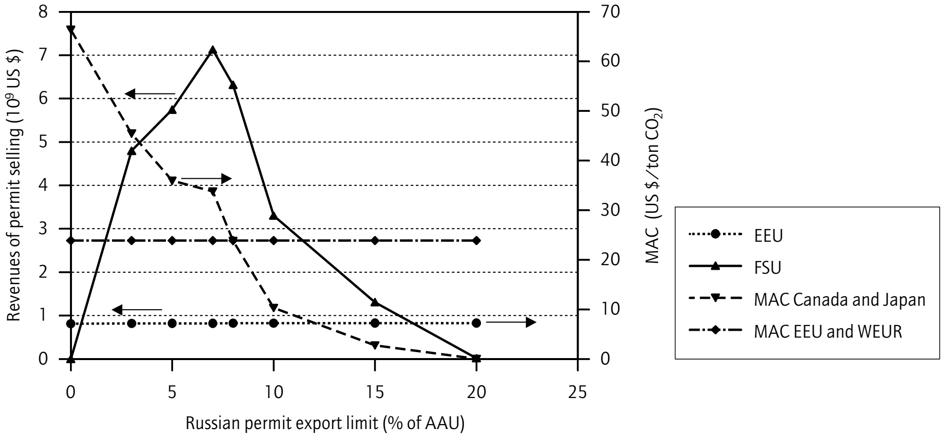
Amounts of Hot Air Sold by Russia to Canada and Japan, Amounts of Certified Emission Reduction Credits (CERs) from CDM Projects Purchased by the WEU, Canada, and Japan on the other Side, “Divided Market” Scenario



Source: Authors’ calculations.

Figure 11

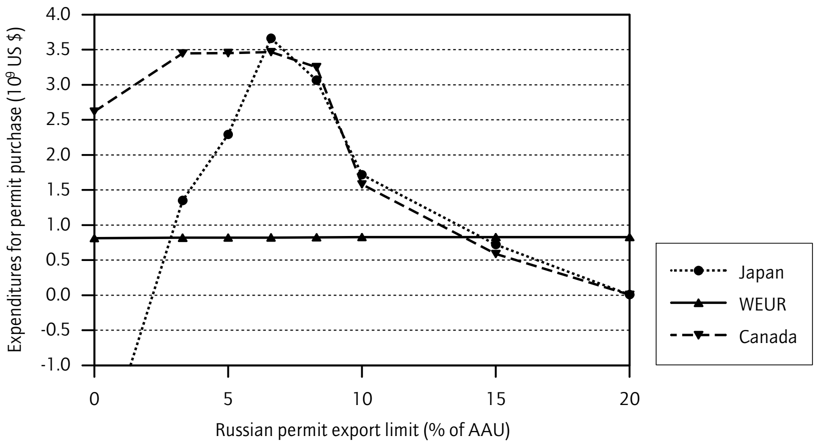
Russian and EEU Revenues from Selling Different Amounts of GHG Emission Permits and Marginal Abatement Costs, (MAC) in Canada, Japan, and WEU, "Divided Market, no CDM" Scenario



Source: Authors' calculations.

Figure 12

Total Costs for Permit Purchasing of Canada, Japan, and WEU at Different Amounts of Sold Permits, "Divided Market, no CDM" ScenarioI



Source: Authors' calculations.

3.6 The "Divided Market, no CDM" (DMnCDM) Scenario

This scenario analyzes the effect of CDM in the "Divided Market" scenario by excluding the CDM option. Maximizing Russia's trading revenues from permit sales is illustrated in Figure 11.

An analysis of the results further shows that purchasing "hot air" amounts to 29% of Canada's, 10% of Japan's and 64% of WEU's reductions to comply the Kyoto Protocol. Because of WEU's unlimited access to EEU's "hot air" assumed for this scenario, WEU even exports more energy-intensive goods for the global market than in the Reference scenario.

4 Comparative Presentation of the Results and Conclusions

In the previous section, we have characterized the scenarios mainly in their own terms. Now we want to compare all scenarios in one place (Table 2). The table not only permits to evaluate the benefits of carbon trade and the relative value of carbon trading schemes, but also indicates economic costs and environmental benefits of each scenario.

As described before, in all trading scenarios (scenarios 3–6) it is assumed that exporters of emission rights form a cartel to maximize their revenues from permit selling by limiting the "hot air" exports. The "hot air" export limit which yields optimal revenues for the exporters is given in Table 2 in the third column as fraction of the exporters' Assigned Amount Units (AAU).

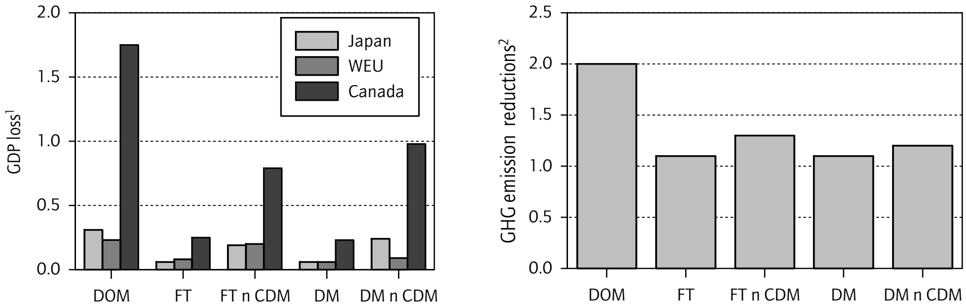
The fourth column of the table gives the global GHG emission reductions in 2010 compared to the Reference scenario. For interpreting the global GHG emission reduction (Figure 13) one has to take into account that in the in the MERGE Reference scenario, global GHG emissions increase by 28% between 1990 and 2010. A reduction of 2% compared to REF in 2010 therefore means a 26% increase compared to 1990.

In this summary of compliance cost, a number observations stand out. One is that trade can reduce the GDP losses of Canada, Japan, and Western Europe significantly to fractions of one percent. In all compliance scenarios, Canada has the highest compliance cost of all MERGE-I regions that observe GHG emission limits. In terms of GDP lost, Canada's costs range from 0.15% in the most favorable scenario to 1.75% in the "Domestic Measures Only" scenario. For comparison, the according ranges for Japan and WEUR are 0.04 to 0.31 and 0.05 to 0.23% respectively. At the same time, this summary also shows that GDP losses in all scenarios remain relatively small. Relative to projected GDP growth, a 1% loss for instance, would mean the loss of less than one year's growth or, in other words, the "postponement of growth" by less than one year.

Most of the past studies of compliance costs did not consider the possible monopolistic behaviour of the dominant permit seller Russia. Here, we investigate the combined effects of a possible monopolistic permit selling cartel and a CDM supply that reacts to carbon prices. In this case, a functioning CDM scheme considerably lowers the carbon price. This is not only a result of the additionally available CDM permits, but also a result of the "hot air" sellers' cartel competing for market shares with CDM and thereby possibly increasing the amount of hot air sold. A further result is that in the absence of CDM, the permit seller

Figure 13

Compliance Costs in Five Scenarios Given as GDP Loss



1 In percent of Reference scenario GDP.
2 The global GHG emission reductions in 2010 are given in percent of the Reference scenario emissions in 2010.

Source: Authors' calculations.

revenues show a narrow maximum around selling 6.6% of the AAUs. In contrast, if CDM is available, then permit seller revenues are almost constant for a broad range of permit exports (from approximately 5% to 15%). Similarly, the compliance costs for Canada, Japan and WEU depend rather weakly on the "hot air" supply if CDM is available, where as the costs vary strongly with the available "hot air" in the absence of CDM. The results show that the differences between compliance costs for Canada, Japan and WEU between the "Full Trade" scenario and the "Divided Market" scenario are only marginal when CDM is available. In the absence of CDM, European compliance costs in the "Divided Market" scenario are cut approximately to one-half compared to the "Full Trade" scenario without CDM. The costs of Japan and Canada in the "Divided Market" scenario without CDM are similar as in the "Full Trade" scenario, but much higher than the costs of WEU. Ukraine not selling emissions permits would increase Canada's and Japan's compliance cost by approximately 25% in the "Divided Market" scenario.

In this paper we assume that a sellers' cartel optimizes revenues from permit selling, but Russia may also follow other considerations. Holtsmark, e.g., argues that Russian oil and gas interests are likely to boost Russia's inclination to sell permits, ultimately resulting in lower permit prices (Holtsmark 2003). We regard the effect of the Kyoto Protocol on the oil prices to be negligible, since the oil price is more influenced by political decisions and demand growth than by the small fraction of sectors subject to the Kyoto Protocol. Switching to natural gas to reduce GHG emissions would be even profitable for Russia. In addition, as is argued by Moe and Tangen (2000), the Russian government could be inclined to restrict "hot air" sales in order to stimulate Joint Implementation (JI) projects, enabling valuable technology transfers. So we think the sellers' cartel assumption reasonably justified.

An overview of the compliance costs and the GHG emission reductions is given in Figure 13.

Table 3

Comparison Results by other Authors with Results Obtained by this Study

Model	MAC (2000 US$/tCO2)	Share of "Hot Air" sold (%)	Sinks
Cartel RUS+UKR+EEU:			
MACGEM[1]	22	17	None
PACE[2]	17	40	B
POLES[3]	19	36	B,M
POLES&ASPEN[4]	5	10	B,M
WORLDSCAN[5]	5	60	B,M
Cartel RUS+UKR:			
GTEM[6]	12	55	B
MIT-EPPA[7]	7	50	B,M
POLES[8]	11	34	B,M
This Study:			
FT	4	44	B,M
FT n CDM	26	29	B,M
DM	3 (WEU) , 4 (Jap., Can.)	53	B,M
DM n CDM	3 (WEU) , 34 (Jap. Can.)	35	B,M

Sinks: Bonn (B), Marrakesh (M)

Sources: [4]Blanchard et al. (2002), [2]Böhringer (2002), [7]Babiker et al. (2002), [5]den Elzen and de Morr (2002), [1]Eyckmans et al. (2001), [6]Jakeman et al. (2001), [3],[8]Löschl and Zhang (2002).

From the figure it can be seen that the GHG emission reductions for all trading regimes are similar: approximately 60% of the DOM scenario. But comparing the achieved GHG emission reductions with the GDP losses of each scenario makes it clear that the “Full Trade” and “Divided Market” scenarios with CDM achieve this emission reduction at much lower GDP losses.

In conclusion, we present a comparison between our results and those obtained in other studies. We summarize compliance costs obtained by other authors analyzing abatement costs in the presence of a sellers’ cartel with our results in Table 3. This table taken from Springer (2003) was amended with our own calculations.

Results of studies assuming a cartel of only Russia and Ukraine differ from the “Divided Market” scenario, since in these models the EEU is a price taker but with only one global carbon price, where as the “Divided Market” scenario has a separate carbon market in the Europe with a substantially lower carbon price.

References

Babiker, Mustafa H., Henry D. Jacoby, John M. Reilly and David M. Reiner (2002): The Evolution of a Climate Regime: Kyoto to Marrakech and beyond. *Environmental Science & Policy*, 5, 195–206.

Blanchard, Odile, Patrick Criqui and Alban Kitous (2002): *After The Hague, Bonn and Marrakech: The Future International Market for Emissions Permits and the Issue of Hot Air.* Cahier de rechèrche No. 27bis. Institut d'économie et de politique de l'énergie (IEPE), Grenoble.

Böhringer, Christoph (2002): Climate Politics from Kyoto to Bonn: From Little to Nothing? *Energy Journal*, 23, 51–71.

Den Elzen, Michel G.J. and André P.G. de Moor (2002): *Evaluating the Bonn-Marrakesh agreement*. Clim. Policy 2, 111–117.

EIA-USDOE (2003): *International Energy Outlook 2003*. Download under: *www.eia.doe.gov/oiaf/ieo/index.html*

Eyckmans, J., D. van Regemorter and V. van Steenberghe (2001): *Is Kyoto Fatally Flawed? An Analysis with MacGEM*. Working Paper No. 2001–18. Faculty of Economics and Applied Economic Sciences, Katholieke Universiteit Leuven.

Holtsmark, B. (2003): Russian Behaviour in the Market for Permits under the Kyoto Protocol. *Climate Policy*, 3, 399–415.

IPCC (2001): *Climate Change 2001: The Scientific Basis*. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, Cambridge University Press. Download under: *www.grida.no/climate/ipcc_tar/*

Jakeman, G., E. Heyhoe, H. Pant, K. Woffenden and B.S. Fisher (2001): *The Kyoto Protocol. Economic Impacts under the Terms of the Bonn Agreement*. ABARE conference paper 2001.28. Canberra.

Löschl, Andreas, Zhong X. Zhang (2002): The Economic and Environmental Implications of the U.S. Repudiation of the Kyoto Protocol and the Subsequent Deals in Bonn and Marrakesch. *Weltwirtschaftliches Archiv*, 138, 711–746.

Manne, Alan and Richels Richard (2004): *MERGE: A Model for Evaluating the Regional and Global Effects of GHG Reduction Policies*. Download under: *www.stanford.edu/group/MERGE/*

Moe, A. and K. Tangen (2000): *The Kyoto Mechanisms and Russian Climate Politics*. The Royal Institute of International Affairs, London.

Schrattenholzer, Leo and Gerhard Totschnig (2004): *Economic Analysis of Imperfect Implementations of the Kyoto Protocol.* Final Report on the TEPCO-IIASA Collaborative Study submitted to the Tokyo Electric Power Company. IIASA, Luxembourg.

Springer, Urs (2003): The Market for Tradable GHG Permits under the Kyoto Protocol: A Survey of Model Studies. *Energy Economics*, 25, 527–551.

Tangen, Kristian, Atle C. Christiansen, Anders Skogen and Ian Roche (2004): *Imperfect Implementation of the Kyoto Protocol*. Draft Report to TEPCO-Environment.