Russia's Role in the Kyoto Protocol

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Abstract

As a result of the allocation of emissions reductions, and the differential willingness of countries to ratify, it turns out that Russia is a central player in the Kyoto Protocol. With the U.S. out and Japan and the EU ratifying, the Protocol cannot enter into force without Russian ratification. In part, U.S. rejection of the Kyoto Protocol resulted from the fact that, had the U.S. been in, its least costly road to implementation would have involved large purchases of emissions credits from Russia. With the U.S. out, Russian credits are worth much less but Russia may be able to exploit monopoly power to increase the value of those permits, or Russia could bank permits on the expectation that prices will rise in the future, perhaps as a result of U.S. reentry into the Protocol in later periods. The Russian decision is more complex, however, in that it is also a major fossil fuel exporter. To the extent it withholds permits from the market, fossil energy prices are depressed further, and the value of its exports of energy are reduced. Thus, Russia faces a tradeoff between maximizing its permit revenue and its revenue from fossil energy exports. We develop this problem as a simple dynamic optimization problem that can be easily solved. We calibrate this simple model to the results of two CGE models (EPPA and GEMINI-E3) that fully capture interactions of energy trade, permit trade, and permit and energy prices. We show that carbon prices are relatively insensitive to Russia's behaviors when the U.S. is assumed to participate. It also shows that, in the absence of U.S.participation, the impacts of market power by Russia & the Ukraine is largely dependent on the elasticity of demand for permits. Finally, we focus on the uncertainty about the supply of CDM by developing countries. It is shown that permits prices are relatively insensitive to CDM supply in the short run but not in the long run.

Contents

1 Introduction

Russia has become a central player in international climate policy. For the Kyoto Protocol to enter into force, Annex B Parties accounting for 55% of 1990 carbon emissions must ratify. The Russian Federation accounted for 16.4% of 1990 carbon emissions. Thus, with U.S. indicating it will not ratify, and alone responsible for almost 34% of 1990 emissions, Russian ratification is necessary for entry into force. With the EC, Japan, and other smaller countries having already ratified Russian ratification is nearly sufficient, all that is needed in addition to Russia is Poland. Canada and Australia, where ratification may not succeed, can neither assure nor block entry into force. The Russian allocation under the Kyoto Protocol also seems to have figured in the U.S. rejection of the Kyoto Protocol. U.S. President Bush, rejected the Protocol as "fatally Flawed." One concern expressed by the U.S. Administration was that the U.S. would need to rely on untested flexibility mechanisms, like permit trading and CDM, to make U.S. costs of meeting the Protocol acceptable. Studies of the Kyoto Protocol show that the availability of Russian hot air, as well as further low cost real reductions there, and in other transition economies like Poland, greatly reduce the price of carbon and welfare impacts in the U.S., compared with a no trading case. These same estimates show the external flow of funds to Russia from the U.S. for the purchase of credits on the order of billions of dollars per year.

Since the withdrawal from Kyoto Protocol negotiations, the U.S. is proposing an alternative strategy, to slow the growth of U.S. greenhouse gases (GHG) emissions. The main goal is to reduce greenhouse gas intensity by 18 percent over the next 10 years, through a policy of voluntary reductions and some tax incentives for renewable energy use. U.S. President Bush's target, by the Administration's own estimates, would require only about 100 MtCe reduction from reference, compared with more than a 650 MtCe reduction required to meet its Kyoto target (Reilly, et al., 2002). Others have shown that even under reference projections (i.e. without any specific climate change policy) the U.S. might achieve the new intensity target (Viguier, 2002; de Moor et alii, 2002). The main focus of the plan is on domestic reductions, and it appears at this time not to include an international permit trading system. We have assumed the new U.S. system is purely domestic, and so the U.S. would not be part of an international permit trading market. In the absence of U.S. participation, the prospects for international markets in carbon emissions permits change drastically. According to most evaluations, the equilibrium price in 2010 was expected to be in the range of 50 to 100 US dollars when all Annex B regions participate in the trading regime, including the U.S. Without the U.S., the emission credits allocated in excess to Russia and other CIS countries (hot air) might be approximately enough to satisfy the potential demand by Annex B countries, even if the latter were not to implement a domestic abatement policy. In other words, the international clearance price of carbon permits approach zero. In fact, many of the Annex B countries that have ratified are actively developing GHG mitigation policies that would further depress the market demand for carbon permits. Their underlying reasons for implementing costly policies when hot air may be available for near-nothing vary.

In this context, the Russian Federation and the Ukraine have a strong incentive to adopt monopolistic behavior, and sell only a share of available permits from the hot air in order to maximize revenues from permits sales. Such a behavior is not at all inconsistent with the Kyoto Protocol. Parties are under no requirement to make full use of the flexibility mechanisms, and the Protocol includes specific provisions on banking, the possibility to save unused permits for credit against commitments in later periods.

The incentive for monopoly behavior by the Russian Federation and the Ukraine have been analyzed elsewhere, both before (Burniaux, 1998; Bernstein, et al.,1999) and after the withdrawal of the U.S. from the Kyoto Protocol. With the U.S. in the Protocol, estimates of the international trading price with optimal monopolistic behavior by Russia and the Ukraine increases on the order of 38% (Burniaux, 1998) to 43% (Bernstein, et al.,1999). The trading price in these studies is, in turn, nearly three times the domestic marginal cost in the Russia, reflecting the fact that Russia would then undertake much less real domestic reduction. Recent studies (Babiker et al.,2002; Bernard and Vielle, 2001; Blanchard and Criqui, 2002; Böhringer, 2001; Ciorba et al., 2001; den Elzen and de Moor,2001; Manne and Richels, 2001) have also considered Russian monopoly power with the withdrawal of the U.S. The studies generally find that it is optimal for Russia and the Ukraine to sell only about 50% of the hot air available with the equilibrium price of permits ranging from 20$ to 57$.

One of the key findings of CGE modeling of greenhouse gas mitigation is that climate policy can have strong effect on welfare for some countries through a terms of trade effect. The main effect occurs through international fossil energy prices. As oil and gas are a major source of export revenue for the Russia, this effect is potentially important in evaluating an optimal strategic response by them. Essentially, by restricting carbon permits sales, Russia would force greater reductions of energy use in the other Annex B countries. This, in turn, would cause a greater reduction in the international producer price of fossil fuels than without the permit sales restrictions. Russia would thus face a loss of export revenue due both to declining quantity and price of oil and gas exports. The optimal decision is thus a tradeoff between increasing gains from permits sales and reductions in oil and gas revenue.

Still another issue that has arisen is that it may be in the interest of Parties to bank permits for use in future periods, and such banking is allowed under the terms of the Kyoto Protocol. In the simplest case, banking would be desirable if, absent banking, the permit price was expected to rise at greater than the discount rate. It would then make sense to hold back sales of permits (reduce emissions further in earlier periods) to slow the rate of permit rise to the discount rate. In this regard emissions permits are a scarce resource and the problem is to optimally allocate them over time. Thus, similar to the oil market, observed prices for permits may include both 'Hotelling' scarcity rents, reflecting Parties interests in allocating permits over time, and monopoly rents reflecting the exercise of monopoly power by some Parties. That is, the failure of Russia to sell all of its permits, would not by itself be evidence of the exercise of monopoly power but could reflect a decision to bank based on its expectations of future demand.

To the extent these various studies have found similar or different results, the reasons for these similarities or differences are not immediately obvious. In some cases, the focus has been on banking and in others on monopoly rents. Several have looked at the purely static, one period problem of maximizing rents whereas others have considered the problem in a dynamic CGE context.[1]

Not all analysis have included the terms of trade effects, and different models can give rise to different results solely because of different assumptions about abatement opportunities. In this paper, we seek to clarify the source of differences in results. We develop a simplified dynamic model whose parameters can be set to reflect the underlying structure of more complex models. In so doing, we can better explain the conditions under which there is, or is not, room for substantial monopoly and Hotelling rents to be earned by permit sellers. Moreover, we explicitly consider the tradeoff between oil and gas revenue and permit revenue.

Actually, even if Russia has a monopolistic (or quasi-monopolistic) position in the markets for tradable emissions permits, Russia might be in competition with other flexibility mechanisms such as the Clean Development Mechanism (CDM). Annex B countries will make trade-offs between the two options, according to their comparative costs. If the net cost of Certified Emission Reductions (CERs) generated through CDM projects is less expensive than emissions permits available in the international emissions trading market, Annex B regions will prefer to buy CERs. At the equilibrium, the marginal costs will be equalized, and the "supply" function of CDM will be determined.

The aim of the paper is to simulate an international trading regime characterized by a monopolistic

[1] See the analysis done by Manne and Richels with MERGE that considers explicitly banking. The authors show that it is profitable for concerned countries to defer a substantial share of hot air for later use. Of course the incentive is higher when the U.S. does not ratify the Kyoto Protocol than when it does. According to Manne and Richels, the sales of hot air would be limited to 50 Mt of carbon in 2010 in the first case, while in the second case most of the hot air would be brought to the market (more than 250 Mt of carbon).

behavior by Russia & the Ukraine. Two profit-maximization schemes are successively assessed, a static one and an inter-temporal one. The latter considers the time horizon through (2040), in order to assess the potential gains Russia could expect with a steady increase of the carbon price over time. Following a previous study by Bernard and Vielle (2002), the simulations are implemented through a recursive dynamic inter-temporal mathematical program of optimization calibrated on two Computable General Equilibrium (CGE) model (EPPA and GEMINI-E3). Beside the working of the carbon market - including the competition from other flexibility mechanisms, in particular the CDM -, the optimization program simulates the behavior of the other Annex B regions on the emissions markets, and the effects on their income and terms of trade.

Defining a long term strategy for Russia is subject to several uncertainties; i.e. the competition with other flexible mechanisms, the future of the Kyoto Protocol, both in the relative short run (in the next budget period, just after 2012), and in the long run. How will the Framework Convention on the Climate Change evolve? What will be the participation of the U.S. and developing countries? Will Russia benefit from a future allocation of hot air, and be allowed to accumulate permits after 2012? Other uncertainties are related to the macro-economic context (i.e. economic growth in developed and developing countries) and technological change, either concerning renewable energy and efficient use of fossil energy in the various sectors.

In this paper, the optimal long term strategy of Russia is assessed under a "Kyoto Forever" scenario, implying that Annex B countries are committed to a constant level of emissions over time - the one set in the Protocol - while non-Annex B countries remain free of any commitment. We find that Russia would have little to gain from exercising monopoly power if the Kyoto Protocol were to be ratified by all of the Annex B regions, including the U.S. The equilibrium price is not far from the competitive one in that case, whatever the CGE model used to calibrate our model and whatever the assumption about Russia's monopolistic behavior (myopic or not). In the absence of U.S. participation, we find that the incentive for Russia & the Ukraine to act as a monopoly varies greatly between the two models we evaluated. Since the two CGE models give comparable marginal abatement costs curves for Russia & the Ukraine, we show that the results depend mainly on the elasticity of permits demand to changes in carbon prices.

In section 2, we present the general formulation of the inter-temporal optimization model. Section 3 deals with the calibration of the model to the outcomes of two computable general equilibrium (CGE) models of the world economy (GEMINI-E3 and EPPA-MIT). Numerical results are discussed and compared in section 4. Section 5 presents the sensitivity of numerical results to the amount of CDM available. Section 6 concludes.

2 The model

The model is presented for the most general case of inter-temporal optimization, and the case of myopic behavior will then be derived. General notations are given below, with index t representing time, from 0 to T (in the numerical model, years from 2010 to 2040). The inter-temporal character of the model stems from the possibility for Russia to bank unused permits for latter periods; i. e. to stock emissions permits associated with the hot air and through real emissions reductions.

Notations

$\bar{HA}_t$	:	available Hot Air
q_t	:	emissions abatement by Russia & Ukraine
d_t	:	demand for flexible instruments by other Annex B countries
s_t	:	abatement realized through the CDM mechanism
v_t	:	permits sold by Russia & Ukraine ($= d_t - s_t$)

p_t	:	price of permits
r_t	:	revenues from the sales of permits ($= p_t v_t$)
c_t	:	abatement cost in Russia & Ukraine
g_t	:	gains from Terms of Trade (or change from a reference situation)
π_t	:	social value of permits
S_t	:	stock of permits of Russia & Ukraine available at the beginning of year t
S_{T+1}	:	residual stock of permits of Russia & Ukraine at the end of year T
p_{T+1}	:	unit value of permits at the end of year T
i	:	discount rate (supposed constant over time)

Hot air arises because the permits allocated to Russia & the Ukraine are more than the projected reference emissions. Concerning hot air, it is conventionally defined prior to any abatement policy implemented by the Russia & the Ukraine. The total amount of available new permits is then the sum of hot air and of emissions abatement. Hot air is a function of revenues from the sale of permits, proxy of change in demand for energy in Russia & the Ukraine.

The inter-temporal optimization program can then be written in the form:

$$\max \left[\sum_{t=1,T} e^{-it} \left[r_t + g_t(p_t) - c_t(q_t) \right] + e^{-i(T+1)} p_{T+1} S_{T+1} \right] \tag{1}$$

under the constraints:

(π_t)	:	$S_{t+1} - S_t - q_t - \bar{HA}(r_t) + d_t(p_t) - s_t(p_t) = 0$
with	:	$S_1 = 0$
(μ_t)	:	$S_t \geq 0$
(μ_{T+1})	:	$S_{T+1} \geq 0$
(θ_t)	:	$q_t \geq 0$

where π_t, μ_t , μ_{t+1}, θ_t are the Lagrangian multipliers associated each of the constraints. The g_t term captures the welfare effects on Russia through the terms of trade (mainly fossil energy price) effects. The objective function represents the discounted welfare gain over the period and the first constraint describes the accumulation of permits over time. Others are non-negativity constraints. Resolution yields the Kuhn & Tucker conditions for optimality:

(p_t)	:	$\pi_t[\frac{\partial d_t}{\partial p_t} - \frac{\partial s_t}{\partial p_t} - \frac{\partial \bar{HA}_t}{\partial r_t}\frac{\partial r_t}{\partial p_t}] = e^{-it}[\frac{\partial r_t}{\partial p_t} + \frac{\partial g_t}{\partial p_t}]$
with	:	$\frac{\partial r_t}{\partial p_t} = p_t(\frac{\partial d_t}{\partial p_t} - \frac{\partial s_t}{\partial p_t}) + d_t(p_t) - s_t(p_t)$
(S_t)	:	$-\pi_t + \pi_{t-1} + \mu_t = 0$
with	:	$\mu_t = 0 \quad \text{if} \quad S_t > 0$
	:	$\mu \leq 0 \quad \text{if} \quad S_t = 0$
(S_{T+1})	:	$\pi_{T+1} + \mu_{T+1} = e^{-i(T+1)} p_{T+1}$
with	:	$\mu_{T+1} = 0 \quad \text{if} \quad S_{T+1} > 0$
	:	$\mu_{T+1} \leq 0 \quad \text{if} \quad S_{T+1} = 0$
(θ_t)	:	$q_t \geq 0$

If the non-negativity constraint on the stock of permits (μ_t) is not binding, the discounted social value π_t is constant over time[2]. Decision variables, supply of permits and emissions abatement are determined by the two relations (p_t) and (q_t). The first may be written under the form:

$$\boxed{\pi_t e^{it} = p_t \frac{1+\eta_t}{1-\zeta_t-\frac{1}{1+\varepsilon_t}}} \tag{2}$$

with : $\varepsilon_t = \frac{p_t}{v_t}\frac{\partial v_t}{\partial p_t}$ (price elasticity of permits demand)
: $\eta_t = \frac{\partial g_t}{\partial r_t}$ (effect of permits revenues on GTT)
: $\zeta_t = p_t \frac{\partial HA_t}{\partial t_t}$ (effect of permits revenues on hot air)

Relation (2) generalizes the case of myopic monopolistic behavior, in which the social value of permits is zero. When the macro-economic effects represented by η_t and ζ_t are not taken into account, the condition implies that the price elasticity of demand equals minus one. Elasticity of demand addressed to Russia takes into account the competition by CDM supply, as the former is equal to total demand for flexible instruments less the latter. Greater competition from the CDM mechanism means a decrease of the monopolistic power of Russia.

Condition (q_t) determines the optimal abatement policy, as the one that equalizes the marginal abatement cost to the social value of permits:

$$\boxed{(q_t) \quad \frac{\partial c_t}{\partial q_t} \geq \pi_t e^{it} \quad \text{with equality if} \quad q_t > 0} \tag{3}$$

It can be noted that the same modeling applies to the case where the end of period rule is defined by the residual value of permits p_{T+1} and the case where it is defined by a minimal stock S_{T+1}, as there is obviously a direct monotonic relation between the two. Numerical resolution of the model will be performed with a constraint on the stock, and discussion will bear on the likeliness of the associated value of permits.

Formulas (2) and (3) also apply to the case of myopic monopolistic behavior. The difference is that the social values of permits at each period of time are not linked together. Two regimes are then possible. In the first regime, the available stock of permits (resulting from hot air) is bigger than demand; the social value of permits is equal to zero, and the optimal abatement by Russia is zero. In the second one, the supply meets the demand at a price which is smaller than the monopolistic one, determining the effective market price. The difference with the competitive case is that the social value of permits is smaller, which implies that optimal abatement is also smaller.

3 Calibration of the model with two CGEs

Resolving numerically the model requires that the different functions and/or curves appearing in the optimization model are estimated or calibrated. The methodology we implemented was to estimate functions set out above from simulation results of two CGE models, EPPA (Babiker et al. 2001) and GEMINI-E3 (Bernard and Vielle, 2000). Specifically, we simulated each of these models across wide range of carbon constraints so that the resultant fitted response functions capture model behavior over the full range of results we later evaluate with our dynamic simulation model.

The Emissions Prediction and Policy Analysis (EPPA) model is a recursive dynamic multi-regional general equilibrium model of the world economy that has been developed for analysis of climate change policy. Previous versions of the model have been used extensively for this purpose (e.g., Ellerman and

[2] Equivalent, in the present case, to the Hotelling law.

Decaux, 1998; Jacoby and Sue Wing, 1999; Reilly and alii 1999 Babiker and alii 2000; Ellerman and Wing, 2000). A specific version of the model (EPPA-EU) including a detailed breakdown of the European Union and incorporating an industry and a household transport sectors for each region has been developed (Viguier and alii, 2001; Babiker and alii, 2001). EPPA is built on a comprehensive energy-economy data set (GTAP-E[3]) that accommodates a consistent representation of energy markets in physical units as well as detailed accounts of regional production and bilateral trade flows. The base year for the model is 1995 and it is solved recursively at 5-year intervals. The version of EPPA used here includes some recent updates as described in Babiker et al., 2002. It includes endogenous estimation of the cost of abatement of non-CO2 greenhouse gas emissions CH4 , N2O, HFCs, PFCs and SF6) but for comparability with GEMINI-E3, we considered only a constraint on carbon emissions to develop the response functions estimated here. Other revised features of this model include greater detail in the electricity sector so that fossil, nuclear, hydro, biomass, and solar & wind electric generation are explicitly treated; reevaluation of fossil energy resources, improved representation of recent developments in Chinese energy use, and reevaluation of trends in energy efficiency improvements. Among the developed countries and Russia, the focus of analysis here, the energy efficiency of the electric sector is modeled as improving at a rate of 0.40 to 0.45 percent per year while non-electric sectors increase in energy efficiency by 1.2 to 1.3 percent per year.

GEMINI-E3 is a multi-country, multi-sector, dynamic General Equilibrium Model incorporating a highly detailed representation of indirect taxation (Bernard and Vielle, 2000). For some purposes, namely the assessment of energy policies directly involving the electric sector, e.g., implementation of nuclear programs, the model can incorporate a technological sub-model of power generation better suited for comparing investments in different types of plants. We use the third version of the model that has been especially designed to calculate the social marginal abatement costs (MAC), i. e. the welfare loss of a unit increase in pollution abatement. Beside a comprehensive description of indirect taxation (mainly for France), the specificity of the model is to simulate all relevant markets: markets for commodities (through relative prices), for labor (through wages), for domestic and international savings (through rates of interest and exchange rates). Terms of trade (i.e. transfers of real income between countries resulting from variations of relative prices of imports and exports), and then "real" exchange rates, can then be precisely measured[4].

3.1 The set of analytical scenarios and their expected outputs

These functions and curves are:

- the *demand for flexible instruments* by non Annex B countries (other than Russia & Ukraine, and including or not the U.S. according to the case); i. e. what these countries are globally willing to purchase at a given price (or, symmetrically, what they are willing to pay for a given amount of flexible instruments, either emission permits or CDM);
- the *supply of CDM*, i.e. the amount of CDM projects (measured in terms of yearly emission abatement) which are profitable, for both contracting Annex B and non-Annex B countries, at a given price of permits;
- the *carbon prices and marginal abatement costs curves* in Russia & Ukraine, functions of the level of abatement in these countries;

[3]For description of the GTAP database see Hertel, 1997.

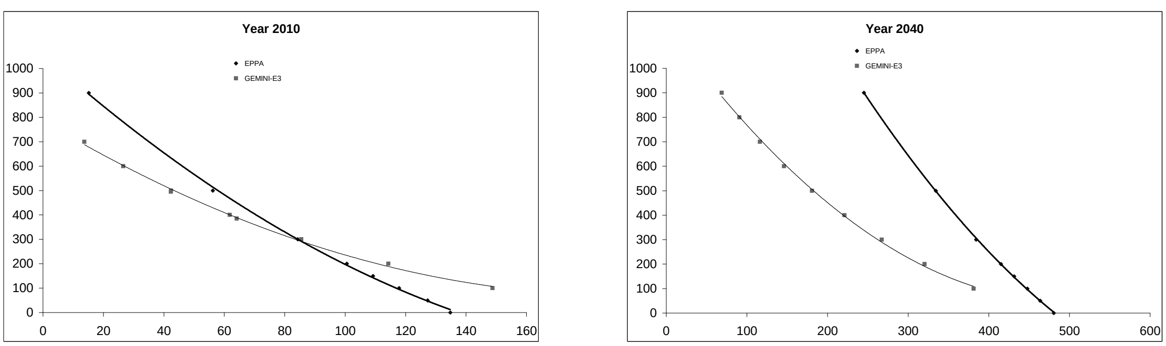
[4]The real exchange rate between two countries is the relative price of the "numéraires" chosen in each country (and usually based on a basket of goods representative of GDP). It is not identical to the monetary exchange rate of the currencies of the two countries: in particular, the real exchange rate can evolve between countries belonging to a same monetary union.

- the *curves of hot air and GTT* for Russia & Ukraine, functions of the price of permits or the revenues from permits sales by Russia & the Ukraine. They summarize the macro-economic impacts of the considered world climate change policy and the spill-over effects on Russia, more precisely the changes in these quantities resulting from the change in the Russian strategy (strategies by other countries being considered as given, and represented by the demand for flexible instruments).

3.2 Law of demand for flexible instruments

Figure 1 represents the demand curves for flexible instruments in 2010 and 2040 computed with EPPA and GEMINI-E3 with and without U.S. participation to the Kyoto Protocol. When the U.S. participates, the demands for flexible instruments estimated on the basis of the two models are closed in 2010. In the long term, EPPA gives higher prices than GEMINI-E3 at any level of permits supply by Russia. It reflects the baseline emissions projected by the two models. In the long run, the EPPA model supposes higher levels of carbon emissions than GEMINI-E3 for annex B countries. In the "Kyoto forever" scenario, it induces that abatement levels and effort rates will be more important with EPPA. As a result, carbon prices tend to be higher in EPPA in the long term.

When the U.S. does not participate, the results are much more different. Carbon prices derived from GEMINI-E3 are always higher than that of EPPA. It is partly due to the regional disaggregation of the two models. In GEMINI-E3, the Annex B is disaggregated into 5 regions: France, European Union, U.S., Japan and Former Soviet Union (FSU). The EPPA model complete this description with two other Annex B regions: other OECD Countries (OOE) and Eastern European countries (EET). The latter region plays an important role in the markets for tradable permits when the U.S. does not participate the Kyoto Protocol. Supposed to have some hot air (36 MtC in 2010) and low abatement costs in the EPPA model, Eastern European countries have the capacity to limit Russia's market power. Since EET are not represented, GEMINI-E3 cannot take into account this effect on the trading markets.



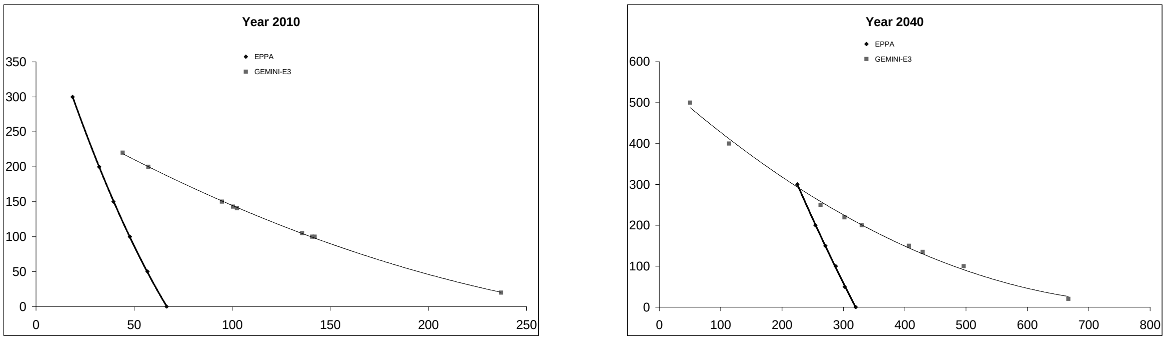


Figure 1: Demand for flexible instruments by Annex B except Russia & Ukraine (with and without U.S.)

3.3 MAC curves in Russia

Marginal abatement curves are derived by setting progressively tighter abatement levels and recording the resulting shadow price of carbon or by introducing progressively higher carbon taxes and recording the quantity of abated emissions. As explained by Ellerman and Decaux (1998), a computable general equilibrium (CGE) model can produce a "shadow price" for any constraint on carbon emissions for a given region R at time T. A MAC curve plots the shadow prices corresponding to different level of emissions reduction. MAC curves are upward-sloping curve: the shadow price of emissions reduction rise as an increasing function of emissions reduction.

Figure 2 shows MAC curves for Russia & Ukraine estimated in EPPA and GEMINI-E3. They have been plotted as a function of the amount of carbon emission reduction below reference emissions. We can see that the marginal costs of reducing carbon emissions by a given level are closed in the two models.

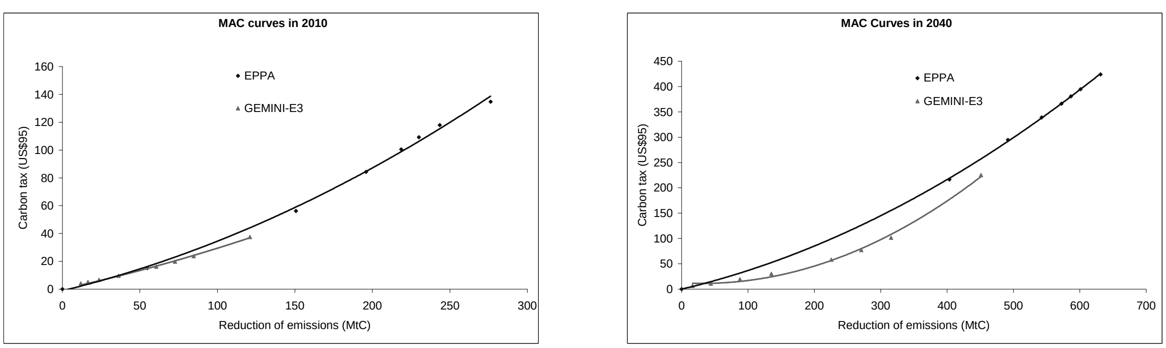


Figure 2: MAC curves in Russia & Ukraine

These curves do not represent the amount of hot air available to Russia & Ukraine in the 2010-2040 period. The size of the Russian hot air is far from being certainly established as it largely depends on GDP forecasts. The amount of hot air (in 2010) estimated by the economic models range from 150 to

500 MtC (Paltsev, 2000). In the new International Energy Outlook, the U.S. Department of Energy projects annual energy-related carbon emissions in the Former Soviet Union to rise from approximately 1036 MtC in 1990 to 745 MtC in 2010 and 884 MtC in 2020 in the baseline scenario (DOE, 2002). According to the DOE, and if we assume the terms of the "Kyoto Forever" scenario, the hot air might be equal to 291 MtC in 2010 and 152 MtC in 2020. In the EPPA model, the hot air is projected to decline from 186.5 MtC in 2010 to 41 MtC in 2020 whereas it goes from 300 MtC in 2010 to 136 MtC in 2030 in GEMINI-E3. Our study will be based on the EPPA estimates about the Russian hot air.

3.4 Curves of CDM supply

The last component of the model is the curve of CDM supply. Very few studies have been devoted to assess the potential of this flexibility mechanism. Ultimately the potential of CDM – measured in tons of carbon – can be defined as the total amount of GHG abatement in non Annex B countries at a cost less than or equal to the equilibrium price of permits.

With CDM rules yet to be fully developed, estimates of available CDM credits are fairly speculative. If fairly strict conditions of eligibility exist, and as likely, case-by-case evaluation is required to certify them, high transaction costs are likely, and the actual supply may be a small share of the total hot air; i.e. 5 to 10% or even less. We consider different levels of CDM credits to evaluate the potential impact, while realizing that estimates of the actual level will depend on how CDM rules of set. Without any reliable information, the extent of the market has been parameterized through a conventional "yardstick": *the amount of CDM (in terms of carbon emissions abated) profitable in 2010 at 100 dollars of 1990*[5] (Figure 3). Most scenarios have been performed with the assumptions of 50 ("low") and 150 ("high") millions tons of carbon. The equation used in the model is the following:

$$S_t = (1+\delta)^{t-2010} \alpha \sqrt{\frac{p_t}{100}} \tag{4}$$

where α represents the CDM parameter, and δ the annual growth of the CDM per year parameterized in this paper to 2.5%/year.

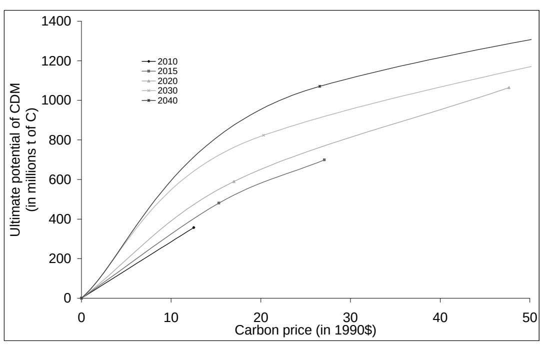


Figure 3: Ultimate potential of Clean Development Mechanism

[5]The curve is then completed assuming a function of power ½. For latter period, it is assumed than the potential at 100$ increases at the rate of world growth, 2.5 % a year.

4 Numerical results

Assessing the monopolistic behavior requires us to consider first, for comparison purposes, the competitive case where Russia & the Ukraine do not restrict its supply of hot air. Then, we assess the case where Russia & the Ukraine act as a “myopic” monopoly, and maximize their revenues at each period of time.

Finally, the inter-temporal monopolistic behavior can be evaluated. The optimal long term strategy is based on – or includes – two decision variables which are the discount rate and the value of emissions permits accumulated at the end of the whole period (alternately the minimum stock of permits remaining at the end of the period). Scenarios have been implemented for central values of these parameters; we study the sensitivity of these results to different assumptions in the next section.

4.1 Kyoto forever with the U.S.

Figure 4 shows that the equilibrium prices of permits are very similar in the three regimes, even if the competitive prices are always lower than the monopolistic ones. In other words, the carbon prices are fairly insensitive to Russian behavior when thedemand of permits is higher than the amount of hot air. We also find that the myopic monopolistic prices are lower than the inter-temporal monopolistic prices in the short term (2010-2015), and higher in the long term (2030-2040). Russia & Ukraine are better off when they have the opportunity to reduce their permits sales in the short term compared to the competitive case, and to sell the banked permits in latter periods, when carbon prices are expected to rise.

Finally, the carbon prices computed on the basis of the two models are very similar at the beginning of the simulation and diverge after 2020. Since the amount of hot air is exogenously set and MAC curves for Russia & Ukraine are very similar in the two models, this result is explained by the demand for flexible instruments derived from the models. Indeed, we saw that EPPA gives higher demand than GEMINI-E3 in the long run (see Figure 1).

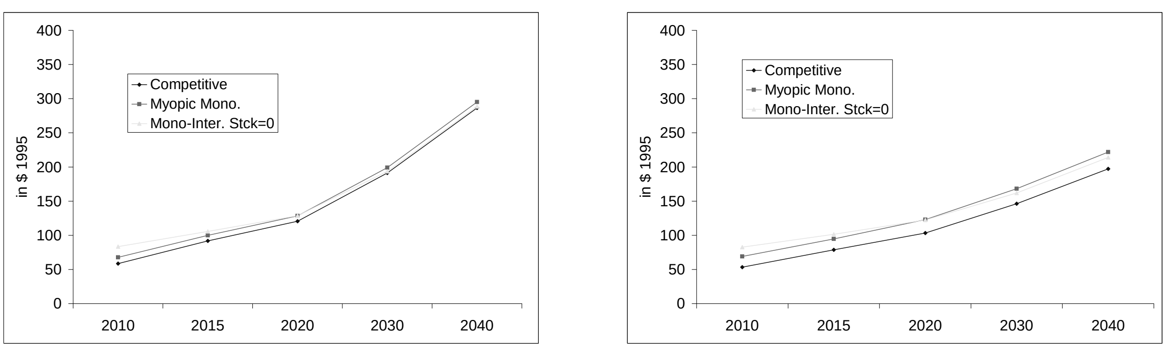


Figure 4: Price of permits depending on Russia’s behavior – EPPA (left) *versus* GEMINI-E3 (right)

In Figure 5, we can see that the amount of permits supplied by Russia & Ukraine depends on the behavioral assumption. When Russia & the Ukraine are allowed to behave strategically, they have an interest in restricting their supply of permits and to bank them. The sales of permits by Russia are always higher in the competitive case compared to the monopolistic scenarios. In the competitive and in myopic monopolistic cases, the supply of permits by Russia is always decreasing other time. This is not true in the inter-temporal monopolistic case where Russia banks some permits in order to maximize its trading gains. This result is observed with the two models, although Russia banks more permits with EPPA since carbon prices increase more rapidly in the long run than in GEMINI-E3.

As expected, Russia & the Ukraine are better off when them act as a monopoly in the emissions trading markets (Figure 6). Moreover, we can see that the gains associated with permits banking (or inter-temporal optimization) are as large as the gains from maximizing profits at each period of time. However, welfare effects are not so large when U.S. participation is assumed. Welfare[6] increases by 28 billions of US $ in Russia & the Ukraine in 2040 between the two extreme regimes with the EPPA figures and by 25 billions when the optimization model is calibrated with GEMINI-E3.

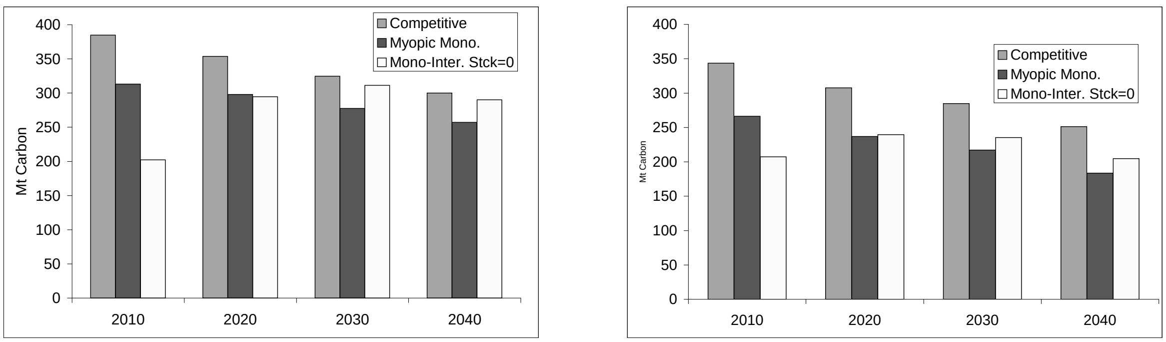


Figure 5: Supply of permits by Russia & Ukraine – EPPA (left) *versus* GEMINI-E3 (right)

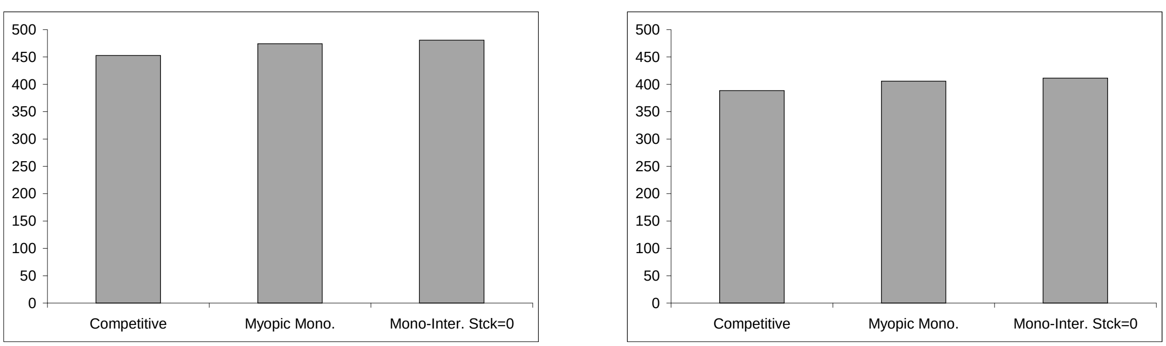


Figure 6: Discounted welfare gains for Russia & Ukraine in 2040 (billions US $ 95)

4.2 Kyoto forever without the U.S.

The U.S. withdrawal from the Kyoto Protocol has a depressing impact on the price of carbon permits (Figure 7). Both models report this negative effect of demand reduction on the trading market, although the detailed results coming from the two models differ more sharply than in the previous scenario. In the shortrun, modeling results based on EPPA and GEMINI-E3 are similar when the

[6]Discounted welfare in US $ 95 on the period 2005-2040.

market is assumed to be perfectly competitive. Carbon prices tend to rise more rapidly in EPPA than in GEMINI-E3 when Russia & the Ukraine take advantage of their market power. The demand of carbon permits is higher in EPPA at this relatively low level of carbon price.

Under the GEMINI-E3 assumptions, Russia has an incentive to behave as a monopolist, that is to restrain its supply of permits and to maintain higher carbon prices than the competitive one (figure 7 and 8). Russia has the same incentive to act strategically in the EPPA model, but the gains from monopolistic behavior are more limited. The difference comes from the fact that the curves of permits demand produced by GEMINI-E3 are flatter than the demand curves derived from EPPA. In the EPPA model, the quantity of emission permits demanded by Annex B countries is very responsive to change in prices. Since the demand of permits is very elastic to prices in EPPA, the carbon price resulting from market power is very close to marginal cost, and the monopolized markets look much like competitive one.

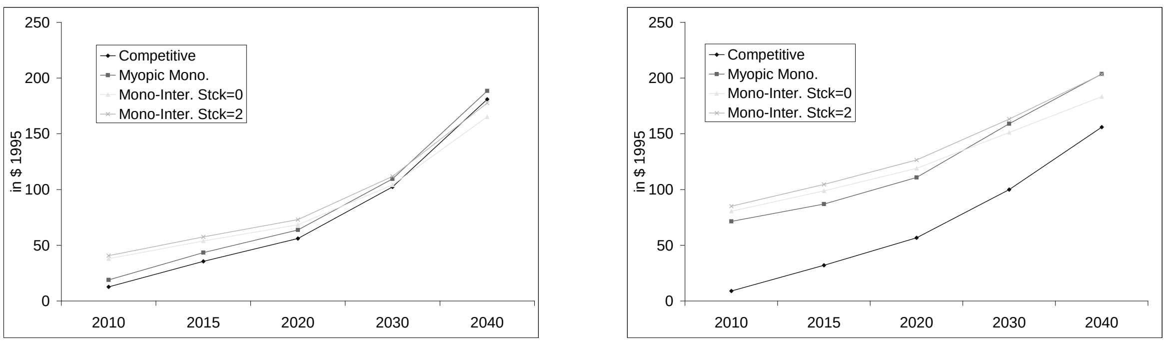


Figure 7: Price of permits depending on Russian behavior – EPPA (left) *versus* GEMINI-E3 (right)

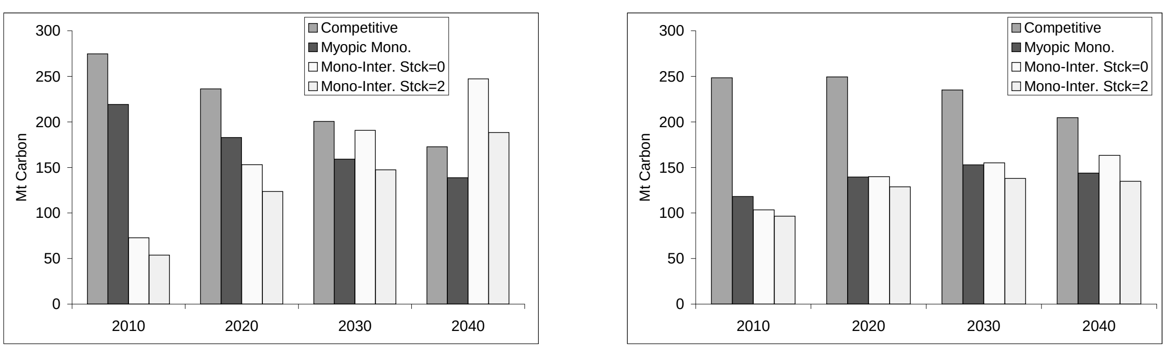


Figure 8: Supply of permits by Russia & Ukraine – EPPA (left) *versus* GEMINI-E3 (right)

One of the possible explanation for this difference between the two models is that the EPPA model, contrary to GEMINI-E3, explicitly represents Eastern European countries which are part of Annex B and have accepted a cap on their emissions. In EPPA, these countries have some hot air to sell (36 MtC in 2010 and 13 MtC in 2015) and low abatement costs. When we apply "Kyoto forever" without the U.S., and assuming a full use of the Russian hot air, the share of permits supplied by Eastern countries is closed to 18 percent in the whole period. By contrast, when, for example, the supply of hot air from Russia & the Ukraine is restricted to 50 MtC, the share of Eastern Europe in permits supply ranges from 27 to 29 percent. The demand curves from EPPA are probably steeper than that of GEMINI-E3 partly because of the permits supplied by Eastern countries. Since Russia & Ukraine compete with other regions in the emission markets, their market power is reduced. The impact of market interactions between Russia and Eastern European countries has been studied by Löschel and Zhang (2002). The authors show that the overall compliance costs of all remaining Annex B regions in the case where Russia and Eastern European countries form a sellers' cartel could reach as much as two times that in the case where only Russia acts as a monopoly. Babiker et al. (2002) also show that Eastern European countries gain substantially from exercise of monopoly power by Russia and the Ukraine; by free-riding on the cartel, Eastern Europe gains are greater (2.77 billion compared to 2.5 billion) than Russian and Ukrainian gains. Since the major Eastern European countries are expected to become part of an expanded EU, however, they may come under an EU bubble and perhaps subject to a revised burden-sharing agreement that reallocates their commitments.

The main result when the U.S. does not participate is that Russia & Ukraine are substantially worse off than with U.S. participation in emissions trading at its Kyoto target: depending on the model, welfare gains are 3 to 4 time lower than in the previous scenarios (figure 9). By contrast, monopolistic behaviors tend to have a larger effect on welfare in Russia & Ukraine when the U.S. does not participate. Moreover, welfare gains from market power are higher in GEMINI-E3 than in EPPA. This result is consistent with our previous conclusion about the slope of the demand curves: as the demand is very elastic to prices in the EPPA model, Russia & Ukraine cannot gain as much from strategic behavior.

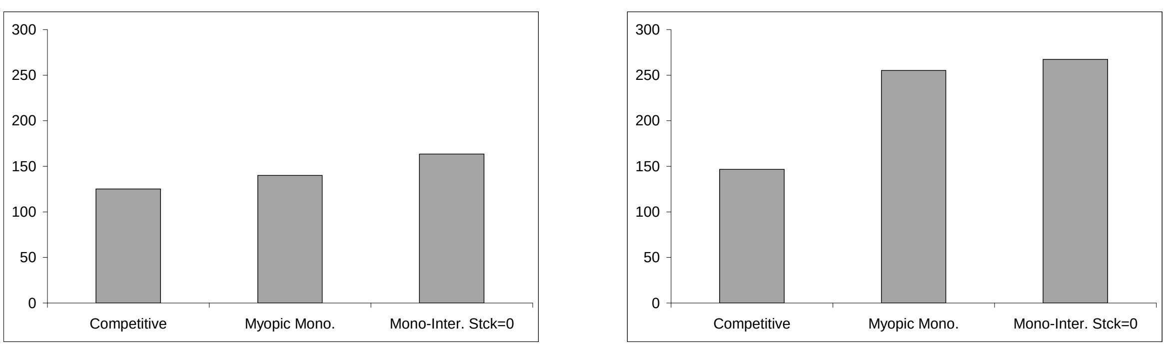


Figure 9: Discounted welfare gains for Russia & Ukraine (billions US $ 95)

5 Sensitivity analysis

In this section, we assess the sensitivity of our modeling results to exogenous hypothesis on CDM potential in developing countries. In this sensitivity analysis, we assume that Russia has the capacity to maximize its revenues from permit sales (inter-temporal optimization case). We also assume that the stock of Russian hot air is completely exhausted in 2040.

As shown on figure 10, in the short run the permits prices are relatively insensitive to the quantity of CDM whatever the MAC curves for Russia & Ukraine and the demand curves of the remaining

Annex B countries. In the long run, however, the prices of carbon permits tend to go down when more CDM is available. This is particularly true when we use the demand curves generated by GEMINI-E3. Since the demand curves are relatively flat in GEMINI-E3, carbon prices decline more rapidly when the demand of permits is reduced. When the U.S. carbon emissions are not constrained, the demand estimated with GEMINI-E3 is even more inelastic to prices in the long run. As a result, the assumption about CDM tend to have a larger impact on the price of carbon emission permits (figure 11).

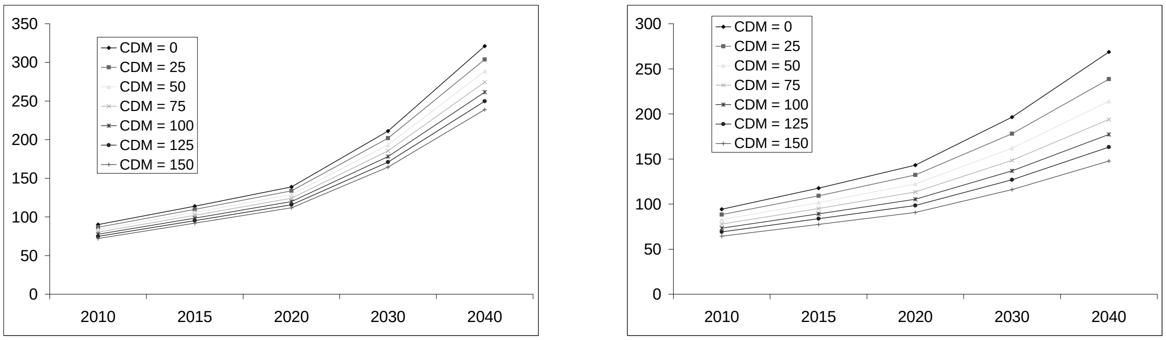


Figure 10: Price of permits with the U.S. depending on CDM potential – EPPA (left) *versus* GEMINI-E3 (right)

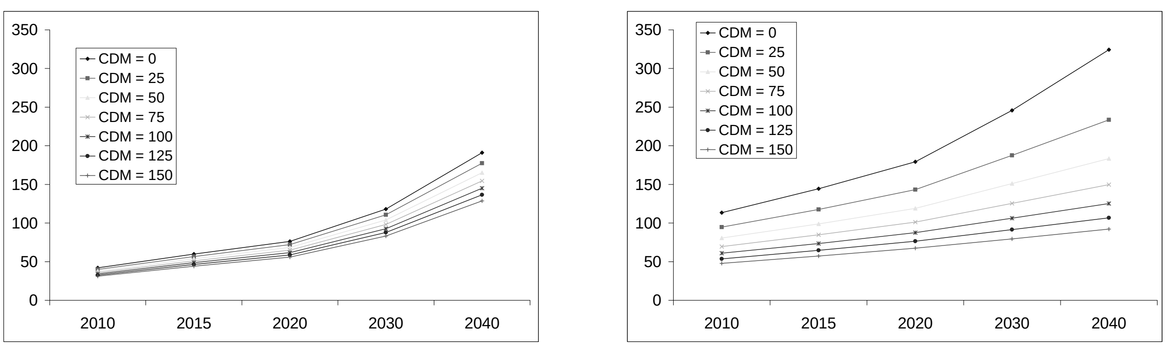


Figure 11: Price of permits without the U.S. depending on CDM Potential – EPPA (left) *versus* GEMINI-E3 (right)

6 Conclusion

The U.S. withdrawal from the Kyoto Protocol changes drastically the nature of the Kyoto Protocol, and increases the incentives for Russia and the Ukraine to exercise monopoly power. Since Russia could be a dominant supplier of emissions permits, it may be tempted to exert its market power to maximize its revenues from permits sales. As pointed in several previous papers, permits prices could rise substantially in the short run if we suppose that Russia & the Ukraine act as a monopoly. However, the existing literature is based on a static framework assuming a myopic behavior of the monopoly. In this paper, we have extended the analysis to a dynamical framework where Russia & the Ukraine could decide to bank a portion of emissions permits in order to maximize their revenues in the long run. The main teachings of our analysis can be summarized as follows:

- Independently of the U.S. decision itself, there are many uncertainties on the way the flexibility mechanisms agreed upon in Bonn and Marrakech will work and consequently will allow Annex B regions to alleviate the cost of their commitments. Beside the uncertainties related to technological change, the main uncertainties are related to the potential of CDM, the amount of hot air available in the long run, and the behavior of Russia & Ukraine on emissions trading markets.

- For both of the CGE model used to calibrate our optimization model, Russia & the Ukraine have a limited incentive to act as a monopoly or to bank credits when the U.S. participates in the Kyoto Protocol. Indeed, we found that the optimal level of permits supply of the monopoly (myopic or not) is not very far from the competitive one.

- When the U.S. does not participate, and if we assume a forward looking behavior, Russia & the Ukraine would maximize their revenues from permit sales by banking a large amount of the available hot air in 2010. The accumulation of unused permits allows Russia & the Ukraine to dominate the market well after 2040, despite the entry of CDM projects. These results are obtained with the two economic models, EPPA and GEMINI-E3.

- Since the elasticity of the permits demand of permits to carbon prices differ in the two CGE models, the impact of market power on carbon prices vary greatly from one model to another in the long run. The demand is rather inelastic to prices in GEMINI-E3 compared to the EPPA model. As a result, there is a higher incentive for Russia to act as a monopoly, and to let prices go up by restricting its supply of permits. It is however important to note that the uncertainty on the long run Russian strategy has a very limited effect in the short run, and in particular on the price of permits in 2010.

- Our results are more or less sensitive to the assumption about the potential of CDM projects available, depending on the CGE model used for the calibration. Carbon prices are not very sensitive to the size of CDM when we use the steep demand curve generated by the EPPA model. With the relatively flat demand curve of GEMINI-E3, Russia might gain a lot from a monopolistic behavior, even if a large amount of CDM is available in the long run.

Other research might be conducted in that direction. A first direction might be to address more accurately the uncertainties about the amount of hot air, the behavior of Russia, and the potential for CDM projects in the long run. It might be done through a stochastic version of our model. A second direction could be to include more accurately developing countries' behaviors in the model, and to analyze how Russia and DCs might interact strategically on the international market for carbon emissions. In our model, Russia is supposed to take into account DCs' decisions but the reverse is not true. However, one might expect DCs to determine their date of entry in trading regimes, and to set their level of permits supply, in accordance with Russian decisions, especially about the supply of hot air.

7 Acknowledgements

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