The Effects of U.S. Withdrawal from the Kyoto Protocol on International Emission Trading

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Abstract

The U.S. decision not to ratify the Kyoto Protocol changes dramatically the prospects on the actual working of the international markets for carbon emissions. When the U.S. participate in Kyoto, according to most evaluations, the equilibrium price of permits in 2010 is expected to be in the range of 50 to 100 US$. Without the U.S., it would be considerably smaller, even close to zero in some modeling scenarios. This reflects the fact that the emission credits allocated in excess to Russia and other CIS countries (hot air) will be approximately enough to satisfy the potential demand by the remaining Annex B regions, even if the U.S. implement a modest domestic abatement policy. In such a context, it is very likely that the Former Soviet Union (FSU) adopts a monopolistic behavior, that is to restrict the supply of permits in order to maximize its revenues from permits sales. Even before the recent U.S. decision, the possibility and the outcome of a monopolistic behavior by FSU have been analyzed and assessed through Computable General Equilibrium (CGE) models. However, most of the studies are based on a short-run or "myopic" approach, without consideration of the possible gains accruing from banking emissions rights, either for domestic use or for sale. In this paper, we adopt an inter-temporal approach, which is subject to several uncertainties concerning both the short term, in particular the competition from other flexibility mechanisms, and the long run (i.e. economic growth, technological change, and the future of the Kyoto Protocol). Using an optimization mathematical program calibrated on two CGE models (EPPA and GEMINI-E3), the paper shows that carbon prices are relatively unsensitive to FSU's behaviors when the U.S. is assumed to participate. It also shows that the impacts of market power by FSU is largely dependent on the elasticity of permits demand when the U.S. have no emissions constraint. Finally, we focus on the uncertainty about the supply of CDM by developing countries. It is shown that permits prices are relatively unsensitive to CDM supply in the short run but not in the long run.

Contents

1 Introduction

According to president Bush, the Kyoto Protocol is "fatally flawed" because 1) it is not consistent with the limits of our scientific knowledge, 2) it is unfair and uneffective because it excludes developing countries, and 3) Kyoto targets are unrealistic, arbitrary and not based upon science. Since the withdrawal from international negotiations, the Bush Administration is seeking an alternative strategy to the rejected Kyoto Protocol to reduce greenhouse gases. On February 14, President Bush has presented a voluntary plan 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. Considering the U.S. economic and political context, one might not expect more than a moderate gradual approach aiming at slowing emissions growth in the first round. It has been shown that the Bush plan could be easily reached, under realistic hypothesis, without any specific climate change policy (Viguier, 2002; de Moor et alii, 2002).

The prospects on international markets for carbon emissions change drastically when the U.S. do not participate and implement a very modest domestic climate policy. According to most evaluations, the equilibrium price in 2010 was expected to be in the range of 50 to 100 US$ 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 do implement a domestic abatement policy. In such a context, it is very likely that the Former Soviet Union (FSU) adopts a monopolistic behavior, and sells only a share of available permits from the hot air in order to maximize its revenues. Such a behavior is not, under any circumstance, inconsistent with the Kyoto Protocol considering its provisions on banking, and the possibility to transfer unused permits to later periods.

The incentive for the FSU to behave as a monopolistic seller of emission permits has already been analyzed, both before and after the withdrawal of the U.S. from the Kyoto Protocol. Burniaux (1998) was the first to analyze this possibility in the context of the Kyoto Protocol. Using a reduced form of the GREEN model, he assumed that FSU has the ability, by restricting its supply, to impose the market price that maximizes its net monopolistic rent. The "markup" on the price of permits offered for sale by the FSU is estimated at 170 percent (i.e. the equilibrium permit price is almost three times the marginal abatement cost). The permit price in 2010 would then reach 67 dollars of 1985 per ton of carbon compared to 48 dollars in the case of a competitive behavior. Bernstein and alii (1999) examine this issue in nearly the same context. They introduce in the MS-MRT model different markups on the price of permits offered for sale by the FSU in order to maximize its welfare. Their analysis takes into account the effects of higher permits prices on the economic performance of other Annex B regions, and the resulting spill-over effects on the FSU. In 2010, the optimal markup is estimated at 180% – corresponding to a supply restricted to 30% of hot air – , and it declines to 18% in 2030. The U.S. withdrawal from the Protocol sets a new interest for assessing the impacts of the FSU's market power. Several studies, in particular Babiker and alii (2002), Bernard and Vielle (2001), Blanchard and Criqui (2002), Böhringer (2001), Ciorba and alii (2001), den Elzen and de Moor (2001) Manne and Richels (2001) find that the competitive price of permits might fall below 10$ in 2010. Most studies converge to say that the FSU might decide to sell only 50 percent of the hot air in 2010. The equilibrium price of permits corresponding to this case range from 20$ to 57$.[1]

These previous studies analyze the issue in a *static* context, assuming that the FSU maximizes each year its revenues from the sales of permits.[2] However, the FSU has to consider constraints and

[1]The target function is not always the same. It is the revenues from sales in Den Elzen and de Moor (2001), and households' welfare in Böhinger (2001). Babiker, Jacoby, Reilly and Reiner (2002) test the two criteria and obtain that they lead to roughly the same results.

[2]Excepted the analysis done by Manne and Richels with MERGE which 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

opportunities in the long run: for example, a higher demand of permits in the medium to long run may allow a more rewarding price (in discounted value), justifying to sell less than what is justified by short run optimization. It may also be desirable for the FSU to bank permits in order to avoid, in the very long run, costly domestic abatement policies or costly purchases of permits. In other words, the optimal policy is clearly to be set in an *inter-temporal framework*, not in a succession of static optimizations. Actually, even if the FSU has a monopolistic (or quasi-monopolistic) position in the markets for tradable emissions permits, the FSU 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 behavior by the FSU. Two profit-maximization schemes are successively assessed, a static one and an inter-temporal one. The latter requires to consider a long term horizon (2040), in order to assess the potential gains when the FSU expects a steady increase of carbon price over time. Following a previous study by Bernard & Vielle (2002), the simulations are implemented through an 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 the FSU 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 the FSU 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 FSU 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 the FSU has not a very high incentive to act strategically when the Kyoto Protocol is ratified by all 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 FSU’s monopolistic behavior (myopic or not). Adversely, we find that the incentive for the FSU to act as a monopoly, and to make carbon prices go up by restricting its supply of permits, vary greatly from one model to another when the U.S. has no emissions constraint. Since the two CGE models give comparable marginal abatement costs curves for the FSU, the results depend mainly on the elasticity of permits demand to change 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.

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).

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 the FSU 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 the FSU
d_t	:	demand for flexible instruments by other Annex B countries
s_t	:	abatement realized through the CDM mechanism
v_t	:	permits sold by the FSU ($= d_t - s_t$)
p_t	:	price of permits
r_t	:	revenues from the sales of permits ($= p_t v_t$)
c_t	:	abatement cost in the FSU
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 the FSU available at the beginning of year t
S_{T+1}	:	residual stock of permits of FSU 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)

Concerning hot air, it is conventionally defined prior to any abatement policy implemented by the FSU. 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 the FSU.

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

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

under the constraints:

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

The objective function represents the discounted welfare gain over the period $t = 1, T$ and the first constraint the accumulation of permits over time. Other are non-negativity constraints. Resolution yields the optimality Kuhn & Tucker conditions:

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

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[3]. 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:

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

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

Relation (1) 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 the FSU takes into account the competition by CDM supply, as the former is equal to total demand for flexible instruments less the latter. A higher competition by the CDM mechanism means a decrease of the monopolistic power of the FSU.

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

$$\boxed{(q_t) \quad \frac{\partial c_t}{\partial q_t} \geq \frac{p_t}{1-\frac{1}{1+\varepsilon}} \quad \text{with equality if} \quad q_t > 0} \tag{2}$$

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 (1) and (2) 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 the FSU 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]Equivalent, in the present case, to the Hotelling law.

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 which has been implemented is to build these functions and curves by points from a set of analytical scenarios implemented with two CGE models, EPPA and GEMINI-E3.

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 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). A new version of EPPA including the cost of abatement of non-CO2 greenhouse gas emissions (CH_4 , N_2O, HFCs, PFCs and SF_6) is also available (Babiker and alii, 2002). EPPA is built on a comprehensive energy-economy data set (GTAP-E[4]) 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. A full documentation of EPPA is provided in Babiker and alii (2001).

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[5].

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 the FSU, 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;

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

[5] 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.

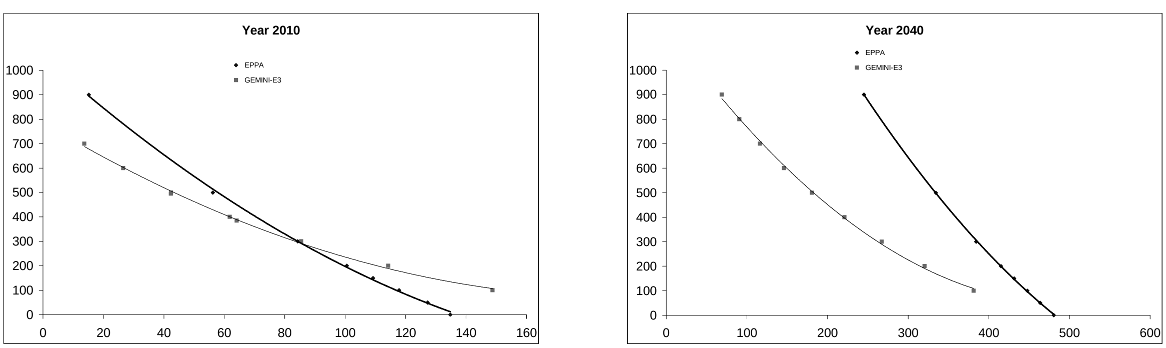
- the *carbon prices and marginal abatement costs curves* in the FSU, functions of the level of abatement in these countries;

- the *curves of hot air and GTT* for the FSU, functions of the price of permits or the revenues from permits sales by the FSU. They summarize the macro-economic impacts of the considered world climate change policy and the spill-over effects on the FSU, more precisely the changes in these quantities resulting from the change in the FSU 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 the FSU. 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 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 FSU's market power. Since EET are not represented, GEMINI-E3 cannot take into account this effect on the trading markets.



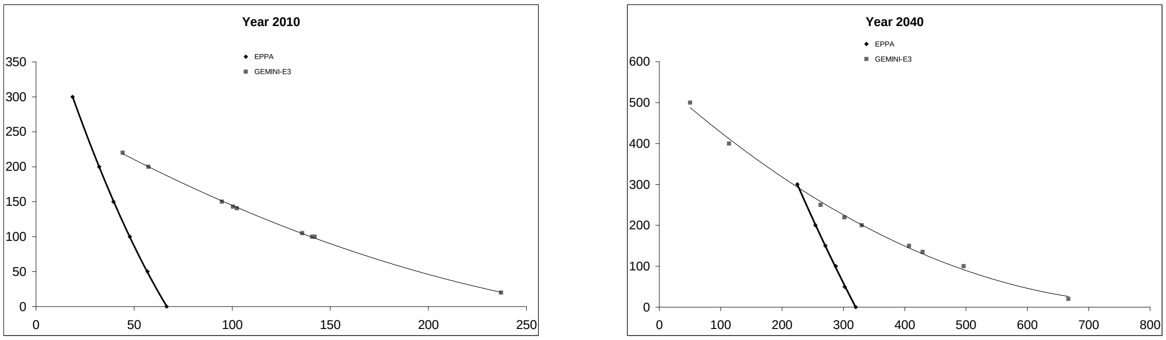


Figure 1: Demand for flexible instruments by Annex B except FSU (with and without U.S.)

3.3 MAC curves in FSU

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 the FSU 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.

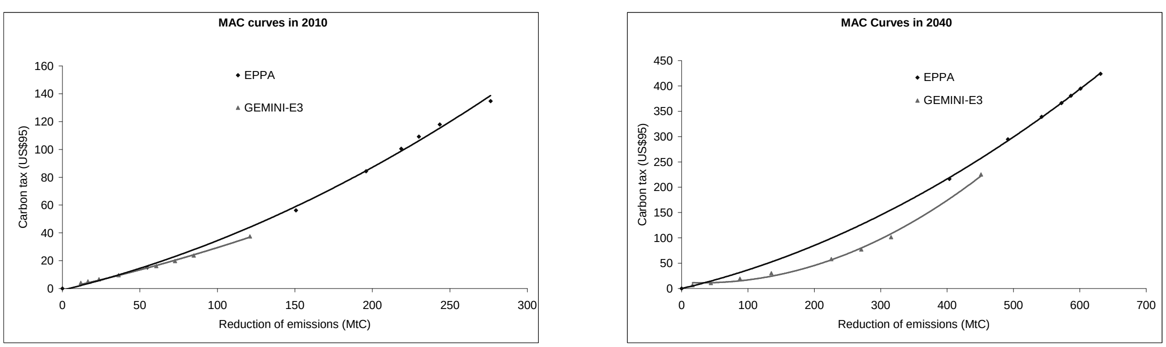


Figure 2: MAC curves in FSU

These curves do not represent the amount of hot air available to FSU in the 2010-2040 period. The size of the FSU’s 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 FSU’s annual energy-related carbon emissions 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 FSU's 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 inferior or equal to the equilibrium price of permits.

Strict conditions of eligibility and high transaction costs will bring down the actual supply to a small share of the total hot air; i.e. 5 to 10% or even less. 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*[6] (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:

$$S_t = (1+\delta)^{t-2010}\alpha\sqrt{\frac{p_t}{100}} \tag{3}$$

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

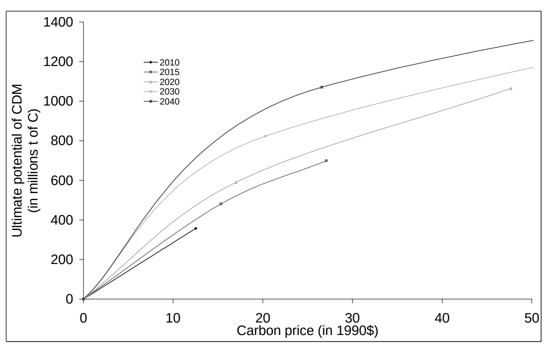


Figure 3: Ultimate potential of Clean Development Mechanism

4 Numerical results

Assessing the monopolistic behavior requires to consider first, at least as a yardstick, the competitive case where the FSU does not restrict its supply of hot air. Then, we assess the case where the FSU acts as a "myopic" monopoly, and maximizes its revenues at each period of time.

Finally, the inter-temporal monopolistic behavior can be evaluated. Optimal long term strategy is based on – or includes – two decision variables which are the discount rate and the value of emissions

[6]The curve is then completed assuming a function of power 1/2. For latter period, it is assumed than the potential at 100$ increases at the rate of world growth, 2.5 % a year.

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; a sensibility analysis will be performed in the next section to assess the stability of the results, mainly concerning the short run.

4.1 Kyoto forever with the U.S.

Figure 4 shows that the equilibrium prices of permits are very closed in the three regimes, even if the competitive prices are always lower than the monopolistic ones. In other words, the carbon prices are fairly unsensitive to FSU's behaviors when the demand 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). The FSU is better off when it has the opportunity to reduce its 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 closed at the beginning of the simulation and diverge after 2020. Since the amount of hot air is exogenously set and MAC curves for the FSU are very closed 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).

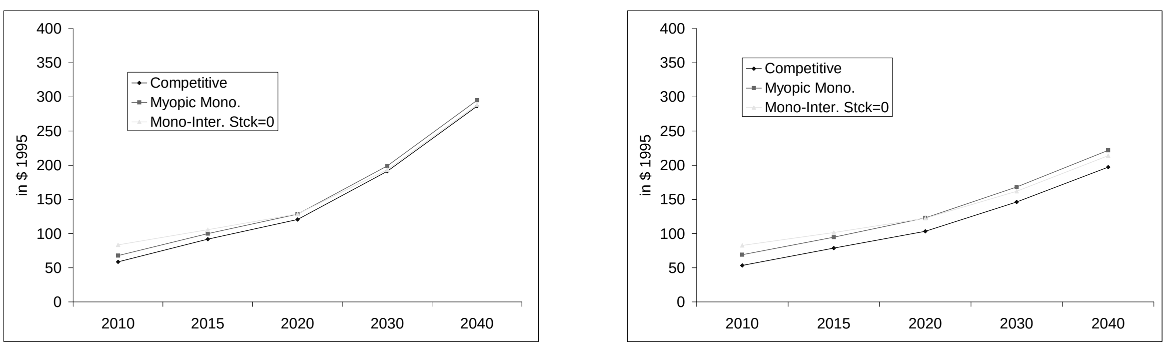


Figure 4: Price of permits depending on FSU's behavior – EPPA (left) *versus* GEMINI-E3 (right)

In Figure 5, we can see that the amount of permits supplied by the FSU depends on the behavioral assumption. When the FSU is allowed to behave strategically, it has an interest in restricting its supply of permits and to bank them. The sales of permits by the FSU 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 the FSU is always decreasing other time. This is not true in the inter-temporal monopolistic case where the FSU banks some permits in order to maximize its trading gains. This result is observed with the two models, even if the FSU banks more permits with EPPA since carbon prices increase more rapidly in the long run than in GEMINI-E3.

As expected, the FSU is better off when it acts 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. FSU's welfare[7] increase by 28 billions of

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

US $ in 2040 between the two extreme regimes with the EPPA figures and by 25 billions when the optimization model is calibrated with GEMINI-E3.

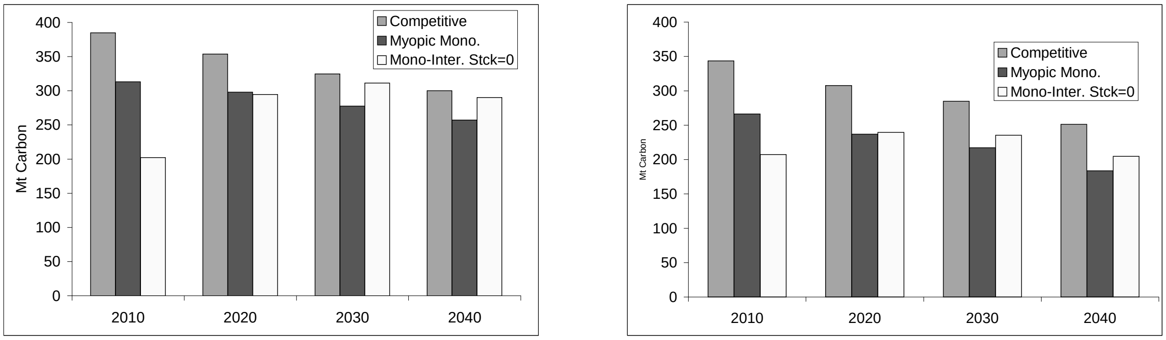


Figure 5: Supply of permits by FSU – EPPA (left) *versus* GEMINI-E3 (right)

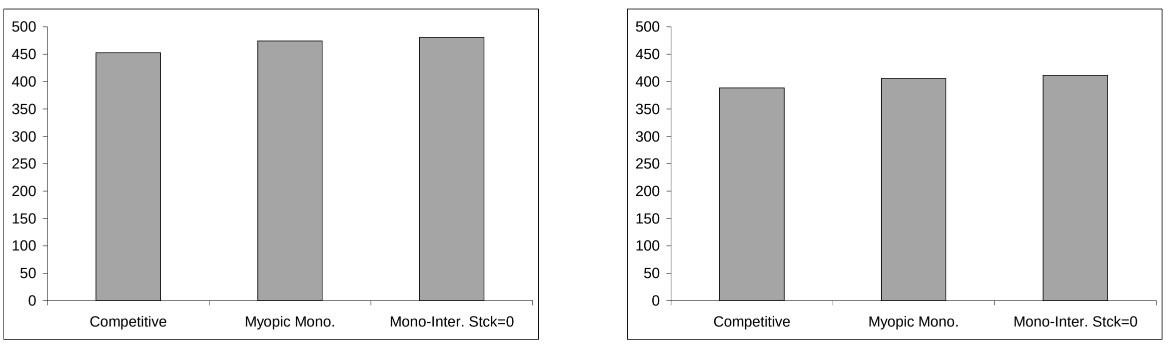


Figure 6: Discounted welfare gains for FSU in 2040 (billions US $ 95)

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). Even if the two models report this negative effect of demand reduction on the trading market, the detailed results coming from the two models are more contrasted than in the previous scenario. In the short run, modeling results based on EPPA and GEMINI-E3 are similar when the market is supposed to be perfectly competitive. Carbon prices tend to rise more rapidly in EPPA than in GEMINI-E3 when the FSU takes advantage of its market power. The demand of carbon permits is higher in EPPA at this relatively low level of carbon price.

Under the GEMINI-E3 assumptions, the FSU has an incentive to behave as a monopolist, that is to restraint its supply of permits and to maintain higher carbon prices than the competitive one (figure 7 and 8). The FSU 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 closed to marginal cost, and the monopolized markets look much like competitive one.

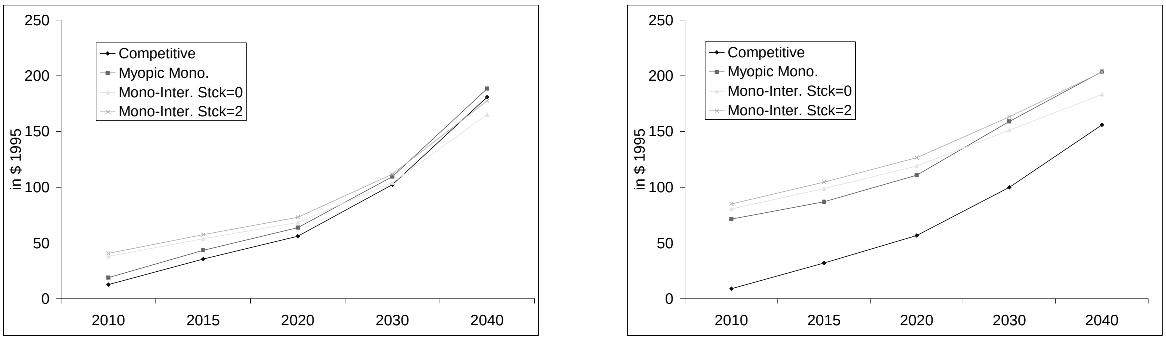


Figure 7: Price of permits depending on FSU's behavior – EPPA (left) *versus* GEMINI-E3 (right)

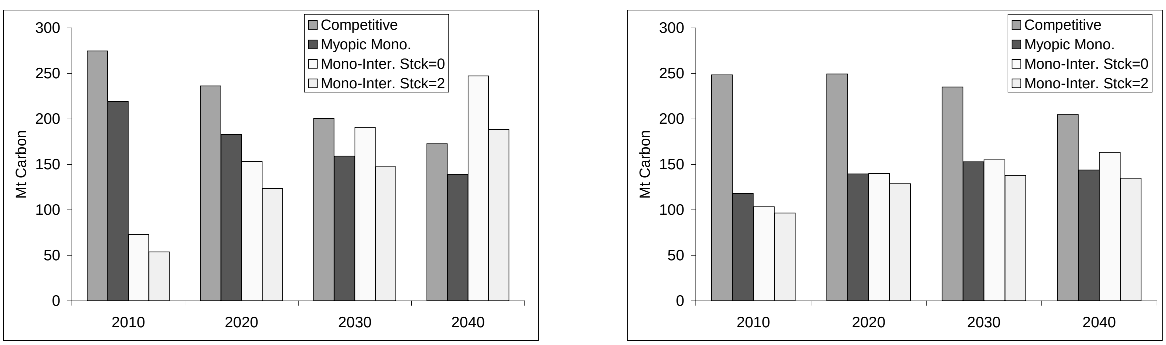


Figure 8: Supply of permits by FSU – EPPA (left) *versus* GEMINI-E3 (right)

One of the possible explanation for this difference between the two models is that the EPPA model, contrary to GEMINI-E3, does explicitly represent Eastern European countries which are part of Annex B and have accepted to cap 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 FSU's 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 the FSU 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 the FSU compete with other regions in the emission markets, its market power is reduced. The impact of market interactions between the FSU 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 the FSU and Eastern countries form a sellers' cartel could reach as much as two times that in the case where only the FSU acts as a monopoly.

As a result, the FSU is worse off when the U.S. does not participate in the emission trading markets: 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 FSU's welfare when the U.S. have no emission constraint. 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, the FSU cannot gains so much from strategic behavior.

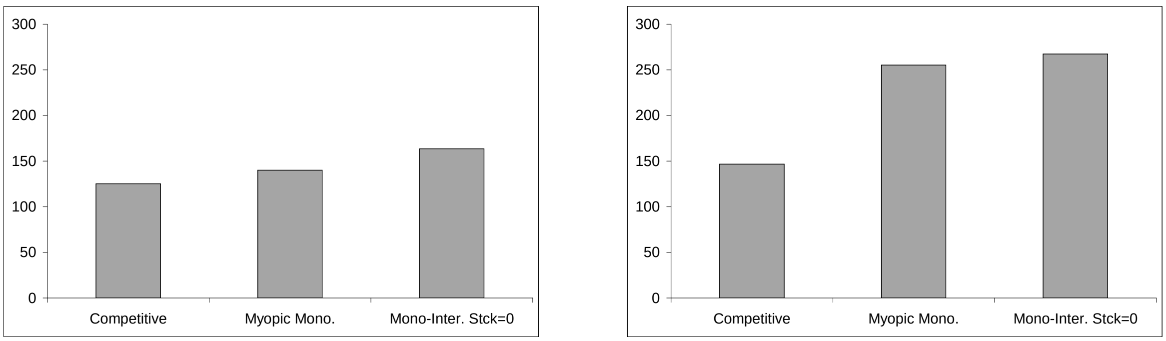


Figure 9: Discounted welfare gains for FSU (billions US $ 95)

5 Sensitivity analysis

In this section, we assess the sensitivity of our modeling results to exogenous hypothesis on CDM potential in developing countries. The uncertainty on CDM development is very high since it will ultimately depend on the progress of climate negotiations, the number of participating countries, the definition of emissions baselines, the amount of transaction costs associated with each project, etc. In this sensitivity analysis, we assume that the FSU has the capacity to maximize its revenues from permit sales (inter-temporal optimization case). We also assume that the stock of FSU's 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 the FSU 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).

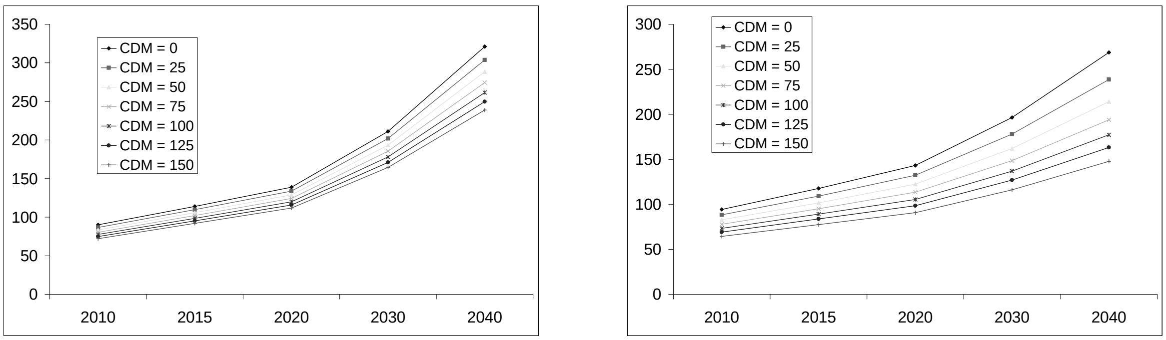


Figure 10: Price of permits with the U.S. depending on CDM potential – EPPA (left) *versus* GEMINI-E3 (right)

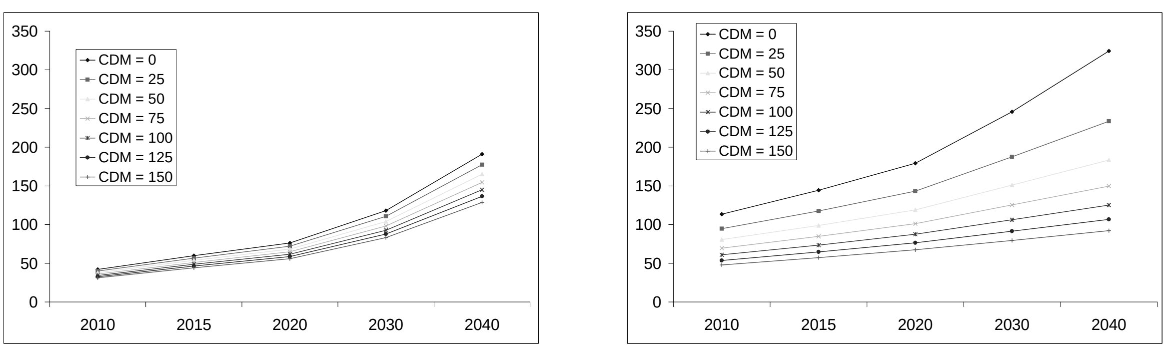


Figure 11: Price of permits without the U.S. depending on CDM Potential – EPPA (left) *versus* GEMINI-E3 (right)

6 Conclusion

The U.S. withdrawal from the Kyoto Protocol changes drastically the environmental efficiency of the agreement. It might also increase the compliance costs for the remaining Annex B regions. Since the FSU 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 the FSU 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 the FSU could decide to bank a portion of emissions permits in order to maximize its 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 the FSU on emissions trading markets.

- Whatever the CGE model used to calibrate our optimization model, the FSU has a limited incentive to act as a monopoly 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, the FSU would maximize its revenues from permit sales by banking a large amount of the available hot air in 2010. The accumulation of unused permits allows the FSU 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 the FSU 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 FSU's 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, the FSU 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 the FSU, 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 the FSU and DCs might interact strategically on the international market for carbon emissions. In our model, the FSU 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 FSU's decisions, especially about the supply of hot air.

7 Acknowledgements

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