Does Non Ratification of the Kyoto Protocol by the US Increase the Likelihood of Monopolistic Behavior by Russia in the Market of Tradable Permits?

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Abstract

After the decision by the US not to ratify the Kyoto Protocol, the prospects on the actual working of the world carbon market change dramatically. While in the case of US participation, according to most evaluations, the equilibrium price in 2010 was expected to be in the range of 50 to 100 US$, after the recent US decision it would be considerably smaller, even close to zero in some 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 Annex B countries, even if the latter implement a very modest –and a fortiori none- domestic abatement policy.

In such a context, it is very likely that Russia and its Former Soviet Union partners adopt a concerted monopolistic behavior, and sell only a share of available excess permits, in order to maximize receipts. Such a behavior is not, under any circumstance, inconsistent with the Kyoto Protocol considering its provisions on banking, and the possible transfer of unused permits to later periods.

The aim of the paper is to simulate the working of the world carbon emissions market under the assumption of monopolistic behavior by FSU. Successively are assessed two profit-maximization schemes, a static one and an inter-temporal. The latter requires to consider a long term horizon (2040), in order to assess the potential gains for FSU of an expected steady increase over time of carbon price. Simulations are implemented through an inter-temporal mathematical program of optimization calibrated on an Applied General Equilibrium model (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 all other countries, taken together, and the macro-economic effects in particular changes in the prices of international markets and the associated Gains from Terms of Trade.

Over such a long period, many uncertainties affect the strategy of FSU. Most important are the potential of the CDM mechanism and the future of the Kyoto Protocol, which is critical in determining the value of carbon in the long run. Notwithstanding, some robust results are obtained. The first is that the market price of carbon in the short run is nearly insensitive to FSU long run strategy, but very sensitive to the potential of CDM. According to a realistic range for this potential, the market price would be in the interval of 45 to 90 US$90 in 2010.

The second result concerns the macro-economic effects of US withdrawal. If, as it could be easily expected, emissions abatement at the world level is significantly reduced (nearly dropped to zero in the short run, more than halved in the long run), the welfare cost for other Annex B countries (except FSU) remains approximately unchanged. Effectively, the monopolistic power of FSU allows to sustain a high price of permits, implying a high cost of compliance of the commitments taken by Annex B countries in Kyoto, while a higher demand for fossil fuels limits the price decrease and the associated Gains from Terms of Trade for remaining Annex B countries.

Keywords: Climate Change, Kyoto Protocol, Tradable Permits, Monopolistic Behavior, Terms of Trade

JEL Classification: D58, H32, L61, Q43

Does Non Ratification of the Kyoto Protocol by the US Increase the Likelihood of Monopolistic Behavior by Russia in the Market of Tradable Permits?

After the rejection of the Kyoto Protocol by the US, the prospects on the actual working of a market of tradable permits change dramatically. While in the case of US participation the equilibrium price in 2010 was expected to be, according to most evaluations, in the range of 50 to 100 US$ per ton of carbon, after the recent US decision the competitive price would decrease significantly, even be close to zero in some scenarios. This reflects the fact that the emission credits allocated in excess to Russia and other CIS countries and known as “Hot Air” will then be approximately enough to satisfy the potential demand by other Annex B countries, even if the latter implement no –or a very limited- domestic abatement policy.

In such a context, it is very likely that Russia and its Former Soviet Union partners adopt a concerted monopolistic behavior, and sell only a share of available permits, in order to maximize receipts and/or welfare. Such a behavior is not under any circumstances inconsistent with the Kyoto Protocol considering the provisions on banking and the possibility of transferring unused permits to later periods.

Section 1 : The problematic and the methodology

1.1. Previous appraisals and main results of the existing literature

The incentive of Former Soviet Union (FSU) to behave as a monopolistic seller of its Hot Air has already been analyzed in the economic literature, both before and after the withdrawal of the US from the Kyoto Protocol. Burniaux (1998) was the first to analyze this possibility in the context of the Kyoto protocol. Basing his appraisal on a reduced form of GREEN model, he assumes that FSU has the ability, by restricting 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 in the case of a competitive behavior.

Bernstein & 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 welfare. Moreover, the appraisal takes into account the effects of an higher permit price on the economic performance of FSU trading partners and the resulting spill-over effects on 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 US withdrawal from the protocol sets anew the interest for appraising a monopolistic behavior by FSU. Several studies, in particular Babiker & alii (2002), Bernard & Vielle (2001), Blanchard & Criqui (2002), Böhringer (2001), Ciorba & alii (2001), den Elzen & de Moor (2001) Manne & Richels (2001) find that the competitive price of permit falls below 10$ in 2010.

Most studies converge, with the notable exception of Blanchard & Criqui (2002), on the approximately same result that, if adopting a monopolistic behavior, FSU would restrict by around 50% its supply in 2010. Differences are broader on the equilibrium price of permit, ranging from 20$ to 57$ as shown in the table below[1].

Table 1 : - Competitive VS monopolistic behavior of FSU in 2010
Some results in the literature

	Permit Price – Competitive behavior	Permit Price – Monopolistic behavior	Share of Hot Air offered in the market of permits
Babiker, Jacoby, Reilly and Reiner (2002)	$ 5	$ 25	50%
Blanchard and Criqui (2002)	$ 0	$ 17	10%
Böhringer (2001)	$ 0	$ 57	60%
Den Elzen and de Moor (2001)	$ 9	$ 20	50%
Manne and Richels (2001)	≈$ 0	n.a.	47% to 60%

In Blanchard & Criqui (2002) a low level of CO_2 emissions by Annex B countries in the baseline and the inclusion of sinks as agreed upon in Marrakech lead to a low demand for flexible instruments. Then FSU is induced to restrict drastically supply, to around 10% of Hot Air.

However most previous studies analyze the issue in a static context, excluding any inter-temporal optimization. Only the analysis done by Manne & Richels with MERGE considers explicitly banking, and 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 US does not ratify the Kyoto Protocol than when it does. According to Manne & 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).

1.2. The basic issues

Appraisal of the likely monopolistic behavior by FSU is fairly complex because it is to be assumed that this group of countries takes into account the impacts of its decisions on all other countries, supposed to behave in a competitive manner, and the resulting effects on all markets. Basically, FSU has two available instruments each year: i) the *amount of permits offered* in the carbon market, or equivalently the minimum price at which it is willing to sell; and ii) the *domestic abatement policy*, defined either by the amount of GHG emissions reduction, or equivalently by the domestic carbon price –not necessarily equal to the price of permit-, eventually the marginal abatement cost if the two curves differ owing to tax distortions.

In the *simplest static* framework, FSU maximizes each year the receipts accruing from the sales of permits. This is classically obtained when the elasticity of demand by other Annex B countries is exactly equal to minus one. If this demand is smaller than the amount of available Hot Air, FSU will stick to such a level of supply, discarding any costly abatement because permits available in excess mean that their opportunity cost (or social value) is zero. Unused permits will be banked and transferred to later periods, increasing the stock of available permits for sale.

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

If on the contrary the demand corresponding to the would-be monopolistic price is higher than available Hot Air, then supply is limited to the latter and the competitive behavior is the one which maximizes receipts. Permits have then a social value for FSU equal to the market price, and the optimal domestic policy is to abate up to the level where the marginal abatement cost is equal to the market price.

Clearly, as will be shown, the latter situation prevails when the US participates to the Kyoto Protocol, and the former situation when the US does not.

This *myopic* behavior has several flaws. First of all, FSU has to consider constraints and opportunities of future periods: a higher demand for 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 FSU to bank permits in order to avoid, in the very long run, costly domestic abatement policies or costly purchases of permits. Clearly the optimal policy is to be set in an *inter-temporal framework*, not in a succession of static optimizations.

A second set of factors is to be considered. The market of carbon permits may not be considered as a "small" market, without spill-over effects on other markets, either domestically or internationally. The corresponding *macro-economic* impacts of climate change policies must be taken into account.

The first effect is on international markets; directly on energy markets owing to the restricted demand for fossil energy, or indirectly on other goods and services in proportion of their carbon intensity. In particular Energy Intensive Industries are most affected by the increased cost of energy in Annex B countries (while of course they benefit from lower costs in non Annex B countries). The corresponding *Gains from Terms of Trade*, and particularly those accruing to FSU, depend on the carbon price in the market of permits, because a higher price means a higher abatement by Annex B countries, a smaller demand for energy and ultimately a smaller price of energy in international markets.

The second macro-economic effect is related to energy consumption in FSU and the effect on Hot Air. Hot Air depends on energy consumption in FSU, and can then be linked to either the price of permits (a higher price means a lower price of energy, and then a higher domestic consumption), or to the receipts from the sales of permits (a higher national income means a higher domestic demand for energy). Receipts are correlated to the price of permits, though the relation is not monotonic: increasing for low prices –below the elasticity of minus one-, then decreasing. Any of the two possible relations could then represent simultaneously the price- and the income- effect on energy demand. However, it is not anymore true when the price of permits and receipts are not directly linked, and this is in particular the case when other flexibility mechanisms considered by the Kyoto Protocol are taken into account.

Effectively, even if FSU has a monopolistic (or quasi-monopolistic) position in the market of tradable permits, it is under competition from other flexibility mechanisms and in particular the Clean Development Mechanism. Annex B countries will make trade-offs between the two, in function of their comparative costs. If the net cost of permits obtained through a CDM project is less expensive, it will be preferred to a direct purchase of permits. At the equilibrium, the marginal costs will be equalized and this determines a "supply" function of CDM.

But while the potential supply of permits by FSU represented by. Hot Air can be forecasted with a relatively good precision, the potential market of CDM is practically unknown and can only be subject to hazardous speculations. Even the conditions of eligibility of projects to the CDM are not yet precisely defined and there is wide speculation on its effective scope. At the present time, only broad assumptions can be made on the potential of CDM and on the related supply curve.

The third flexibility mechanism, Joint Implementation, has been discarded from the present analysis because it has been considered without direct incidence. This is the case for JI between two Annex B countries other than FSU, which does not change the total demand for flexible instruments. In the case of a JI involving FSU, the partners will compare it to a trade of permit, and none will be interested by a JI project which will be more costly for the "buyer", less rewarding for the provider. Then, there is no difference for each of them between an abatement of one ton of carbon performed through JI and an abatement of one ton directly realized by FSU and sold in the market of permits.

Defining a long term strategy for FSU is subject to several uncertainties and in particular, beside competition from other flexible mechanisms, on 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 evolve? What will be the participation of the US and of the developing countries? In particular will FSU benefit from a continued allocation of Hot Air, and be allowed to market accumulated permits after 2012? Other uncertainties are the macro-economic context –growth in developed and developing countries – and technology, either concerning renewable energy and efficient use of fossil energy in the various sectors.

Many scenarios can be contemplated for the future of the Kyoto Protocol, and they obviously affect the optimal long term strategy of FSU. Some are discarded from the present analysis because their results are obvious. It is in particular the case if FSU is not allowed to use accumulated permits after 2012: their residual value is zero and then the optimal behavior is to optimize receipts (or welfare) every year. This policy will leave FSU with approximately one billion tons of C of unused permits.

At the other extreme of the possible range is the assumption known as "Kyoto Forever", 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. In the absence of the US, FSU will then have enough permits from accumulated stock and new Hot Air to remain a net seller, even without any domestic abatement , till at least 2040.

An intermediate scenario would combine the possibility given to FSU to use after 2012, domestically or for sale, permits accumulated in the first budget period but no new Hot Air. The problem for such a scenario is how to set the commitments for the countries belonging to FSU.

If long term strategy of FSU is the topic of the paper, the real –and relevant- question is of a more limited scope. It concerns the short run, and more precisely the expected price of permits in the first budget period: *what is the reasonable range for the price of permits in 2008-2012, and to which risks or uncertainties is it the most sensitive?* This requires to consider a large set of assumptions on the future of the Kyoto Protocol, in particular the "Kyoto Forever" scenario which is the most favorable for FSU and offers maximum opportunities.

1.3. The methodology

Resorting to an AGE model appears the relevant approach to perform the contemplated task, and we can assume that FSU has available such a model, allowing to compare different strategies in order to determine the one which maximizes welfare taking into account all factors and all effects, direct and indirect.

However AGE models are not very tractable for inter-temporal optimization exercises, and moreover are not really “transparent”. Optimization may only result from some kind of “tâtonnement” process, unable to clarify the underlying cost-benefit analysis and the relative importance of the various effects and the main parameters. *Resorting to an explicit mathematical program of inter-temporal optimization, which takes into account all the relevant effects and costs, appears as the only way to provide sensible and understandable results in such a complex issue*.

The main difficulty, apart from writing and resolving the mathematical program, is *calibration*, in order to obtain numerical -and not only theoretical- results. This is realized through the introduction of the relevant functions and/or curves, representing on the one hand the costs and benefits for FSU, on the other hand the behavior of the Rest of the World (other countries taken all together). Functions and curves have been built by points from a great number of analytical scenarios performed with the AGE model GEMINI-E3, well adapted for this kind of assessment.

The plan of the paper is the following. Section 2 describes the inter-temporal optimization model, section 3 its calibration. Section 4 presents the results of the optimization model, under various assumptions. Section 5 is devoted to both checking the results in the comprehensive GEMINI-E3 model, and detailing the results by countries or groups of countries.

Section 6 summarizes the main teachings of the appraisal and discusses further developments of the methodology.

Section 2 : Modeling the inter-temporal optimization behavior

The 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 FSU to bank unused permits for latter utilizations i. e. to pile up a stock of permits, accumulated through available new permits and de-cumulated by sales.

Notations

$\overline{HA}_t$: available Hot Air

q_t : emissions abatement by FSU

d_t : demand for flexible instrument s by other Annex B countries (incl. or not US)

s_t : abatement realized through t he CDM mechanism

v_t : permits sold by FSU $(= d_t - s_t)$

p_t : price of permits

r_t : receipts from the sales of permits $(= p_t v_t)$

c_t : abatement cost in 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 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 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 receipts from the sale of permits, proxy of change in demand for energy in 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:

$$(\pi_t) \qquad S_{t+1} - S_t - q_t - \overline{HA}_t(r_t) + d_t(p_t) - s_t(p_t) = 0$$

$$\text{avec} \qquad S_1 = 0$$

$$(\mu_t) \qquad S_t \geq 0$$

$$(\mu_{T+1}) \qquad S_{T+1} \geq 0$$

$$(\theta_t) \qquad q_t \geq 0$$

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:

$$(p_t) \qquad \pi_t \left[\frac{\partial d_t}{\partial p_t} - \frac{\partial s_t}{\partial p_t} - \frac{\partial \overline{HA}_t}{\partial r_t}\frac{\partial r_t}{\partial p_t}\right] = e^{-it}\left[\frac{\partial r_t}{\partial p_t} + \frac{\partial g_t}{\partial p_t}\right]$$

$$\text{with} \quad \frac{\partial r_t}{\partial p_t} = p_t\left(\frac{\partial d_t}{\partial p_t} - \frac{\partial s_t}{\partial p_t}\right) + d_t(p_t) - s_t(p_t)$$

$$(S_t) \qquad -\pi_t + \pi_{t-1} + \mu_t = 0$$

$$\text{with} \quad \mu_t = 0 \quad \text{if} \quad S_t > 0$$

$$\leq 0 \quad \text{if} \quad S_t = 0$$

$$(S_{T+1}) \quad \pi_{T+1} + \mu_{T+1} = e^{-i(T+1)} p_{T+1}$$

$$\text{with} \quad \mu_{T+1} = 0 \quad \text{if} \quad S_{T+1} > 0$$

$$\leq 0 \quad \text{if} \quad S_{T+1} = 0$$

$$(q_t) \qquad \pi_t = e^{-it}\frac{\partial c_t}{\partial q_t} + \theta_t$$

$$\text{with} \qquad \theta_t = 0 \text{ if } q_t > 0$$

$$\leq 0 \text{ if } q_t = 0$$

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:

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

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

with: $\varepsilon_t = \frac{p_t}{v_t}\frac{\partial v_t}{\partial p_t}$ (price elasticity of demand for permits)

$\eta_t = \frac{\partial g_t}{\partial r_t}$ (effect of receipts from sales of permits on GTT)

$\zeta_t = p_t \frac{\partial HA_t}{\partial r_t}$ (effect of receipts from sales of permits on Hot Air)

Relation (1) generalizes the case of myopic monopolistic behavior, in which the social value of permits is zero. Effectively, neglecting the macro-economic effects represented by η_t and ζ_t, the condition implies that the price elasticity of demand equals minus one. Elasticity of demand addressed to 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 CDM means a decrease of the monopolistic power of FSU.

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

$$\boxed{\begin{array}{l} (q_t) \qquad \frac{\partial c_t}{\partial q_t} \geq \frac{p_t}{1-\frac{1}{1+\varepsilon}} \\ \text{with equality if } q_t > 0 \end{array}} \qquad (2)$$

Finally, 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.

Section 3 : Calibration of the model

Resolving numerically the model requires that the different functions and/or curves appearing in the optimization model be 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 the AGE model GEMINI-E3.

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 FSU, and including or not the US 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 permit;
- the *curves of carbon price and marginal abatement cost* in FSU, functions of the level of abatement in these countries;
- the *curves of Hot Air and GTT* for FSU, functions of the price of permit or the receipts from sales to FSU. They summarize the macro-economic impacts of the considered world climate change policy and the spill-over effects on 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).

Two broad categories of analytical scenarios have been performed, both with and without US in Annex B:

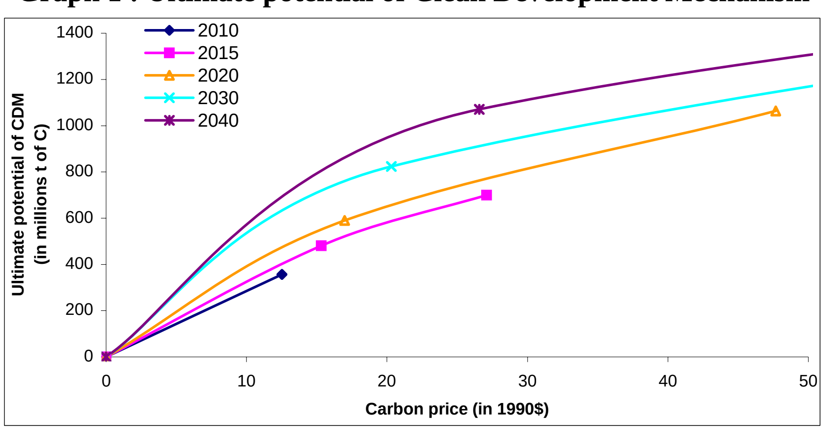
- *scenarios of supply of permits by FSU*: they correspond to different levels of supply of permits by FSU, broadly from 0 to 100% of available Hot Air, in every year.

  In theses scenarios, no abatement policy by FSU is considered, while other Annex B countries optimize their climate change policies, domestic abatement and demand for flexible instruments, through equalization of their cost or marginal cost.
- *scenarios of abatement policy in FSU*: they correspond to different levels of abatement in FSU, and under Business as Usual assumptions for all other countries.

  These scenarios are aimed at determining the curve of carbon price in FSU, i. e. the tax to be implemented in order to obtain a given level of abatement domestically. GEMINI-E3 also determines marginal abatement costs (see Bernard & Vielle, 1999, 2000, 2001) and the corresponding curve which deviates from the curve of carbon price, owing to the market and fiscal distortions existing in the concerned economies. As expected, the curve of marginal abatement cost in FSU is below the curve of carbon tax, reflecting the initial situation of heavy energy subsidization, in particular in the households' sector.

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. This yields very large figures, as shown in the graph below representing for different years the corresponding "supply curves", obtained through various simulations performed with GEMINI-E3.

Graph 1 : Ultimate potential of Clean Development Mechanism



Strict conditions of eligibility and high transaction costs will bring down the actual supply to a small share, 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*[3]. Most scenarios have been performed with assumptions of 50 ("low") and 150 ("high") millions tons of carbon.

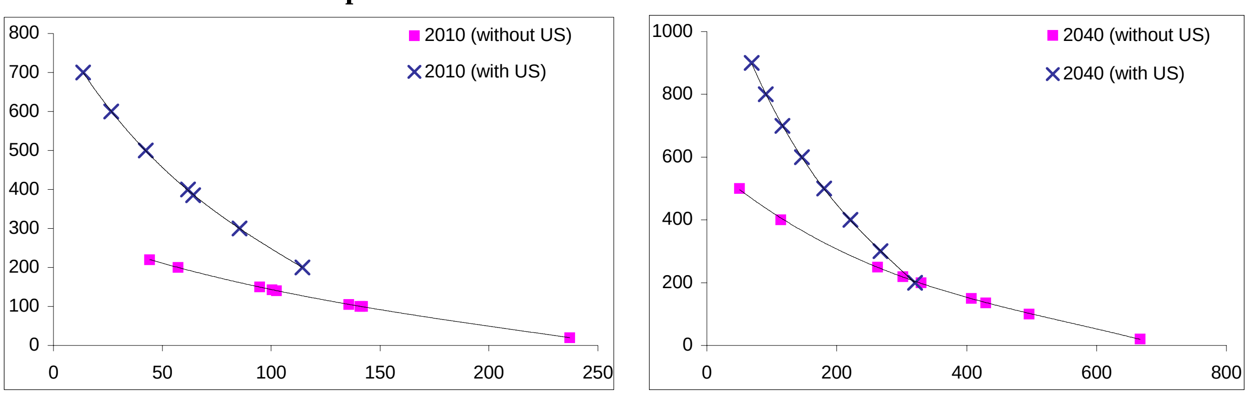
3.2. Results of analytical scenarios and representation through graphs

Results can be most clearly presented through graphs, representing the laws of demand and supply and the relevant curves. Of all the laws, demand for flexible instruments by Annex B countries is obviously the most important, because it commands the possibility for FSU to draw a significant gain by restricting supply. This law is also important because it clearly exhibits the fundamental difference between the two cases, with and without the US. In the limited format of the paper, presentation is limited to demand for flexible instruments and abatement costs.

3.2.1. Law of demand for flexible instruments

The graphs below represent in 2010 and 2040 the demand curves for flexible instruments. As expected, the curve without the US is below the curve with the US. But the most important is the associated elasticity of demand, and its relative position with respect to the value of minus one, which determines (in the static case) the monopolistic supply.

Graph 2 : curves of demand for flexible instruments



Effectively, the graphs below show that, in the case with US in Annex B, the curve is systematically above (in absolute value) the horizontal line minus one, while in the case without US the curve intersects the line.

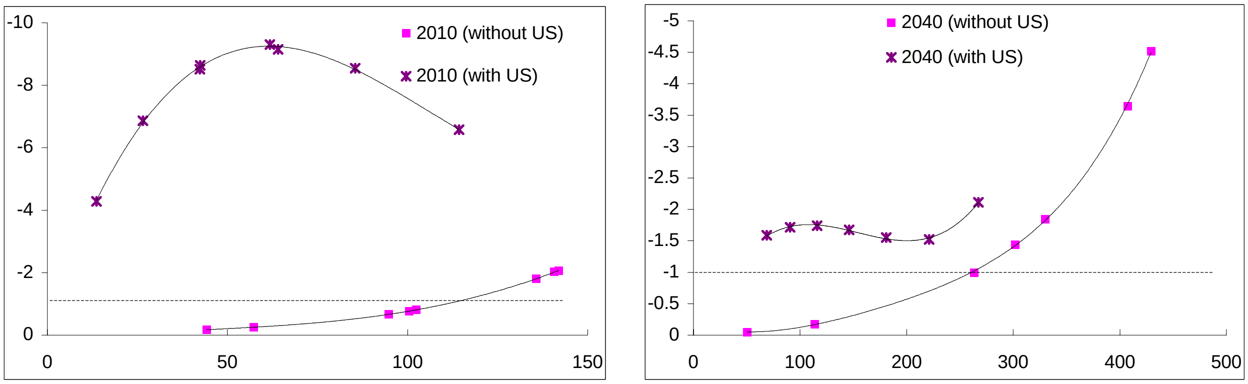
With the US in the Annex B, there is no incentive for FSU to restrict supply as receipts are maximized when all available Hot Air is brought to the market. There is moreover an incentive to abate, up to the level such as the marginal abatement cost equals the market price of permits: competitive behavior is –from a static point of view- the most profitable for countries belonging to FSU. But this is not necessarily the case in an inter-temporal optimization, and with due consideration of competition by CDM and macro-economic effects.

Without the US –and also from a static point of view-, there is a monopolistic supply which is around 120 millions tons of carbon in 2010, and 250 million tons of carbon in 2040. The

[3] 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.

associated prices are 120 and 240 US$ of 1990. As in the previous case, consideration of inter-temporal trade-offs, competition by CDM, and macro-economic effects may change significantly these results, as will be analyzed in the next section.

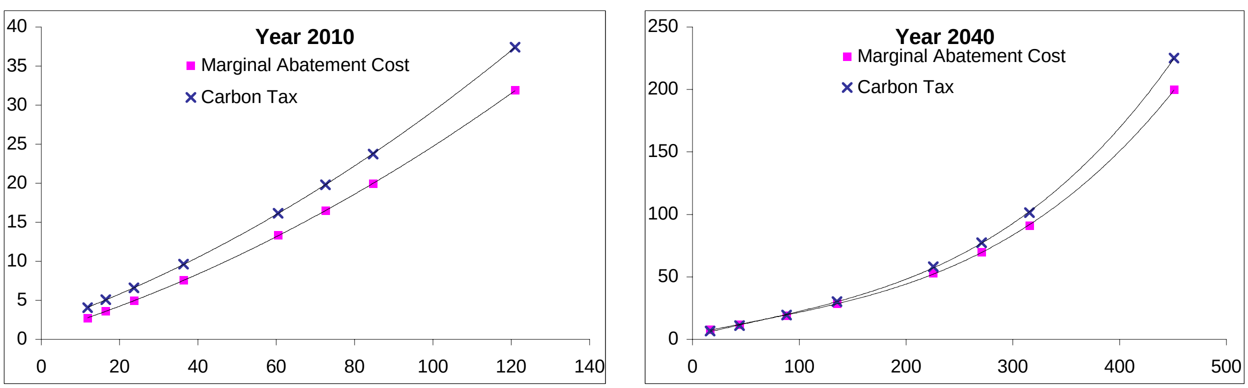
Graph 3 : curves of elasticity of demand for flexible instruments



3.2.2. Curves of carbon price and of marginal abatement cost in FSU

These curves have been determined by analytical scenarios performed in a specific context, but it can be assumed that they are robust, as they represent the possibility and the cost of abating CO2 emissions in the FSU. Results are given in the graphs below.

Graph 4 : curves of carbon price and of marginal abatement cost in FSU



Section 4 : Results of the optimization model

Appraising the monopolistic behavior requires to consider first, at least as a yardstick, the competitive case where FSU offers all available Hot Air. Examination of the monopolistic behavior then follows with the case of myopic behavior, corresponding to short-run welfare maximization. As noted above, this case is only relevant without US participation to the Protocol.

Finally, the inter-temporal monopolistic behavior can be appraised. Optimal long term strategy is based on –or includes- two decision variables which are the discount rate and the value of permits accumulated at the end of the period (alternately the minimum stock of permits remaining at the end of period). Scenarios have been implemented for central values of these parameters, and sensibility analysis performed to assess the stability of the results, mainly concerning the short run.

4.1. The competitive case

Results are presented below, with and without US in Annex B, and under the “low” CDM assumption. The equilibrium price of permits in 2010 is 35 US$90 in the first case, zero in the second case. Welfare gain if of course higher in the first case, as is domestic abatement in FSU.

Table 2 : scenario of competitive behavior by FSU with US included in Annex B

	2010	2015	2020	2030	2040
Price of permits (US$90)	35	50	66	102	150
Social value of permits (US$90)	35	50	66	102	150
Carbon Price (US$90)	41	55	73	113	168
Demand for Flexible Instruments (millions t of C)	486	512	528	532	531
Supply of CDM (millions t of C)	30	40	52	83	128
Sales of Permits (millions t of C)	457	472	476	449	402
Abatement by FSU (millions t of C)	125	165	198	288	400
Gains from Terms of Trade (millions US$90)	1152	1900	2446	3622	5203
Decrease in Hot Air (millions t of C)	4	3	7	10	11
Change in the stock of permits (millions t of C)	-336	-310	-285	-171	-13
Welfare Gain for FSU (billions US$90)	15	22	28	38	43

Table 3 : scenario of competitive behavior by FSU with US not included in Annex B

	2010	2015	2020	2030	2040
Price of permits (US$90)	0	0	16	46	90
Social value of permits (US$90)	0	0	16	46	90
Carbon Price (US$90)	1	2	18	51	100
Demand for Flexible Instruments (millions t of C)	281	339	370	394	419
Supply of CDM (millions t of C)	0	0	25	55	100
Sales of Permits (millions t of C)	281	339	344	338	320
Abatement by FSU (millions t of C)	3	8	62	171	316
Gains from Terms of Trade (millions US$90)	139	100	308	1232	2358
Decrease in Hot Air (millions t of C)	4	0	3	4	9
Change in the stock of permits (millions t of C)	-282	-331	-285	-171	-13
Welfare Gain for FSU (billions US$90)	0	0	5	13	19

Competition by CDM affects the market of tradable permits, even in the competitive case. Results of the Kyoto Protocol including CDM under the “high” assumption (150 million tons of C at a price of 100$ in 2010), which are given below, show a significant decrease in the price of permits, the welfare gain and domestic abatement in FSU.

Table 4 : scenario of competitive behavior by FSU with US included in Annex B (“high” assumption for CDM)

	2010	2015	2020	2030	2040
Price of permits (US$90)	29	41	54	78	107
Social value of permits (US$90)	29	41	54	78	107
Carbon Price (US$90)	34	46	59	87	119
Demand for Flexible Instruments (millions t of C)	527	563	593	631	680
Supply of CDM (millions t of C)	80	109	141	218	325
Sales of Permits (millions t of C)	446	454	452	414	355
Abatement by FSU (millions t of C)	114	146	173	249	346
Change in the stock of permits (millions t of C)	-336	-310	-285	-171	-13
Welfare Gain for FSU (billions US$90)	12	18	22	28	28

Table 5 : scenario of competitive behavior by FSU with US non included in Annex B (“high assumption” for CDM)

	2010	2015	2020	2030	2040
Price of permits (US$90)	0	0	10	29	55
Social value of permits (US$90)	0	0	10	29	55
Carbon Price (US$90)	1	2	11	33	60
Demand for Flexible Instruments (millions t of C)	281	339	382	420	470
Supply of CDM (millions t of C)	0	0	59	133	233
Sales of Permits (millions t of C)	281	339	323	287	237
Abatement by FSU (millions t of C)	3	8	40	118	228
Change in the stock of permits (millions t of C)	-282	-331	-285	-171	-13
Welfare Gain for FSU (billions US$90)	0	0	3	8	9

4.2. The myopic monopolistic behavior in the case without US

This scenario defines the lower bound of permits accumulation for FSU. The two tables below give, for “low” and “high” CDM assumptions, the equilibrium of the market of permits.

Table 6 : Myopic monopolistic behavior by FSU: “low” assumption for CDM

	2010	2015	2020	2030	2040
Price of permits (US$90)	71	87	104	126	143
Social value of permits (US$90)	0	0	0	0	0
Carbon Price (US$90)	1	2	1	0	-2
Demand for Flexible Instruments (millions t of C)	160	192	229	284	351
Supply of CDM (millions t of C)	42	53	65	92	125
Sales of Permits (millions t of C)	118	139	164	192	226
Abatement by FSU (millions t of C)	3	8	4	1	0
Change in the stock of permits (millions t of C)	-118	-134	-167	-197	-237
Welfare Gain for FSU (billions US$90)	9	13	18	26	35

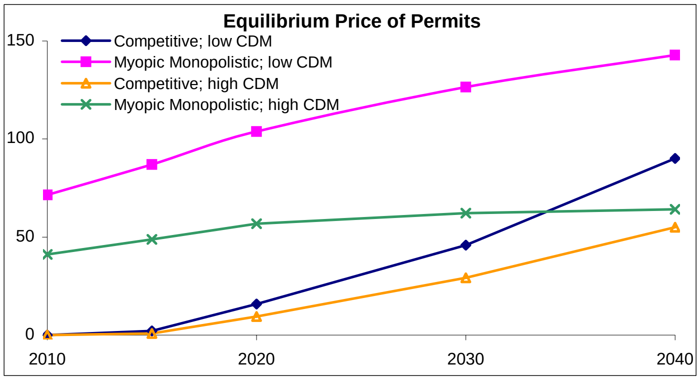
Table 7 : Myopic monopolistic behavior by FSU: “high” assumption for CDM

	2010	2015	2020	2030	2040
Price of permits (US$90)	41	49	57	62	64
Social value of permits (US$90)	0	0	0	0	0
Carbon Price (US$90)	1	2	1	0	-2
Demand for Flexible Instruments (millions t of C)	206	248	297	369	456
Supply of CDM (millions t of C)	96	119	145	194	252
Sales of Permits (millions t of C)	109	130	152	175	204
Abatement by FSU (millions t of C)	3	8	4	1	0
Change in the stock of permits (millions t of C)	-108	-123	-153	-176	-208
Welfare Gain for FSU (billions US$90)	5	7	10	12	15

Concerning accumulation of permits, the major result is the stock still available at the end of year 2040: 733 millions tons of C in the “low” CDM assumption, 1 304 millions tons of C in the “high” CDM assumption. Even prior to any inter-temporal optimization, FSU has enough available permits accruing from Hot Air to be a net seller till well after 2040.

Simulations show that FSU gets very important rents from the Kyoto Protocol, without implementing any domestic abatement policy. Discounted at the 5% rate, total welfare gain amounts to 306 billions of US$90 in the “low” CDM assumption, 152 billions in the “high” assumption. Comparative evolution of prices is given in the following graph.

Graph 5 : Carbon price in various contexts (in US$90)



4.3. The inter-temporal monopolistic behavior

For FSU, optimizing over several periods requires to set two parameters, reflecting constraints on the economy and/or preferences of the decision-maker: i) the discount rate, weighting benefits and costs accruing at different periods; and ii) the "end of period" rule, represented either by the amount of remaining permits or by their unit value.

Discount rate is not really a decision variable, as it necessarily reflects either the structural constraints of the economy (the "marginal net productivity of physical capital"), or the opportunity cost of financial capital in international markets. Uncertainty on the relevant rate requires to consider several possible values.

Forecasting the value of permits in 2040 is a difficult and risky exercise, as it reflects expectations on the possible uses of the remaining stock in the long run, with all uncertainties noted above. In the present analysis, the main considered uncertainty is the future of the Kyoto Protocol, on the one hand the commitments after 2012, on the other hand the possible –and very likely- entry of developing countries in Annex B. For instance, in the case of a "Kyoto forever" scenario with participation of all developing countries (endowed with rights equal to Business as Usual), the price of permits would be around 30 US$ of 1990 in 2040 (see Bernard & Vielle, 2001). With a much more stringent abatement target -taken at 25% below BaU for total world- and with adequate flexibility mechanisms, the equilibrium price of permits would reach 170 US$90 in 2040. This is to say that the range of possibilities is very large, even before consideration of other uncertainties.

Scenarios of inter-temporal optimization have been performed with a final stock of permits ranging from 2 billions tons of C to 8 billions, and a discount rate varying from 0 to 9%. For the simplicity of presentation, only the scenarios corresponding to a final stock of 4 billions at the end of 2040 and a discount rate of 5% are presented in detail. A sensibility analysis will afterwards show how the results vary according to the two parameters.

4.3.1. Low competition from the CDM flexibility mechanism

With the "low" assumption for CDM, the monopolistic power of FSU is not really challenged. Results are given below for the two cases, with and without the US in Annex B. in the former case, sales of permits represent 75% of Hot Air in 2010, and simultaneously FSU is induced by a positive –though significantly below the market price- social value of permits to abate, from 107 millions t of C in 2010 to 355 millions in 2040. Discounted welfare gain for FSU amounts to 475 billions US90.

Table 8: Monopolistic behavior by FSU with US in Annex B: "low" assumption for CDM

	2010	2015	2020	2030	2040
Price of permits (US$90)	78	96	115	150	195
Social value of permits (US$90)	26	33	42	69	113
Carbon Price (US$90)	31	37	47	77	126
Demand for Flexible Instruments (millions t of C)	270	309	334	373	403
Supply of CDM (millions t of C)	44	55	69	100	147
Sales of Permits (millions t of C)	226	254	266	273	257
Abatement by FSU (millions t of C)	107	125	145	230	355
Change in the stock of permits (millions t of C)	-131	-132	-138	-69	62
Welfare Gain for FSU (billions US$90)	18	24	30	37	39

Table 9: Monopolistic behavior by FSU without US in Annex B: "low" assumption for CDM

	2010	2015	2020	2030	2040
Price of permits (US$90)	77	94	112	140	166
Social value of permits (US$90)	9	11	14	23	37
Carbon Price (US$90)	11	14	16	26	40
Demand for Flexible Instruments (millions t of C)	154	183	218	268	324
Supply of CDM (millions t of C)	44	55	68	97	135
Sales of Permits (millions t of C)	110	129	150	170	189
Abatement by FSU (millions t of C)	39	51	57	96	167
Change in the stock of permits (millions t of C)	-73	-80	-100	-81	-33
Welfare Gain for FSU (billions US$90)	9	13	18	25	31

Without the US, FSU offers at the start of the period only 35% of available Hot Air and limits domestic abatement to a low level, thus imposing a fairly high price in the market (not very different from the previous case). Unsold available permits are stockpiled and progressively brought to the market, in order to compensate the decrease of Hot Air, which vanishes in 2040. Discounted welfare gain is significantly smaller than in the previous case (292 billions US$90).

4.3.2. High competition from the CDM flexibility mechanism

Results, with and without the US, are given below. The market price of permits is sharply downsized, and this is particularly the case without the US. Discounted welfare gain is brought down to respectively 351 and 144 billions US$90. Domestic abatement in FSU remains important in the case with US, very limited in the case without.

Table 10 : Monopolistic behavior by FSU with US in Annex B: "high" assumption for CDM

	2010	2015	2020	2030	2040
Price of permits (US$90)	61	73	85	108	135
Social value of permits (US$90)	20	26	33	54	88
Carbon Price (US$90)	24	30	37	60	98
Demand for Flexible Instruments (millions t of C)	343	398	442	512	579
Supply of CDM (millions t of C)	117	145	177	255	365
Sales of Permits (millions t of C)	226	253	265	257	214
Abatement by FSU (millions t of C)	88	103	119	194	313
Change in the stock of permits (millions t of C)	-142	-152	-151	-68	97
Welfare Gain for FSU (billions US$90)	14	19	23	27	22

Table 11 : Monopolistic behavior by FSU without US in Annex B: "high" assumption for CDM

	2010	2015	2020	2030	2040
Price of permits (US$90)	45	53	63	72	79
Social value of permits (US$90)	6	8	10	16	26
Carbon Price (US$90)	8	10	12	18	28
Demand for Flexible Instruments (millions t of C)	200	241	288	355	434
Supply of CDM (millions t of C)	100	124	152	208	280
Sales of Permits (millions t of C)	100	117	136	148	154
Abatement by FSU (millions t of C)	28	38	41	70	120
Change in the stock of permits (millions t of C)	-73	-80	-99	-80	-36
Welfare Gain for FSU (billions US$90)	5	7	9	12	13

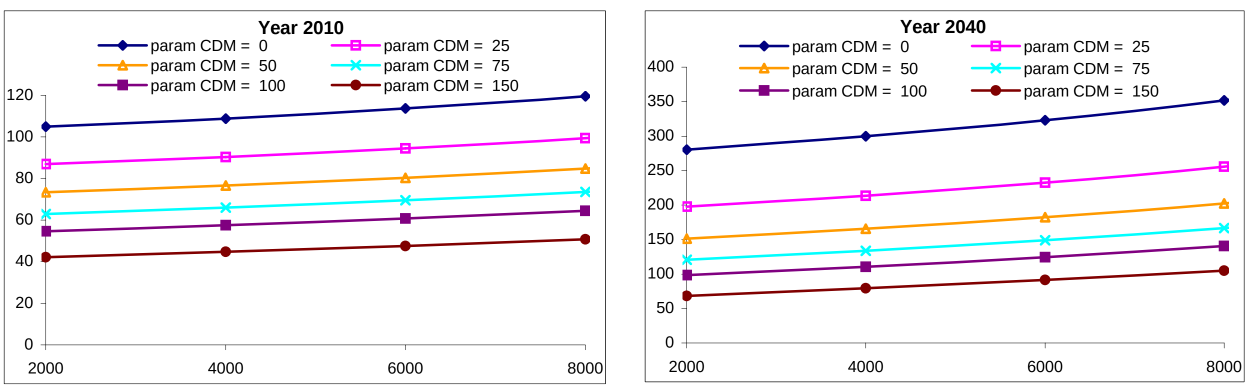
4.3.3. Sensitivity analysis

As the main decision parameters for FSU are the stock of permits (or, equivalently, the market price of permits) at the end of 2040 and the discount rate, it is important to check how the main results vary accordingly. Results are presented only for the case without US in Annex B.

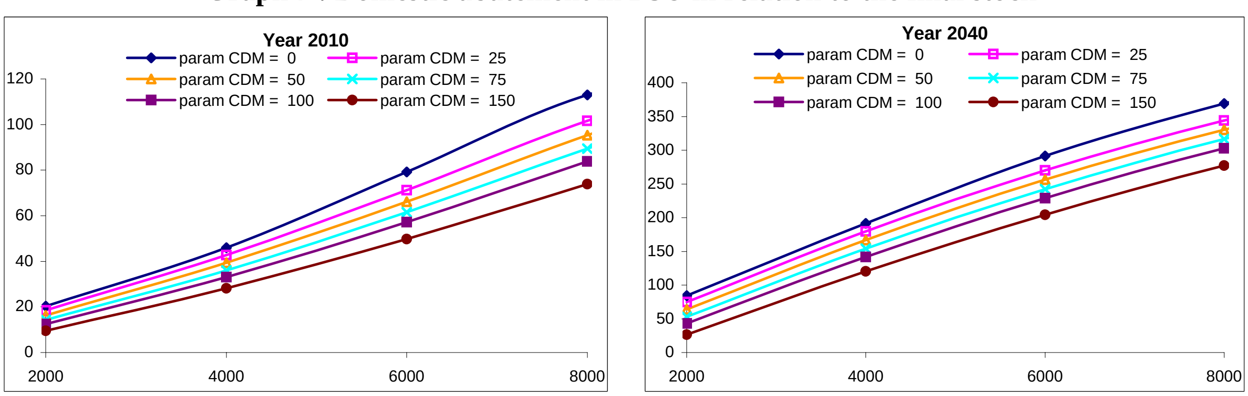
With respect to the final stock of permits

Graphs below show that the price of permits, both in 2010 and 2040, is fairly insensitive to the final stock while domestic abatement is. Symmetrically, abatement is not very sensitive to the potential of CDM flexibility mechanism while the price of permits is.

Graph 6 : Price of permits in relation to the final stock



Graph 7 : Domestic abatement in FSU in relation to the final stock

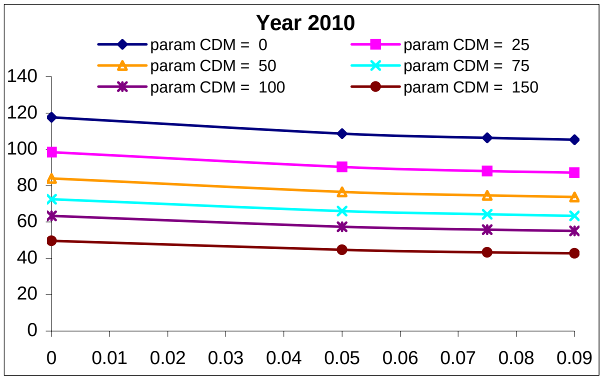


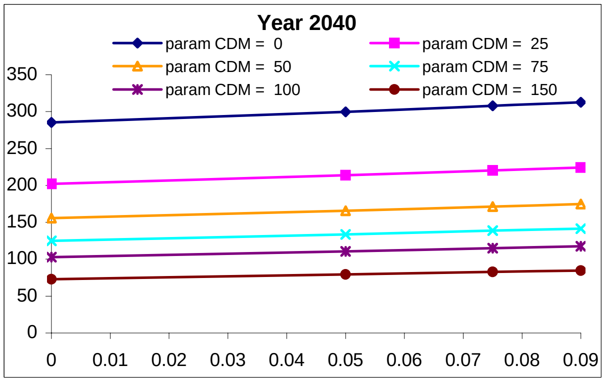
Thus, FSU has little power of imposing the price of permits on the whole period, by accumulating more or less permits for the after 2040 period. A higher or smaller stock would then mainly result from a more or less stringent domestic abatement policy.

With respect to the discount rate

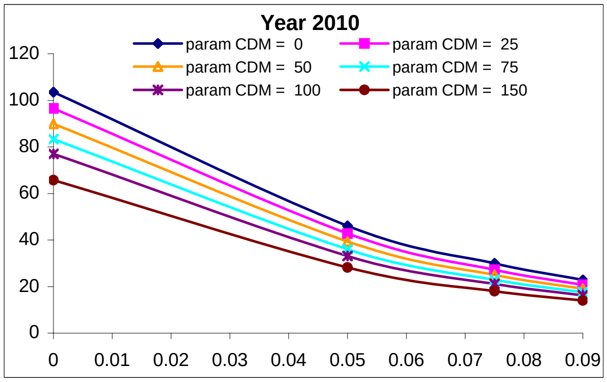
Results are represented in the graphs below for the intermediate value of the final stock of permits (4 billions tons of C).

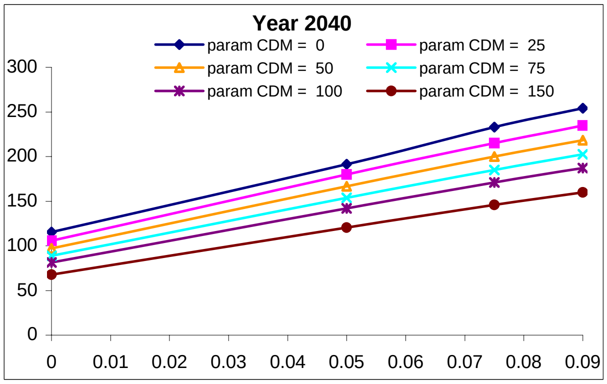
Graph 8 : Price of permits in function of the discount rate





Graph 9 : Abatement in FSU in function of the discount rate





As previously, the sensibility of the price of permits is fairly limited. On the contrary, abatement -more precisely the abatement policy over time- is very sensitive: there is proportionally more abatement in the first years (less in the last years) when the discount rate is low and, conversely, less when the discount rate is high.

Section 5 : Comparison to GEMINI-E3 and detailed results

Injecting in GEMINI-E3 the results of the optimization model, in the form of the two series of sales of permits and domestic emissions abatement by FSU, determines the associated prices, the market price of permits and the price of carbon in FSU. Comparison with the corresponding values directly obtained in the optimization model is presented below for the two central scenarios without the US, “low” and “high” assumptions regarding the potential of CDM. Results are fairly close for both prices of permits, except in 2040 where the difference is slightly more important. On the whole, it can be said that, for the concerned issue, the optimization model simulates with a very good approximation the original AGE model, thus validating the proposed approach.

Table 12 : Comparison of results of central scenarios without the US (in US$90)

		2010	2015	2020	2030	2040
"Low" potential of CDM						
Optimization model	Price of permit	86	104	124	154	182
	Carbon Price in FSU	15	19	23	36	58
	Social value of permits	12	16	20	32	53
AGE model	Price of permit	86	104	122	153	179
	Carbon Price in FSU	14	17	21	33	53
"High" potential of CDM						
Optimization model	Price of permit	50	60	69	80	90
	Carbon Price in FSU	11	14	17	26	42
	Social value of permits	9	11	15	24	39
AGE model	Price of permit	50	59	65	79	86
	Carbon Price in FSU	10	13	16	25	39

The AGE model yields detailed results by country/region, by sector, by period, and the focus will be put here on synthetic results concerning total world abatement of carbon emissions, its repartition by groups of countries and/or by types of mechanisms, and the cost through two indicators, the average world cost of the ton abated (total world cost divided by total world abatement) and the average cost for Annex B countries (except FSU and eventually US) of the abated ton. Results are presented only for the "low" CDM assumption, in the table below.

Table 13 : Balance of world emissions and average cost of abatement –"Low" potential of CDM

	2010	2015	2020	2030	2040
Case with the US					
Price of permits ($90)	76	97	116	152	198
Domestic tax in FSU ($90)	30	36	45	75	127
Abat. (Annex B)	597	706	808	1018	1295
Leakage	-56	-78	-92	-131	-177
CDM	44	55	69	100	147
Total change in em.	-585	-684	-784	-987	-1264
Total emissions BaU	8338	9211	10125	11963	13399
World abat. in %	-7.0%	-7.4%	-7.7%	-8.3%	-9.4%
World cost per t of C (in $90)	32	38	43	51	60
Cost per t of C for Annex B except FSU (in $90)	72	86	98	114	129
Case without the US					
Price of permits ($90)	75	95	111	140	164
Domestic tax in FSU ($90)	11	13	16	25	41
Abat. (Annex B)	180	215	245	333	446
Leakage	-50	-69	-80	-110	-138
CDM	44	55	68	97	135
Total change in em.	-174	-201	-233	-320	-443
Total emissions BaU	8338	9211	10125	11963	13399
World abat. in %	-2.1%	-2.2%	-2.3%	-2.7%	-3.3%
World cost per t of C (in $90)	26	30	32	32	27
Cost per t of C for Annex B except FSU (in $90)	116	146	172	193	194

The big difference between participation and non participation of the US is total world abatement, which is more than halved in the long run (around 3.5% against 9.5%). Correlatively average world cost of abatement is significantly lowered, but this is not necessarily the case for Annex B countries.

This apparent paradox can be easily explained, considering the special situation of "permanent" Annex B countries (other than US, and excluding FSU), as shows table below. Without US participation, these countries remain faced to a high international price of permits (sustained by the FSU monopolistic behavior) and then bear a high cost of abatement -whether they abate domestically or resort to flexibility mechanisms. They benefit from smaller gains from

Terms of Trade, due to a smaller decrease in energy prices. On the whole they bear a welfare cost that is higher without than with US participation. Dividing this welfare cost by a total world abatement which is significantly smaller in the case of non participation by US gives an average cost much higher.

Table 14: Welfare Cost for "permanent" Annex B in the "low" CDM assumption
(in billions of US$90)

	2010	2015	2020	2030	2040
With US participation					
Gains from Terms of Trade	6	9	11	14	19
Net Sales of Permits	-12	-18	-26	-41	-60
Deadweight Loss of Taxation	-9	-12	-16	-25	-38
Total welfare cost	-15	-22	-32	-52	-80
Without US participation					
Gains from Terms of Trade	1	2	2	2	2
Net Sales of Permits	-12	-18	-24	-38	-54
Deadweight Loss of Taxation	-10	-14	-18	-26	-34
Total welfare cost	-20	-29	-40	-62	-86

Section 6 : Teachings and further developments of the methodology

That non participation of the US to the Kyoto Protocol changes considerably its outcome and in particular the working of the flexibility mechanisms is obvious, and has been noted in several previous papers. A thorough investigation of the likely forms and effects of a monopolistic behavior by countries of Former Soviet Union (mainly Russia and Ukraine) confirms this analysis and casts a new light on the Protocol itself. Main teachings can be summarized as follows.

6.1. Main Teachings

1. Independently of US participation, there are many uncertainties on the way the flexibility mechanisms agreed upon in Bonn and Marrakech, but still to define in greater detail, will work and consequently will allow Annex B countries to alleviate the cost of their commitments. Main uncertainties, beside those related to technology, are on the one hand the potential of CDM, on the other hand the behavior of FSU. There is on the contrary less uncertainty on the amount of Hot Air available even in the long run (for a given framework of the Kyoto Protocol after 2012, here taken as the so-called "Kyoto forever" assumption).

Very few studies have been devoted to the CDM mechanism and its potential is practically unknown, only subject to speculation. Two assumptions, a "low" and a "high" have been considered in order to contrast the possible effects of the monopolistic behavior by FSU.

2. The fundamental difference brought by participation or non participation of the US is that, while in the first case FSU has not necessarily the power and the incentive to behave as a monopolist, it has clearly both in the second case. In the first case, a myopic monopolistic behavior is identical to competitive behavior because the monopolistic price is beyond what is possible with available Hot Air. It is only considerations of inter-temporal optimization –through banking- which could then induce FSU to restrict the supply of permits.

Without participation of US, and even with a myopic behavior, FSU would maximize its short run welfare by bringing not more than some 35% of available Hot Air to the market.

Accumulation of unused permits allows FSU to dominate the market well after 2040, notwithstanding the absence of domestic abatement, which is not anyway profitable. The stiffer the competition by the CDM mechanism, the higher is the accumulation of permits and then the available stock in 2040. Clearly, then, the economic problem of monopolistic behavior by FSU and the "political" problem of Hot Air are to be analyzed in the long run, not simply in the short run.

3. There is a fundamental uncertainty on the long-run behavior of FSU, because it may be profitable to go beyond this minimal level of accumulation, and this is obtained in both cases of participation and non-participation of the US. The prospects of a high value of carbon after 2040 may induce FSU to restrict supply (in the first case) or to go farther in restricting supply (in the second case). This in turn depends on the competition by the CDM mechanism, but direct sales of permits from an available stock can work as a deterrent against a system involving long term investments and all the associated risks.

Uncertainty on the behavior of FSU reflects uncertainty on the future of the Kyoto Protocol, including a come-back of the US, and the role of developing countries. Technical progress, both in renewable energy and in the efficient use of fossil fuels, is also an important factor of long-term uncertainty. But obviously, even in the most favorable institutional and technological framework, the long term value of carbon will mainly depend on the target of abatement agreed upon at the world level. Figures as different as 30 and 170 US$90 can be contemplated, and justify for FSU a limited or an important accumulation of permits for the after 2040 period.

4. It is however important to note that *uncertainty on the long run strategy by FSU has very limited effects in the short run, and in particular on the price of permits in 2010. The latter is, on the contrary, very sensitive to the potential of CDM*. Without participation of US, which is the likely assumption for 2010, the price of permits would be around 90 US$90 with "low" competition from CDM, around 45 US$90 with "high" competition from CDM. Annex B countries may then base their strategy on the expectation of a central value of 70 US$90 per ton of C, which is close to the 20 € per ton of CO_2 advocated by the European Commission.

5. It is from a macro-economic point of view that the differences between participation and non participation of US are most significant, and even somehow paradoxical. Clearly, the non participation of US considerably affects the environmental efficiency of the protocol, as total world abatement would be negligible in 2010 (2% instead of 7% of BaU), and more than halved in the long run.

However, for other Annex B countries (except FSU), the cost is approximately the same and even higher in some circumstances. This happens because the monopolistic behavior by FSU allows to sustain a high market price of permits and then makes compliance of commitments costly, whether implemented by domestic abatement or by resorting to flexibility mechanisms. Moreover, gains from Terms of Trade are less important because demand for fossil energy remains high. *The paradox is that Annex B countries (other than US and FSU) would bear a higher welfare cost for a much smaller abatement at the world level.* This highlights the inconsistency of the Kyoto protocol when a major country, notably in terms of GHG emissions, remains outside.

6.2. Further developments

In the dissymmetric situation represented by a country (or group of countries) behaving as a monopolist and facing all other countries supposed to behave as “price-takers”, the approach followed in the present analysis has demonstrated its relevance. It consists, let us recall, in devising an inter-temporal model of optimization calibrated on a world AGE model.

Possible further developments are manifold but only two will be discussed. One would be to deal explicitly with uncertainty, which is easily manageable in this type of model. Beside social values of carbon, which appear as dual variables of the optimization program, risk premia could be determined in association to the main stochastic variables, and yield some information on the volatility of the carbon market. There is for FSU a problem of “irreversible decision under uncertainty” linked to the more precise information which will be available after 2010, concerning in particular the relevance of the CDM and the future of the Protocol.

A second task would be to calibrate the same optimization program on another AGE model, which would exhibit more clearly their similarities and their differences. This appears particularly desirable because GEMINI-E3 has few regions (only 7 including Rest Of the World) and may not exactly individualize the group of Annex B countries (only defined as a “proxy”). This approximation should not impair the results which have been obtained, at least in the comparison between participation and non participation of US to the Kyoto Protocol. But this may be more damaging in the implementation of this approach to other types of problems.

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