Multi-Gas Strategy in Committing to the Kyoto Protocol

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Abstract

Though the Kyoto Protocol concerns six greenhouse gases, most appraisals in the past have focused exclusively on CO_2. But it is now acknowledged that, at least for some countries, there is an important potential of abating non-CO_2 greenhouse gases with a relatively low cost. It is then the topic of the paper to present a multi-gas assessment of the Kyoto Protocol and to compare the results with the single CO_2 case.
The assessment is done with GEMINI-E3, a world General Equilibrium Model. The first part of the paper describes the database and the methodology implemented in order to model non-CO_2 greenhouse gases. The second part presents the results of the standard No Trade Kyoto scenario, with a single CO_2 or a multi-gas strategy. Taking into account the potential of abatement of non-CO_2 greenhouse gases greatly reduces the cost of committing to the Kyoto Protocol, but exhibits significant differences between countries according to the importance of the corresponding emissions in the initial situation.

Keywords: Kyoto Protocol – Carbon Tax – Applied General Equilibrium Models
JEL: D58, Q32, Q43

Introduction

The Kyoto Protocol contemplates several flexibility mechanisms, namely tradable permits, clean development mechanism and joint implementation, but also takes into consideration six greenhouse gases. Optimization among these various degrees of liberty allow to reduce the cost of committing to targets by Annex B countries and this has been extensively demonstrated by all the studies and assessments implemented up to now.

However, most of these studies (see in particular the special issue of The Energy Journal, May 1999) have focused on a single GHG, which is effectively the most important in terms of weighted emissions, but also the best known and easiest to model as it is directly linked to fossil energy consumption. Obviously the contribution of other GHG may only be positive because the cost of abatement is usually very small in the first stages of emissions reduction, and allocating optimally the targets of abatement between the six gases may yield a welfare gain, compared to a single CO2 strategy. The question is the importance of this potential gain and whether the gain is transitory or permanent.

Some recent work has been devoted to the topic (see references in bibliography) but not yet systematized as in the case of CO_2. The issue has been considered important enough by the Energy Modeling Forum to create a specific working group in order to cope with it. Curves of abatement cost have been established by EMF for the five other GHGs, and the task of WG 21 is to assess, through several CGE models, the effects of their incorporation in the abatement strategy of the various Annex B countries.

The present paper[1] yields the results obtained with the modeling team of GEMINI-E3, which is participant to WG 21. Section I describes the methodology implemented, section II the reference (Business as Usual) case. Section III presents the results of the scenarios, the definition of which was decided in the working group, and section IV analytical scenarios aimed at explaining the main factors at work.

Main teachings are drawn in the conclusion, and possible further work considered.

I. Methodology Implemented in GEMINI-E3

I.1 The model GEMINI-E3

GEMINI-E3 was the name of the first General Equilibrium Model developed jointly by the French Ministry of Equipment and CEA (French Atomic Energy Agency). It is now the name of a family of models, including GEMINI-E3/***GemWTraP***, which is a world dynamic semi-aggregate model, and GEMINI-E3/**XL France**, which is a static detailed one-country model (France, 88 sectors).

GEMINI-E3/***GemWTraP*** is a *multi-country*, *multi-sector*, *dynamic* General Equilibrium Model incorporating a *highly detailed representation of indirect taxation*. For some purposes, namely appraisal 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

[1] Special thanks are due to EMF and in particular to John Weyant and Francisco Delachasnay for having made available to all participants a precious database concerning the non CO2 greenhouse gases.

better suited for comparing investments in different types of plants. It is the third version in succession and has been especially designed to calculate the social marginal abatement costs (MAC), i. e. the welfare loss of a unit increase in pollution abatement, and then to simulate tradable permits markets based either on market prices (carbon tax) or on social marginal costs. Trade of permits based on MACs corresponds to the optimization behavior by countries in taxation and environmental policy implementation, and is in most cases more efficient than trade of permits based on market prices or equivalents[2].

Table 1: Identification card of GEMINI-E3/*GemWTraP*

Full Name : **G**eneral **E**quilibrium **M**odel of **I**nternational-**N**ational-**I**nteraction for **E**conomy-**E**nergy-**E**nvironment/***G***eneral ***e***quilibrium ***m***odel for assessment of ***W***orld ***Tra***dable ***P***ermits
7 zones : France, Other European Countries (EU11), USA, Japan, Former Soviet Union (FSU), Energy Exporting Countries (EEC), Rest of the World (ROW)
3 Institutional Sector (IS) : Households (Incl. Private Administration), Firms, Government
12 sectors/commodities for France and EU11; **8** for USA, Japan, FSU, EEC and ROW (5 of which for Energy : coal, gas, electricity, crude oil, refined oil products)
Starting Year : 1990
Terminal Year : 2040 (with yearly steps)
Productions Functions : Nested CES with fix factors for fossil fuel sectors
Households' Demand Function : Linear Expenditure System (Stone-Geary model)
Function of Imports : Nested with domestic production (consistent with Armington assumption)
Indirect taxation and social contributions : 13 categories with rates differentiated : - by commodity (taxes on production, on imports) - by sector (social contributions, subsidies) - by sector x commodity (intermediate consumption) - by commodity x institutional sector (final demand) - by commodity x sector x IS (investment)
Linkage of periods : with endogenous real rates of interest (determined by equilibrium between savings and investment)
Linkage of national/regional models : with endogenous real exchange rates (resulting from constraints on foreign trade deficits or surpluses)
Outputs : by country, annually : - carbon taxes, marginal abatement cost and price of tradable permits when relevant - effective abatement of CO_2 emissions, net sales of tradable permits (when relevant) - total net welfare loss and components : net loss from terms of trade, pure deadweight loss of taxation, net purchases of tradable permits (when relevant) - macro-economic aggregates : production, imports and final demand (change in volume and change in price); real exchange rates and real interest rates - industry data : production and factors of production (change in volume and change in price or remuneration)

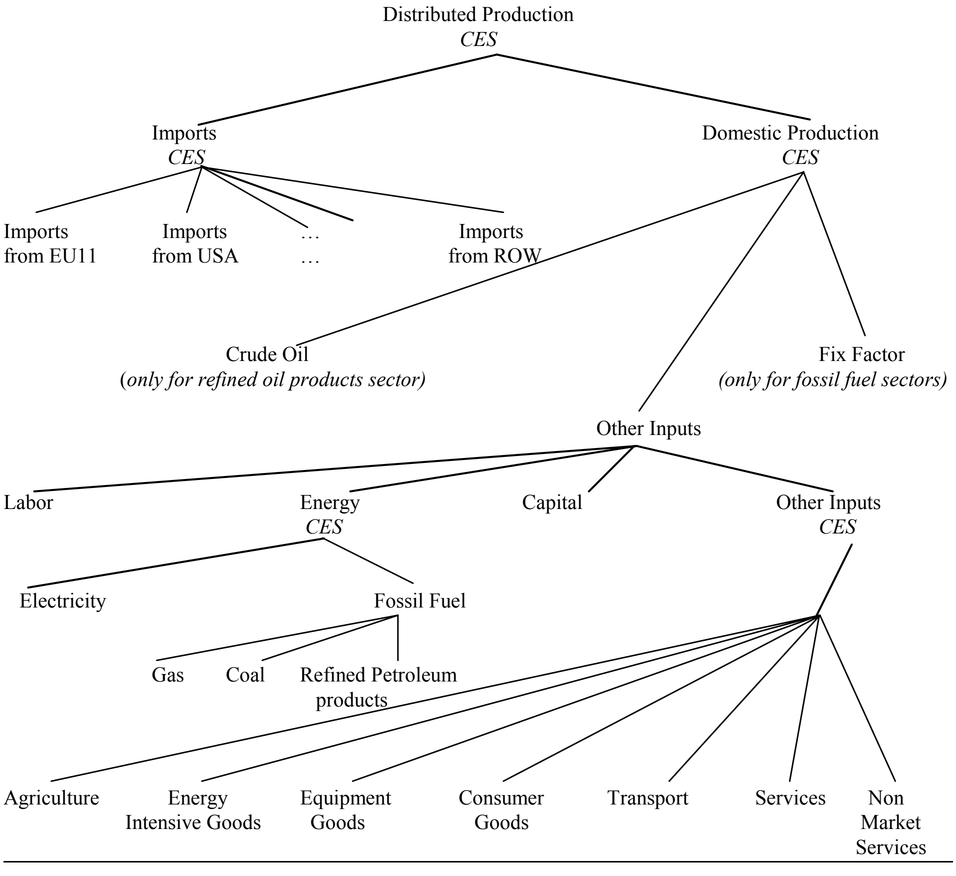
[2] See Bernard (1999) and Bernard and Vielle (2003).

Table 1 above gives an overall description and the main characteristics of the model. 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[3].

The specification of production functions

Figure 1 represents the nesting of factors in production functions, for all sectors and all countries or regions. Important parameters are the various elasticities of substitution, between imports and domestic production, between aggregate domestic factors (capital, labor, energy, other inputs), and for the two last nests, between individual fuels and between commodities.

Figure 1
Nesting of factors in the production function (example of France)



[3] 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.

Allowing more or less easy substitution between factors, they command much of the numerical results in scenarios: abatement of CO_2 emissions with a given carbon tax, and then cost of abatement; substitution of domestic factors to imports and then terms of trade, and so on. The values of elasticity of substitution employed in the model were determined according to various sources and econometric estimations.

Cost of pollution abatement: measurement and factors

Cost of abatement policies, in the various possible ways of implementation, is a key indicator of the efficiency of climate change policies. Effectively, when there exists a perfect substitute to the polluting good, or a de-polluting device, the additional cost of the good or of the device measures the welfare cost of abatement. In the case of greenhouse effect, this is rarely possible, and the bulk of abatement results from refraining from consuming polluting goods, and from replacing them by other goods and factors, through taxation and changes in relative prices. Measuring welfare cost is more complex, and in particular macro-economic aggregates such as GDP or Households' Final Consumption (HFC) are not relevant because they are calculated at constant prices, ignoring the welfare effects of changes in the structure of prices.

The only consistent measure of welfare cost is households' surplus, which can be based either on the Compensative Variation of Income (CVI) or on the Equivalent Variation of Income (EVI). Though theoretically slightly different, they yield very close results as the change in the structure of prices is limited (and energy is a small share in average production cost of the economy, as well as in households' budget). Deriving demand by households from a utility function then allows to have a direct economic measure of the welfare cost of abatement policies. Households' surpluses may be directly reckoned from the output of scenarios, for every year and every country/region, and they can be aggregated in various ways: either *weighted by exchange rates* and summed for a given year or period; or *discounted through interest rates* for a given country and then measuring the total discounted cost of the abatement policy.

For a given period, households' surplus is representative of the total welfare gain if the other elements of final demand (except exports) are held constant. This is the case of the final demand of government, which is exogenous in the model as in most general equilibrium models. Concerning productive investment, which is endogenous in the model and is sensitive to change in relative prices (and in particular to change in the relative price of consumption and capital goods), surpluses calculated annually are representative of welfare cost if its total investment - but not of course its allocation between sectors - is constrained to be constant in the scenario. Such a constraint has effectively been retained in the model[4].

In a closed economy, households' surplus reflects the pure substitution effect of taxation, i. e. the Deadweight Loss (DWL). In an open economy, income effects are added to the pure substitution effect, and they are channeled through the change in the relative prices of foreign trade. Corresponding gains or losses from "terms of trade", as they are known in the specialized literature, may be an important and in some cases a dominant part of the total welfare gain or loss for a given country (though of course, they represent transfers and consolidate at the world level).

[4] Retaining such a constraint is not necessary. It is possible to implement a simulation in two steps: first without constraint, to assess the effects on productive investment; secondly, at constant total investment, to measure welfare loss. In fact, experience shows that the effect of climate change policies on the allocation of GDP between final consumption and investment is very small.

Table 2 below recapitulates the "algebra" of welfare measurement in the case of an open economy, as described just above.

Table 2 : Algebra of Welfare Measurement

S (Total Welfare Gain)	=	ΔR (Variation of Income)	-	CVI (Compensating Variation of Income)
	=	-DWL (Deadweight Loss of Taxation)	+	G (Gains from Terms of Trade)
G	=	$\Sigma EXP\ \Delta P_{EXP}$	-	$\Sigma IMP\ \Delta P_{IMP}$
	$\cong$	$\Sigma P_{IMP}\ \Delta IMP$	-	$\Sigma P_{EXP}\ \Delta EXP$

Total welfare gain and gains from terms of trade can be computed directly from the numerical detailed results of scenarios: formulas above then determine by difference the deadweight loss of taxation, which represents the pure substitution effect of domestic pollution abatement[5].

Definition of the marginal abatement cost may appear obvious, but its precise determination is more complex. According to theoretical analysis[6], what is relevant for exchange in a market of tradable permits is the marginal abatement cost defined as the *welfare loss at constant prices of foreign trade*. On the other hand, this welfare loss is to be deflated by the *social value of goods*, since the permit is exchanged against tradable goods. Social values[7] of goods differ from market prices of a quantity which is equal to the marginal cost of public funds (MCPF).

Calculating marginal abatement costs at constant prices of foreign trade[8] would normally require to operate separately for each country and for each period. However, it is possible to operate globally, and to eliminate the effects of change in the relative prices of foreign trade by subtracting to marginal surplus the marginal gain or loss from terms of trade. In other terms, the marginal abatement cost is equal to the marginal deadweight loss of taxation deflated by MCPF:

$$\boxed{MAC = \frac{1}{MCPF}\frac{\partial DWL}{\partial A}}$$

I.2. Non CO2 Greenhouse Gas Emissions

For non CO_2 GHG, all the data (emissions and abatement curves) come from the EMF21 Working Group[9] on Multi-Gas Mitigation and Climate Change.

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[5] In case of tradable permits, corresponding sales or purchases must be taken into account.
[6] See Bernard (1999).
[7] They are determined by measuring the welfare gain of a unit additional resource of the given good.
[8] This is also the case for the MCPF.
[9] See for information on the Energy Modeling Forum : http://www.stanford.edu/group/EMF/home/index.htm

Methane

We take into account 12 sources of CH_4 emissions on the basis of EMF21 database. The emissions of each source are linked to an activity level (or an economic driver) the coefficient of which is calibrated on the baseline scenario: for example if $CH4^{E}_{2010}$ is the level of CH4 emitted in the year 2010 by Enteric Fermentation, the equation introduced in the model is:

$$CH4^{E}_{2010} = A^{CH4E}_{2010} \times XD^{1}_{2010}$$

where the coefficient linking agriculture production to emissions is determined by the following expression:

$$A^{CH4E}_{2010} = CH4^{E}_{2010} / XD^{1}_{2010}$$

For the other years we interpolate the coefficient between the reference years (1990, 1995, 2000, 2005, 2010).

The table below shows the correspondence between the sources and the sectors/products in GEMINI-E3, the variable of the model representing the level of emissions, and whether an abatement curve is available.

Table 3 : Methane and GEMINI-E3 Activities

Source	Economic Drivers	Sector/Product	MAC
Biofuel Combustion	Households' consumption	Other goods & services	
Biomass Burning	Households' consumption	Other goods & services	
Coal	Production	Coal	Yes
Enteric Fermentation	Production	Agriculture	
Fuel Stat & Mobile	Domestic Consumption	Refined Oil	
Manure	Production	Agriculture	Yes
Natural Gas	Domestic Consumption	Natural Gas	Yes
Oil	Production	Refined Oil	Yes
Rice	Production	Agriculture	
Solid Waste	Households' consumption	Other goods & services	Yes
Wastewater	Households' consumption	Other goods & services	
Other	Household consumption	Other goods & services	

Nitrous Oxide

For N_2O emissions we adopt the same formulation and the following table gives the economic drivers for the 9 sources of emission.

Table 4 : Nitrous Oxide and GEMIN-E3 Activities

Source	Economic Drivers	Sector/Product	MAC
Agri. Soil Management	Production	Agriculture	
Other Agri. Sources	Production	Agriculture	
Biomass Fuel	Households' consumption	Other goods & services	
Fossil Fuel	Fossil Fuel Consumption	Coal, Refined Oil and Gas	
Manure	Production	Agriculture	
Other Non Agri.	Households' consumption	Other goods & services	
Adipic Acid	Production	Energy Intensive Industry	Yes
Nitric Acid	Production	Energy Intensive Industry	Yes
Human Sewage	Households' consumption	Other goods & services	

Fluorinated Gases

We distinguish four types of fluorinated gases : PFCs, SF_6, HFC-23, other HFCs.
PFCs include all high-GWP gases emitted from aluminium and semiconductor manufacture, including CF_4, C_2F_6, and C_3F_8. SF_6 include all high-GWP emissions from the production and processing of magnesium and from use of electrical equipment. HFC-23 represents all high-GWP emission from the production of HCFC-22. Other HFCs include all high-GWP gases emitted during their use as substitutes for ozone-depleting substances, including emissions from air conditioning and refrigeration equipment, foams, solvents, MDI and non MDI aerosol, and fire extinguishing equipment. This includes primarily HFCs with lifetimes under 100 years.

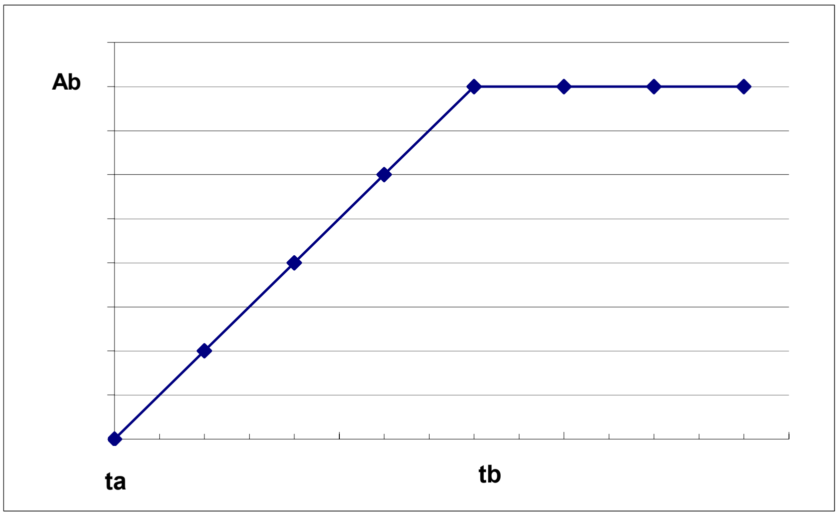
Table 5 : Fluorinated Gases and GEMIN-E3 Activities

Source	Economic Drivers	Sector/Product	MAC
PFCs	Households' consumption	Other goods & services	Yes
SF6	Households' consumption	Other goods & services	Yes
HFC-23	Households' consumption	Other goods & services	Yes
Other HFCs	Households' consumption	Other goods & services	Yes

I.3.Curve of abatement

Abatement is computed on the basis of the EMF21 abatement curves. These curves have the generic form described below:

Graph 1: Abatement Curves in %



We can then compute the level of CH_4 emissions from *tax* (the carbon tax at constant prices of 2000):

$$E_i^t = a_i^t \ (1 - f(tax)) \ XD_i^t$$

where

$$f(tax) = \begin{cases} 0 \quad if \ tax \leq ta \\ \alpha \ tax^2 + \beta \ tax + \delta \quad if \ tb \geq tax \geq ta \\ Ab \quad if \ tax \geq tb \end{cases}$$

I.4. Cost of abatement and tax receipts

The cost of abatement is equal to $F(tax) \times a_i^t \times XD_i^t \times f(tax)$, where *F(tax)* is the integral of the function f^{-1} in the interval $[0, f(tax)]$

In order to avoid non-constant returns to scale in production functions, we suppose that the operational cost of abatement is borne by the Government (and consists of consumption in commodity 08). Government consumption is then the sum of two terms: a "**final"** good, which is representative of various services for the economy and in particular for households; an "**intermediate"** good which is the abatement cost and equal to $F(tax) \times a_i^t \times XD_i^t \times f(tax)$. This distinction is important for GEMINI-E3 because, in order to get relevant yearly measures of welfare cost, we implement the climate change scenarios at **constant final demand** (except obviously households' final consumption and imports, and in particular at constant Government "final" consumption and constant total investment[10]).

Taxes on non CO_2 emissions are paid by the concerned sectors and accrue to the Government receipts. The tax is a charge for firms and, according to the working of the model, it is incorporated in the production cost and then in the production price.

II. Reference Case

II.1. Macro-economic trends and GHG emissions

The baseline scenario of GEMINI-E3 is mainly calibrated on IEO 2002, build by the US Energy Information Administration and published in March 2002. The following tables give for the 7 countries/regions of GEMINI-E3 the rates of growth of GDP, energy consumption and fossil fuel CO_2 emissions, and the detailed GHG emissions in MMTCE.

Table 6 :Baseline Scenario: Macro-economic Data
(annual average growth in %)

Country/Region	GDP		Energy Consumption		Fossil fuels CO_2 Emission	
	2000-2010	2010-2020	2000-2010	2010-2020	2000-2010	2010-2020
France	2.5	2.3	1.1	1.6	0.7	1.4
EU11	2.4	2.4	1.2	1.3	0.8	0.9
USA	3.0	3.0	1.7	1.7	1.6	1.6
Japan	1.8	2.4	0.9	1.4	0.7	1.2
Former Soviet Union	4.7	4.7	1.9	1.9	1.6	1.5
Energy Exporting Countries	4.0	4.5	2.8	3.3	2.7	3.3
Rest of the World	4.6	4.9	3.4	3.9	2.7	2.8
World	3.3	3.6	2.8	3.2	2.0	2.2

[10] But of course with an endogenous allocation between sectors.

Table 7 : Baseline Scenario: GHG Emissions
(in MMTCE)

Country/Region	CO_2		CH_4		N_20		PFCs		SF_6		HFC-23		Other HFCs	
	2010	2020	2010	2020	2010	2020	2010	2020	2010	2020	2010	2020	2010	2020
France	117	135	14	14	19	19	0	0	0	0	0	0	3	4
EU11	828	903	73	71	73	73	3	2	2	2	0	0	25	29
USA	1802	2115	183	180	122	128	3	3	5	5	2	0	45	75
Japan	350	393	7	6	8	8	1	1	2	2	1	0	13	15
Former Soviet Union	758	880	209	224	47	59	3	2	1	1	0	0	4	6
Energy Exp. Count.	576	788	127	151	43	55	1	1	1	1	1	1	8	13
Rest of the World	3799	4997	1260	1506	769	915	12	9	7	8	18	19	52	104
World	8231	10212	1872	2153	1082	1258	23	18	17	17	23	20	149	245

II.2. The Kyoto Commitments

We compute the Kyoto commitments on the basis of the GHG emissions, taking into account sinks allocated in Marrakech. Concerning the US, we adjust to the Bush Plan aiming at a decrease of GHG intensity of 18% during the 10 years 2002 to2012.

Concerning years 2010 to 2020, as most other modeling teams, we conform to the *Kyoto forever* assumption of stability of emissions in Annex B countries (including US) and no constraint or commitment for non Annex B countries.

Table 8 :GHG Emissions abatement consistent with the Kyoto Protocol
(in MMTCE)

Country/Region	GHG 1990**	GHG 2010	Sinks MMTCE	Kyoto Protocol in %	Target	Effective abatement in 2010 in %
France	142	154	1	0%	143	-7%
EU11	840	1003	3	-8%	776	-23%
USA					2111*	-5%
Japan	207	382	13	-6%	302	-21%
Former Soviet Union	1298	1022	19	0%	1318	29%

** 1995 for fluorinated gases
*target consistent with Bush Plan for the year 2012

III. Kyoto scenarios

Two runs have been performed. In the first one (labeled *CO_2 case*) Annex B countries tax only CO_2 emission resulting from fossil fuel combustion, but the results as presented incorporate all GHG emissions. In the second one (labeled *multi-gas case*) the tax is applied to all GHG emissions. In the two scenarios we do not take into account any flexibility mechanisms (CDM, JI, and ET).

III.1. Carbon tax

The following table shows the carbon tax in the two cases. When all GHG emissions are taxed, as it could be easily expected, the level of the tax is smaller than in the other case in all regions. The difference is bigger in Europe than in Japan (the US being a specific case). There is very little gain in Japan from abatement of CH_4 and N_2O emissions because the potential of abatement is smaller.

Table 9 : Carbon tax in US 2000$

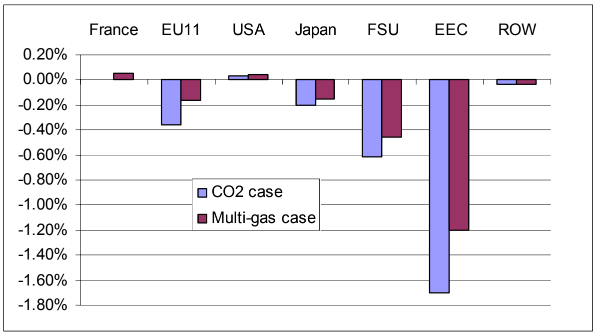
Country/ Region	2010		2020	
	CO2 case	Multi-gas Case	CO2 case	Multi-gas Case
France	187	86	546	328
EU11	405	271	634	454
USA	19	6	86	53
Japan	220	209	391	376

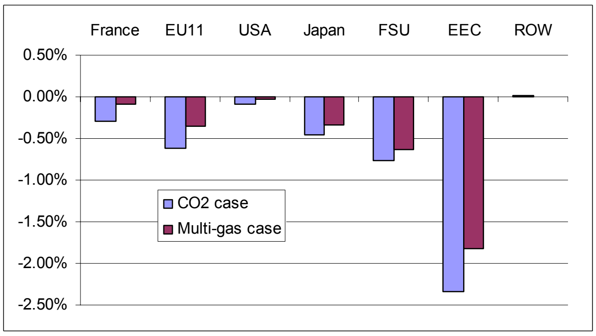
III.2. Welfare Cost

The potential of low-cost abatement of other non CO_2 emissions, mainly in European countries, contributes to reduce the decrease of the welfare cost of implementing the Kyoto Protocol, in Annex B countries but also in non Annex B, mainly energy Exporting Countries (and FSU which can be assimilated to a non-Annex B region in this type of scenario).

Effectively, in the multi-gas strategy, there is a smaller decrease of fossil fuel consumption and then of the price of energy in international markets. Concerning France and the US, there is even in 2010 a welfare gain accruing from the favorable change in the terms of trade.

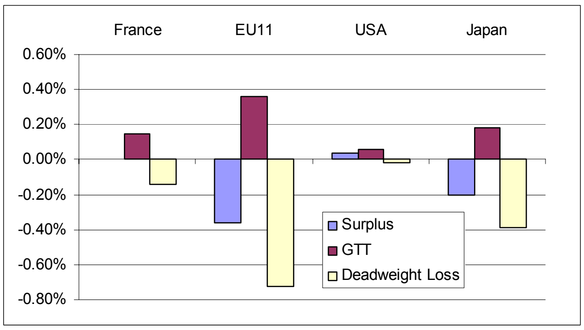
Graph 2: Welfare Cost in 2010 and in 2020 (in % of HFC)

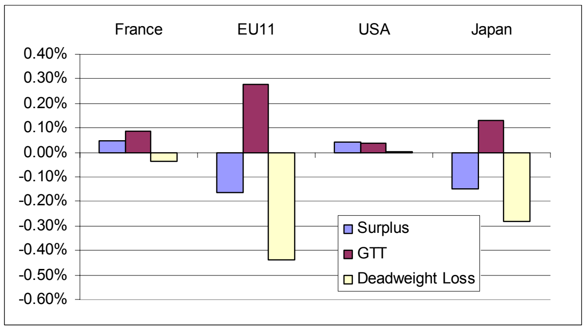




Graph 3: Welfare cost and components in 2010 (in % of HFC)

(left CO2 case; right Multi-gas case)

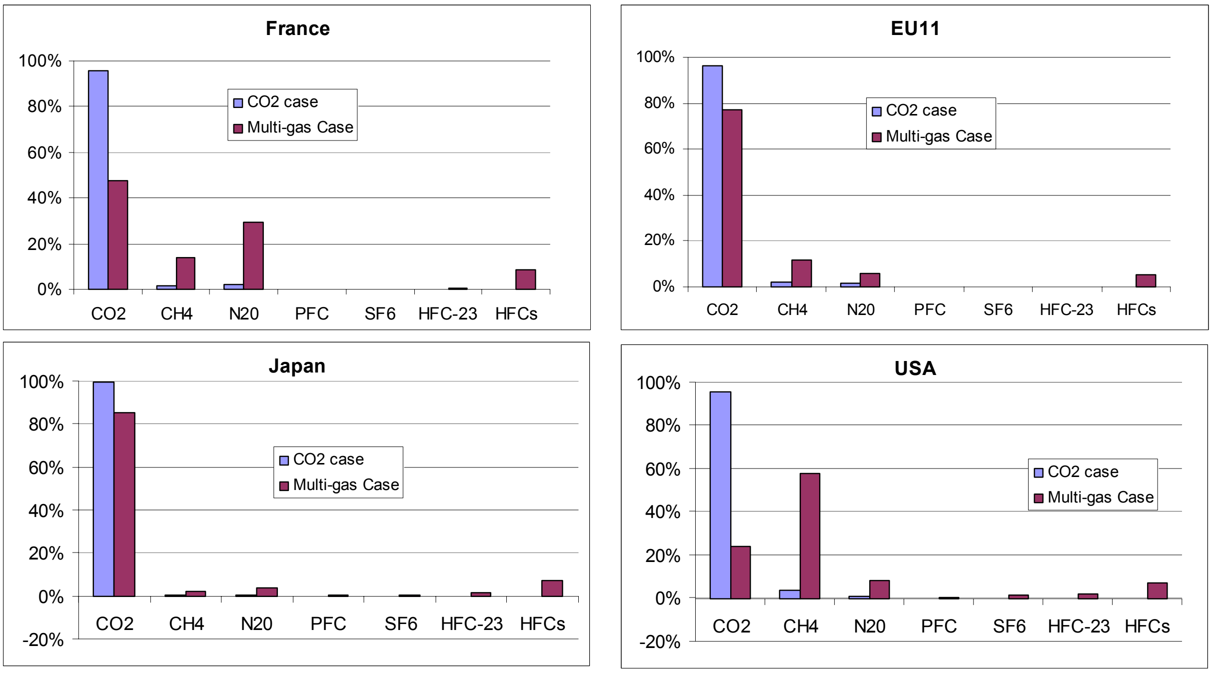




III.3. Contributions of GHG to total abatement

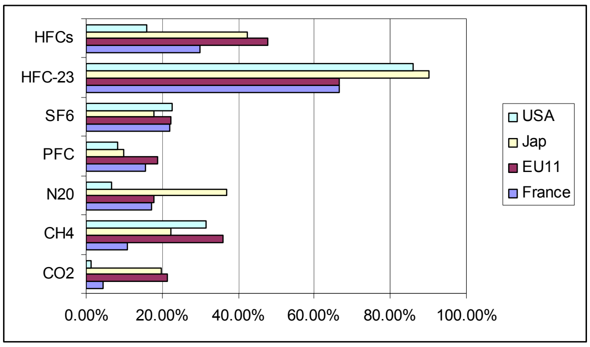
In the multi-gas option the contribution of CO_2 in total abatement remains predominant for Japan and Other European Countries (respectively 86% and 77%), but becomes a minor part for France and the US (respectively 48% and 24%). For the non CO_2 gases, three gas are dominant in the contribution to the abatement : CH_4, N_20 and HFCs with shares varying across countries. The contribution of PFCs and SF_6 to the abatement are negligible (less than 1%) due to the small part of these gases to the overall greenhouse gases emissions. It must be noted that, in the CO_2 case, the contribution of non CO_2 gases is non negligible, around 5% of CO_2 abatement itself in most Annex B countries (see section 4 below). Effectively CO_2 abatement affects indirectly emissions of other non CO_2 gases mainly through the decrease of coal production and fossil consumption.

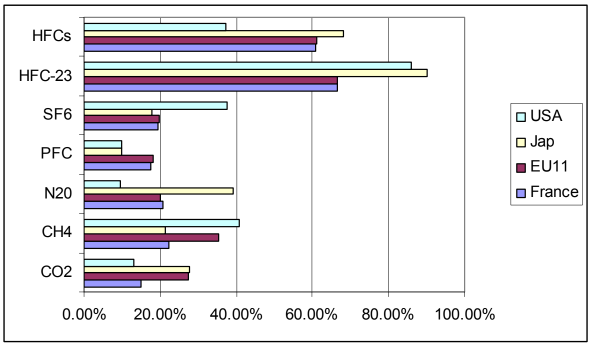
Graph 4: Shares of GHG in Total Emissions Abatement in 2010



Even if the contribution of fluorinated gases are small in the total abatement, their decrease in percentage are always very important in respect to the others greenhouses gases (see Graph 5). This particularly the case of HFCs whose decrease is more than 60% in 2020 showing that for these gases the abatement cost is small.

Graph 5: Decrease of GHG in % in the multi-gas case in 2010 in respect to BaU
(left: 2010; right: 2020)

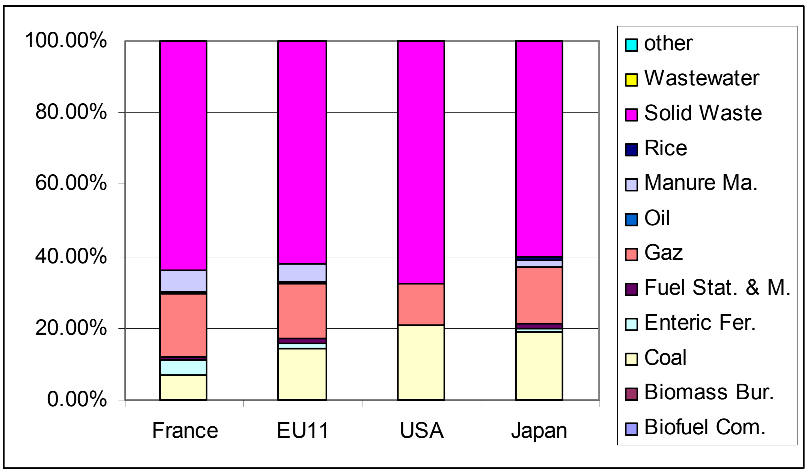




Methane

It can be noted that, for methane, three sources represent the vast majority of the abatement: emissions linked to solid waste, to the gas sector and to coal extraction. But this characteristic must be connected to the fact that for some sources, in particular linked to the agricultural sector, marginal abatement curves are not yet available, this limitation certainly affects the analysis.

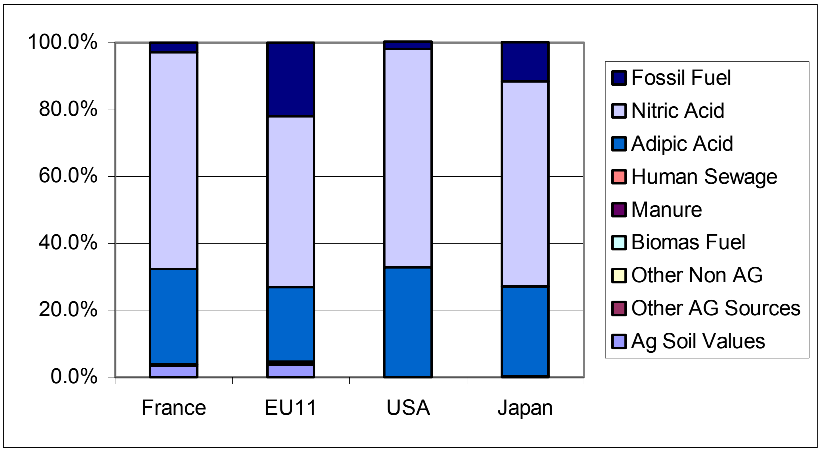
Graph 6: Contribution of sources to methane abatement in %, 2010, multi-gas scenario



Nitrous Oxide

The same phenomenon can be found for nitrous oxide with emissions coming from Nitric Acid and Adipic Acid production, and to a lesser extent fossil fuel combustion, represent the main contributors to Nitrous Oxide Abatement.

Graph 7: Contribution of sources to Nitrous Oxide abatement in %, 2010, multi-gas scenario



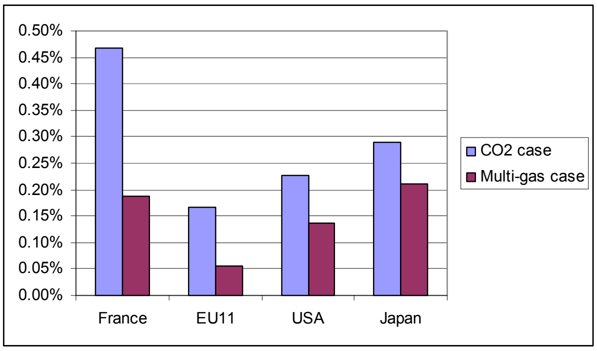
IV. Analytical scenarios

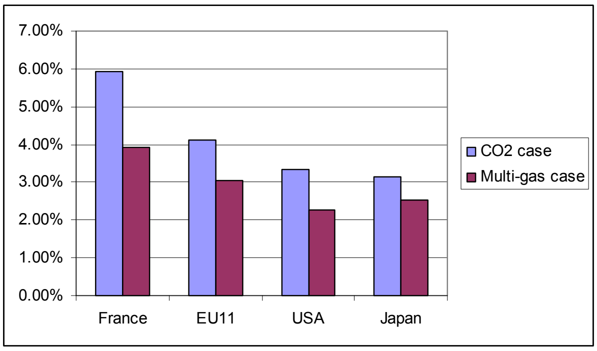
A clear comparison of multi-gas strategies between countries is difficult within the Kyoto Protocol because it considers fairly different levels of abatement in percentage for the Annex B countries and, concerning the US, the Bush plan for US taken into account in the previous scenarios represents a very small percentage of abatement for the year 2010. In order to perform a more accurate comparison between countries we have simulated the two scenarios (CO_2 case and multi-gas case) with four same levels of abatement in 2020: 20%, 30%, 40% and 50%.

IV.1. Welfare Cost

The graph 8 shows the welfare cost by country/region for the two extreme scenarios (20% and 50%) As expected, the relative gain of a multi-gas strategy compared to the CO_2 case decreases with the level of abatement.

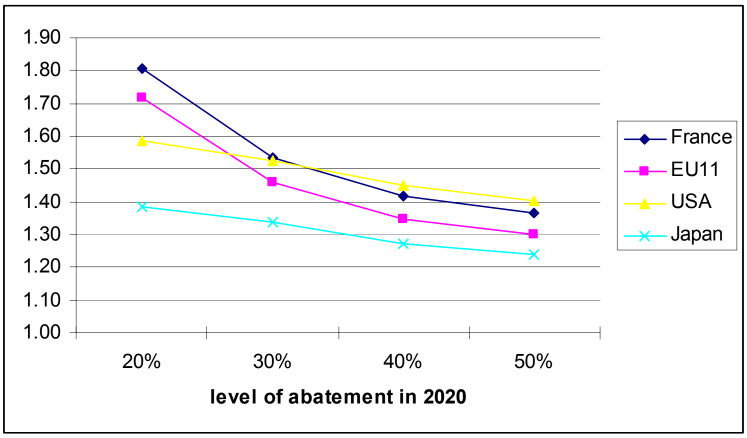
Graph 8: Surplus in % percentage of Household Final Consumption in 2020
(left 20% abatement; right 50% abatement)





In terms of Deadweight Loss of Taxation, which represents the domestic part of the welfare cost, the same observation holds. Graph 9 below which presents the ratio of DWLs between the CO_2 and the multi-gas cases shows that a sharp decrease with the level of abatement, particularly in European countries (France and EU11).

Graph 9: Ratio of DWL between CO_2 case and Multi-gas case with respect to the level of abatement

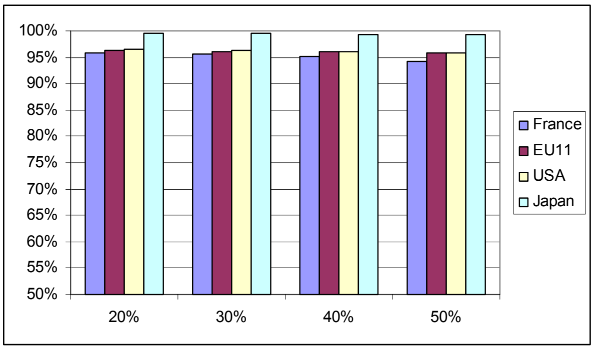


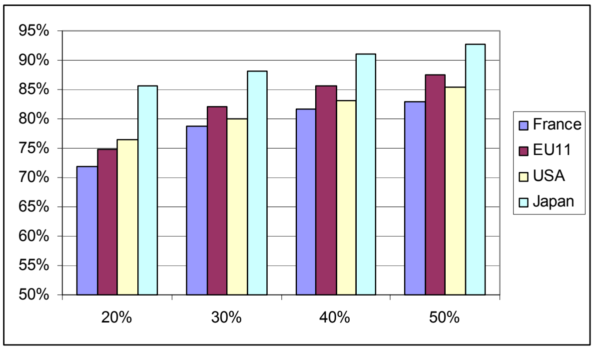
IVI.2. Contributions of GHG to total abatement

The contribution of carbon dioxide to total abatement is similar among countries in the two scenarios as it appears in the graph 8. In the CO_2 case, Carbon dioxide obviously brings the main contribution, over 95%. In the multi-gas strategy this share grows with the level of abatement, more significantly in European countries than in the US and Japan. This confirms that, for low levels of overall abatement, the priority is to abate non CO_2 greenhouse gases in reason of their relatively low cost but that their potential is limited because they represent a small share of total emissions, in particular in the US and Japan.

Graph 9: Shares of CO_2 in Total Emissions Abatement in 2020 with respect to different levels of abatement

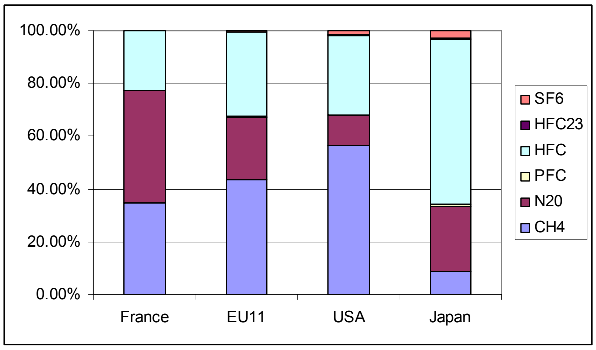
(left CO2 case; right Multi-gas case)

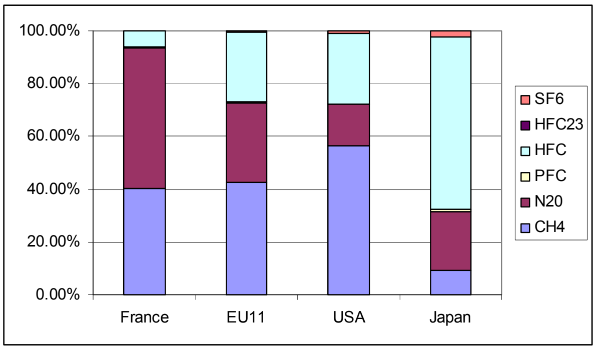




The relative shares non CO_2 greenhouse gases vary across countries and according to the level of global abatement, as represented in the graph 10 below. Of course CH_4, N_2O and HFC are the main contributors to global abatement, but important differences exist between countries in reason of the relative shares of emission in the initial situation. In this respect the two extremes are Japan, with a relatively low share of methane and in the contrary a relatively high share of HFCs, and France with a relatively small share of HFCs and a relatively high share of N_2O.

Graph 10: Contribution of non CO_2 gas to their abatement in %, 2020, multi-gas scenario
(left 20% abatement; right 50% abatement)





Conclusion

Abating all sources of GHG emissions and not the single carbon dioxide may only reduce the welfare cost of committing to a given global target of abatement. What clearly show the various scenario assessments presented in the paper is that the welfare gain is possibly important, of course bigger in countries where the non CO_2 are proportionally higher in the initial situation than in other, but that the long run potential is limited. It is not possible to expect a very large contribution from them with high targets of global abatement.

The analysis has been conducted with the assumption that the same carbon price is levied on all GHGs. As it is well known, and in reason of various pre-existing distortions in the economy and in the fiscal system, the marginal cost of abatement may differ, sometimes very substantially, from the carbon price (see in particular Bernard, 1999 and Bernard & Vielle, 2003). Optimizing the domestic abatement policy in each country (and also across countries) requires equalization of marginal costs, not of levies. How this may affect the results, and in particular the relative shares of the various GHGs is an important topic which will be soon addressed through the model GEMINI-E3, particular well-suited for this type of assessment.

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