Efficient Allocation of a Global Environment Cost between Countries: Tradable Permits VERSUS Taxes or Tradable Permits AND Taxes? An Appraisal with a World General Equilibrium Model[1]

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Abstract

In a first best context, internalizing externalities such as a pollution can be efficiently performed by taxes or by tradable permits, either at a national or international level. The pollution tax is then equal to the social marginal abatement cost, i. e. the welfare loss of a unit additional abatement. This is not any more the case when there are distortions, i. e. in an economy, domestic or international, which cannot be considered as first-best Paretian.

In order to assess more precisely the functioning of a world market of tradable pollution permits for GHG mitigation, and its interactions with other markets of tradable goods, a new version of **GEMINI-E3**, named ***GemWTraP***, has been developed. The model individualizes 7 countries/regions, and performs detailed evaluations of marginal abatement costs.

The paper presents simulations of the Kyoto Protocol realized in various configurations : without and with trade of permits, and in the latter case, between OECD countries and between Annex I countries. It compares trade of pollution permits based on *costs* (marginal abatement costs) and on *prices* (carbon taxes), both on efficiency and equity grounds.

Keywords : Tradable Permits, Marginal Abatement Cost, Fiscal Distortions, GHG Mitigation, Double-Dividend

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[1] A preliminary version of the paper was presented at the Joint Economic Meeting organized by the International Energy Agency, the Energy Modeling Forum and the International Energy Workshop in Paris, 16-18 June 1999

Contents

1. General presentation : pollution tax and marginal abatement cost in a first-best and in a second-best contexts

Appraisal of the Kyoto Protocol raises several issues for the economist, both at the practical level of selecting the adequate tools for simulation, and at the theoretical level of determining the appropriate policies in order to minimize the total cost of pollution abatement, and to find ways to share the burden « equitably » between countries. Both approaches closely interact, as models have to be consistent with theory, and policy measures have to be based on a precise assessment of their quantitative effects.

In the case of a pollution like the Greenhouse Effect, the main conceptual difficulties arise from its world scale. Policies implemented by countries have spill-over effects channeled through foreign trade, as in particular mitigation of CO2 emissions goes through reduction in demand for fossil fuels, and then is likely to decrease the prices in international markets and entail a loss in income for energy exporters (and symmetrically, a gain for net importers).

Another important aspect is related to the « flexibility » mechanisms considered by the Kyoto Protocol - though no formal agreement has yet been reached by involved countries -, and in particular tradable permits. If exchanges of pollution rights have clearly the potential of reducing the total cost of abatement, the basis for this trade is not obvious.

For many economists, and also for a great number of modeling teams, carbon tax (often considered as representing the marginal cost of abatement) is an obvious candidate. An international (or regional) market of tradable permits has then for result that the price paid by polluters is the same in all concerned countries. This is in particular the appropriate device in a first-best (world) economy, i. e. when there are no distortions in domestic economies (and in foreign trade).

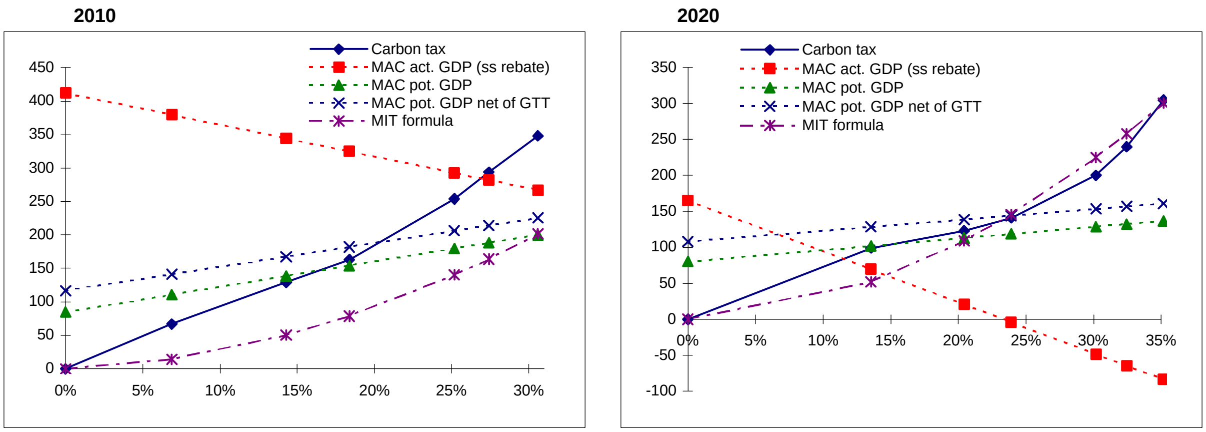
When there are distortions, and in particular fiscal distortions, then for each country taken individually *the marginal cost of abatement (the « social » cost, i. e. the welfare loss of a unit increase of pollution abatement) is not necessarily equal to the pollution tax*. As no country would pay for a pollution right more than it costs to it, or sell for less, marginal abatement cost (thereafter MAC) is more likely to be the basis for exchanges of permits. A market operating on these bases has then for result that marginal abatement costs are equalized across countries, but not carbon taxes. Implementing such a market supposes either that governments are direct traders, or if private agents are to be the operators, that governments set correcting domestic taxes (or subsidies) in order that the total price paid by firms (eventually households) reaches the required level.

1.1. Evidence from existing applied appraisals and applied models

Discrepancy between carbon tax and marginal abatement cost is obtained, explicitly or implicitly, in several applied studies and models.

For example, the very comprehensive appraisal conducted on Kyoto Protocol[2] by the Energy Information Administration of the American Department of Energy yields measures of costs (based on change in GDP, actual or potential) for various levels of abatement, from which can be derived a marginal cost, to be compared to the carbon tax directly obtained. Graphs below represent, for years 2010 and 2020, and for different measures of loss, the corresponding curves.

Figure 1 : carbon taxes and marginal losses of abatement in EIA-DOE study



If one considers the long term horizon of 2020 and potential GDP as providing measures of welfare loss closest to theoretical concepts, the right graph above clearly shows that the marginal abatement cost differs significantly from the carbon tax, being bigger for low levels of abatement and smaller for high levels (over approximately 20 to 25%).

Among models (general equilibrium models) obtaining a discrepancy between carbon tax and MAC, can be cited CICERO of the Center for International Climate and Environment Research in Oslo[3], and GEMINI-E3 of Ministry of Equipment/Atomic Energy Agency in Paris[4].

1.2. Evidence from theory

Effects of fiscal distortions on environmental policy have been analyzed, in the recent period, by Bovenberg and de Moiij (1994) and by Bovenberg and Goulder (1996). In particular the latter obtain theoretical formulas which show a difference between tax and marginal abatement cost, and check its size in a numerical application[5].

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[2] « Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity », October 1998

[3] J. Holsmark, 1998. « From the Kyoto Protocol to the Fossil Fuels Markets », OECD Experts Workshop on Climate Change and Economic Modeling : Background Analysis for the Kyoto Protocol, Paris 17-18 September

[4] A. Bernard and M. Vielle, 1998. « Cost of CO2 Abatement in a Regional or International Context : Discrepancies among Countries and Spill-Over Effects », First World Congress of Environmental and Resource Economists, Venice 25-27 June.

[5] A. Bovenberg and R. de Moij, 1994. « Environmental Levies and Distortionary Taxation », American Economic Review 8 (4) : pp 1085-89

A. Bovenberg and L. Goulder, 1996. « Optimal Environment Taxation in the Presence of Other Taxes : General-Equilibrium Analyses », American Economic Review 8 (6) : pp 985-1000

Conditions under which marginal abatement cost is equal to pollution tax in second-best economies are investigated by A. Bernard (1999). He obtains that this holds when there is a sufficiently large array of fiscal tools, as is the case in the Diamond & Mirrlees model. It is also demonstrated that trade of pollution permits is (second-best) PARETO efficient[6].

If constraints are put on taxation, and in particular when profits cannot be totally taxed[7] as required in the Diamond and Mirrlees model, then MAC differs from pollution tax. However, it is possible (under restrictive assumptions on separability of production functions) that trade of permits based on MACs is PARETO efficient.

1.3. Focus and plan of the paper

The aim of the paper is to appraise the Kyoto Protocol and compare various policies of implementation within a general equilibrium model, taking into account the issues which have been raised above. In particular, scenarios with trade of permits based on MACs are compared to scenarios with trade of permits based on carbon taxes, and to the scenario without trade.

Section 2 presents the model which has been developed in order to simulate these scenarios, and its methodology of utilization. Section 3 yields the results of preliminary scenarios determining the curve of carbon tax and the curve of marginal abatement cost.

Section 4 presents the scenario of Kyoto Protocol implementation without permits, section 5 scenarios with tradable permits of the two types and their comparison. Section 6 concludes and suggests further developments.

2. Appraisal with a General Equilibrium Model : specifications of the model and methodology

GEMINI-E3 has been developed by French Ministry of Equipment and French Atomic Energy Agency in order to assess energy policies in relation to their environmental aspects, and simulations realized in particular concerning GHG mitigation policies have been presented in several seminars. A first appraisal of the Kyoto Protocol has been presented at the World Congress of Environment and Resource Economists in Venice (June 1998).

2.1. The need for a specific model

A new version, **GEMINI-E3/*GemWTraP***, has been established in order to obtain a more precise assessment of the Kyoto Protocol, and in particular to simulate tradable markets in various configurations.

On the one hand, more countries or regions have been individualized : the Energy Exporting Countries (mainly OPEC), in order to have a better evaluation of gains and losses from terms of trade, the Confederation of Independent States (or Former Soviet Union), in order to assess scenarios of tradable permits with their participation, and in particular the availability of the large potential supply consisting of « Hot Air ».

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[6] A. Bernard, 1999. "The Pure Economics of Tradable Pollution Permits", mimeo MELT, July 1999
[7] This assumption is implicit in the Bovenberg & Goulder model.

Beside these two regional organizations, four industrialized countries are individualized, France, Other European Countries (ex European Community at 12 less France, EU11), United States of America and Japan. Though not including all OECD members, this group of four countries is « representative » of this organization, and assimilated to it in the paper. In the same way, the four countries plus FSU are « representative » of Annex I.

On the other hand, the model determines in each period and for each country/region the marginal abatement cost, allowing to simulate the corresponding scenarios of tradable permits.

Appendix 1 details the characteristics of the model, its structure and the specification of production and utility functions, and the main outputs. It shows clearly that the model is more detailed concerning France and Other European Countries than concerning other countries/regions, in particular in describing the fiscal system. This may bias evaluations of costs, namely costs linked to fiscal distortions such as marginal costs of abatement.

Appendix 2 gives detailed description of the baseline scenario (Business as Usual), and in particular assumptions concerning economic growth, energy consumption and CO2 emissions for all countries/regions of the model.

2.2. Cost of pollution abatement : measurement and factors

Cost of abatement policies, in the various possible ways of implementation, is a key indicator in their appraisal. In the case of policy measures aiming at reducing the consumption of certain categories of goods, and going through taxation or equivalent tools, macro-economic aggregates such as GDP or Households' Final Consumption are not relevant as they are calculated at constant prices, then ignoring the welfare effects of changes in the structure of prices.

The unique relevant measure is the households' surplus, i. e. the Compensative Variation of Income (CVI) or 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 of cost in the production sector, and in households' budget). Households' surplus is not exactly CVI or EVI since surplus has to take into account the effective change in income of households.

Households' surplus is representative of total welfare gain of the economy 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. Concerning productive investment, which is endogenous in the model and is sensitive to change in relative prices (and in particular to change of relative prices of consumption and capital goods), surpluses calculated annually are representative of welfare gains if total investment - but not its allocation between sectors - is constrained to be constant in the scenario. This has been effectively retained in the model.

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, in some cases a dominant, part of the total welfare gain or loss. Table below clarifies the « algebra » of welfare measurement in the case of an open economy.

Table 1

Algebra of Welfare Measurement				
S (Total Welfare Gain)	=	ΔR (Variation of Income)	+	EVI (Equivalent 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 simulation results of a scenario : formulas above then determine the deadweight loss of taxation, which represents the pure substitution effect of pollution abatement.

2.3. Calculation of marginal abatement costs

Definition of the marginal abatement cost may appear obvious, its precise determination is more complex.

According to theoretical analysis[8], 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[9] 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[10] 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 (1+MCPF) :

$$MAC = \frac{1}{1 + MCPF} \frac{dDWL}{dA}$$

This is the method which has been used, and has been verified to yield correct results.

[8] See Bernard (1999)
[9] They are determined by measuring the welfare gain of a unit additional resource of the given good
[10] This is also the case for the MCPF

3. Preliminary scenarios : revenue replacement and determination of the curves of carbon tax and marginal abatement cost

Several preliminary scenarios have been performed in order to determine the curves of carbon tax and marginal abatement cost, and the marginal cost of public funds which is an intermediate in the calculation. A pre-requisite is to decide of the rule of revenue replacement of carbon taxes.

3.1. Revenue replacement : comparison between lump-sum transfer and fiscal rebate

Revenue replacement of receipts accruing from the carbon tax is an important and much debated question. Two main possibilities are considered in the literature : distribution to households in the form of lump-sum grants, rebate on existing taxes or on social security payments. Rebate on social security is often advocated in order to alleviate the relative cost of labor and favor full-employment, then yielding a « double-dividend ». But this can only be obtained with a reliable representation of the labor market and its imbalances, what most general equilibrium models do not incorporate as they are devoted to assessing long term policies.

On pure efficiency grounds, fiscal rebate is theoretically superior to lump-sum transfers as it allows to alleviate the distortionary cost of taxation. It is then important, in order to check the reliability of a model, to verify if this result is effectively obtained.

Scenarios of domestic taxation without tradable permits have been performed with each of these rules of revenue replacement. More precisely, concerning the second scenario, fiscal rebate is implemented through a decrease of the rate of Value Added Tax in France and Other European Countries, and a (proportional) decrease of the rate of taxes on production in USA and Japan. As expected, and as shown in the following table, deadweight loss of taxation is smaller, in every concerned country and at each period, with fiscal rebate than with lump-sum transfers.

Table 2 : Implementation of Kyoto Protocol without tradable permits
Welfare loss in constant national money and in percentage of HFC

	Case of lump-sum transfers				Case of tax rebate			
	2005	2010	2015	2020	2005	2010	2015	2020
France	-6,964	-18,292	-33,063	-53,503	-5,538	-15,904	-29,645	-49,003
in % of HFC	*-0.13%*	*-0.31%*	*-0.49%*	*-0.71%*	-0.10%	-0.27%	-0.44%	-0.65%
UE11	-10,989	-34,112	-48,422	-66,080	-8,339	-28,646	-41,394	-57,094
in % of HFC	*-0.32%*	*-0.89%*	*-1.12%*	*-1.35%*	-0.25%	-0.75%	-0.95%	-1.16%
USA	-14,176	-40,291	-54,035	-64,825	-12,442	-36,552	-49,344	-59,402
in % of HFC	*-0.27%*	*-0.66%*	*-0.80%*	*-0.89%*	-0.23%	-0.60%	-0.73%	-0.81%
Japan	-550	-1,408	-2,019	-2,826	-443	-1,235	-1,809	-2,570
in % of HFC	*-0.18%*	*-0.42%*	*-0.54%*	*-0.68%*	-0.14%	-0.37%	-0.49%	-0.62%

From now on, scenarios will be performed with the more efficient rule of revenue replacement, i. e. tax rebate[11].

3.2. Determination of the curves of carbon tax and marginal abatement cost

Table 3 below gives the values obtained for the marginal cost of public funds (MCPF) in concerned countries/regions. The calculation has been made for the baseline scenario, and it was checked that the values are nearly identical in abatement scenarios.

Table 3 : Marginal Cost of Public Funds

	1998	2000	2005	2010	2015	2020
France	0.10	0.10	0.13	0.13	0.13	0.13
UE11	0.12	0.13	0.13	0.13	0.14	0.14
USA	0.03	0.03	0.03	0.02	0.02	0.02
Japan	0.04	0.04	0.04	0.03	0.03	0.03
FSU	0.23	0.22	0.22	0.25	0.23	0.23
EEC	0.05	0.04	0.04	0.04	0.05	0.06
ROW	0.01	0.01	0.01	0.01	0.02	0.02

Values obtained are consistent with what could be expected : high for FSU, intermediate for European Countries including France, and small for USA and Japan.

3.3. Design of preliminary scenarios

The curves of carbon tax and of marginal abatement cost are obtained from a series of preliminary scenarios, corresponding to various levels of abatement for the concerned countries/regions. Instead of taking arbitrary values of abatement, these preliminary scenarios correspond to levels of abatement consistent with Kyoto Protocol, without or with tradable permits, in different configurations.

The latter ones are not strictly scenarios of tradable permits as transfer payments for sales or purchases are not effectively implemented. In this preliminary stage, it is appropriate to eliminate the « income effects » of such transfers in order to focus on the pure « substitution effects » of taxation. Scenarios are then of the « Iso-Tax » or « Iso-CMA » type, and they are interesting in themselves as they represent a solution for allocating efficiently pollution rights among countries without resorting to a market of pollution permits.

Beside the scenario of pure domestic taxation (i. e. without permits), the implemented scenarios are the following ones :

- « Iso-Tax OECD » : equalization of carbon taxes in OECD countries[12], on the basis of total abatement of OECD countries in Kyoto Protocol ;

[11] The scenario of domestic taxation without trade of permits will be presented in more detail in section 4

- « Iso-Tax OECD with Hot Air » : equalization of carbon taxes in OECD countries, on the basis of total abatement of Annex I countries in Kyoto Protocol ;
- « Iso-CMA OECD » : equalization of marginal abatement costs in OECD countries, on the basis of total abatement of OECD countries in Kyoto Protocol ;
- « Iso-CMA OECD with Hot Air » : equalization of marginal abatement costs in OECD countries, on the basis of total abatement of Annex I countries in Kyoto Protocol ;

Scenarios are implemented by application to each energy consumption, either intermediate or final, of a carbon tax proportional to CO2 emissions.

3.4. Results of preliminary scenarios

Results of preliminary scenarios are presented in the table 4 of next page. The table yields, for the years 2005, 2010, 2015 et 2020 and for each country/region, the abatement of CO2, the carbon tax and the marginal abatement cost. Curves of carbon tax and marginal abatement cost are represented in the graphs of Figure 2, at the following page.

Several general comments can be made :

- in each country/region, and at each period, the curve of MAC is above the curve of carbon tax (and in particular the MAC at the origin is positive[13]) ;
- the two curves, and then their relative position, remain approximately unchanged across the period 2000-2020 ;
- the distance between the two curves varies from one country/region to the other : it is biggest in France, and smallest in USA and EU11, with an intermediary position for Japan. This is closely to be related to the present scale of CO2 emissions across countries/regions : less than 2 T per inhabitant in France, around 3 T in Japan and in EU11, more then 5 T in USA.

Relatively to « Iso-Tax » scenarios, « Iso-MAC » equilibria yield a higher abatement for the USA and a lower for other OECD countries, but the difference is negligible. The most important effect is related to the difference between the potential price in an international market of permits, the carbon tax in one case (150 ECUs without Hot Air in 2010), the marginal abatement cost in the second case(166 ECUs).

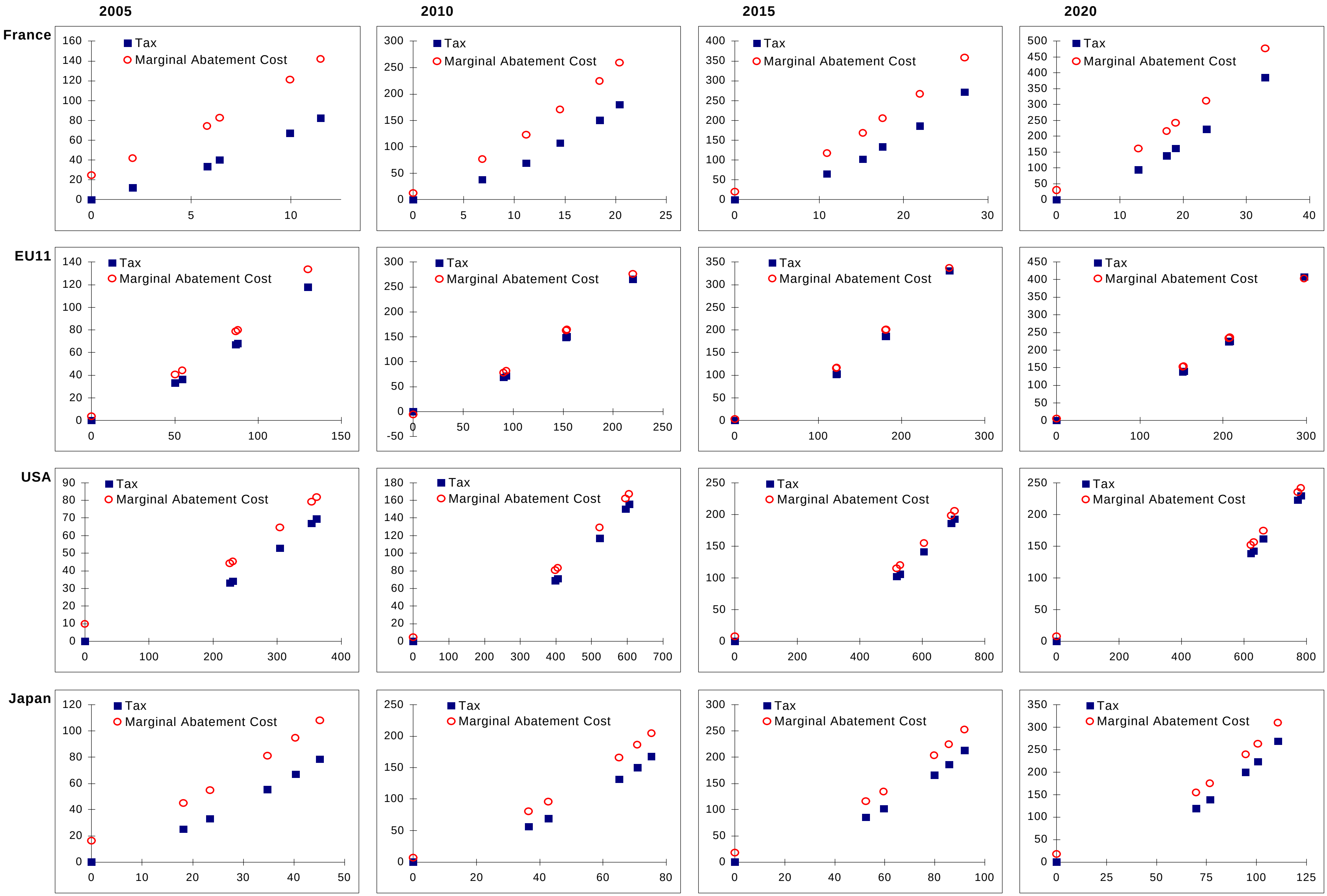
[12] Represented, in the model, by European Countries, USA and Japan.
[13] Except EU11 in 2010 but this erratic result is not very significant

<u>Table 4</u>

Results of Iso-Tax and Iso-MAC scenarios
(Abatement in millions T of C - Costs and Taxes in ECUs 1990)

	2005			2010			2015			2020		
	Abat.	**Tax**	**MAC**	**Abat.**	**Tax**	**MAC**	**Abat.**	**Tax**	**MAC**	**Abat.**	**Tax**	**MAC**
Baseline scenario												
France	0	0	25	0	0	12	0	0	20	0	0	30
EU11	0	0	3	0	0	-6	0	0	3	0	0	5
USA	0	0	10	0	0	5	0	0	8	0	0	8
Japan	0	0	16	0	0	7	0	0	17	0	0	17
Total or average	*0*		*nd*	*0*		*nd*	*0*		*nd*	*0*		*nd*
Domestic taxes												
France	11	82	142	20	180	259	27	271	358	33	385	477
EU11	130	118	133	220	265	276	258	331	337	297	408	403
USA	304	53	65	522	117	129	605	141	155	663	161	175
Japan	45	79	108	75	168	205	92	213	252	111	269	309
Total or average	*491*		*89*	*838*		*177*	*982*		*217*	*1104*		*259*
Iso-Tax OECD without HA												
France	10	67	121	18	150	224	22	186	266	24	223	311
EU11	87	67	79	154	150	164	182	186	200	207	223	233
USA	354	67	79	595	150	162	693	186	198	773	223	235
Japan	40	67	94	71	150	186	86	186	225	101	223	263
Total or average	*491*		*81*	*838*		*166*	*982*		*202*	*1104*		*239*
Iso-Tax OECD with HA												
France	6	33	74	11	69	122	15	102	168	17	138	216
EU11	50	33	40	90	69	78	122	102	116	152	138	152
USA	226	33	44	398	69	81	518	102	115	622	138	152
Japan	23	33	55	43	69	96	60	102	135	77	138	175
Total or average	*306*		*45*	*542*		*82*	*715*		*118*	*868*		*155*
Iso-MAC OECD without HA												
France	6	39	81	14	103	166	18	132	204	19	160	240
EU11	89	70	81	155	153	166	184	190	204	211	231	240
USA	360	69	81	603	155	166	701	191	204	780	228	240
Japan	35	56	81	65	132	166	80	166	204	95	201	240
Total or average	*491*		*81*	*838*		*166*	*982*		*204*	*1104*		*240*
Iso-MAC OECD with HA												
France	3	14	45	8	41	82	11	63	118	13	88	156
EU11	55	37	45	94	72	82	124	104	118	155	142	156
USA	230	34	45	403	71	82	526	105	118	629	142	156
Japan	18	25	45	37	57	82	54	87	118	71	120	156
Total or average	*306*		*45*	*542*		*82*	*715*		*118*	*868*		*156*

Figure 2 : Curves of carbon tax and of marginal abatement cost

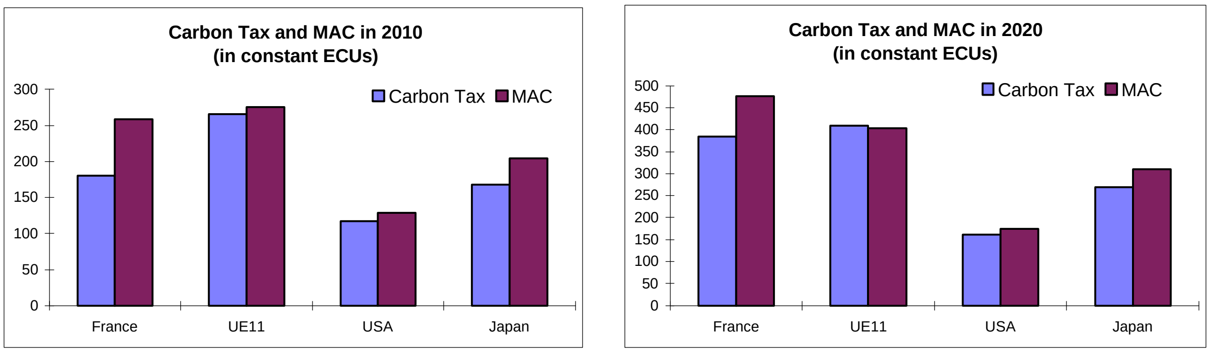


4. Implementation of Kyoto Protocol Without Tradable Permits

Numerical results of the scenario, concerning carbon taxes and marginal abatement costs, have been given in the previous section. They are represented in the graphs below for the years 2010 and 2020.

Figure 3

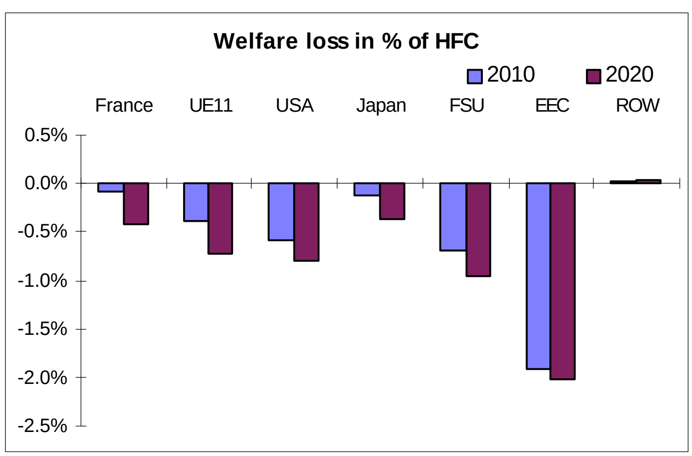
Kyoto Protocol Without Tradable Permits



Carbon taxes are smallest in USA and highest in Other European Countries. The lower level of the carbon tax in France compared to Other European Countries is to be related to the smaller abatement target agreed upon by European Union members (see table 5 in Appendix 2). As for marginal abatement costs, their ranking is close to carbon taxes, except that France reaches the highest level in 2020.

Welfare loss in relative terms (percent of Households' Final Consumption), as represented in Figure 4, is highest in Energy Exporting Countries, and this reflects the incidence of the change in terms of trade. FSU, which is also a net exporter of energy, shares an important part of the burden, higher in relative terms than any OECD country/region.

Figure 4



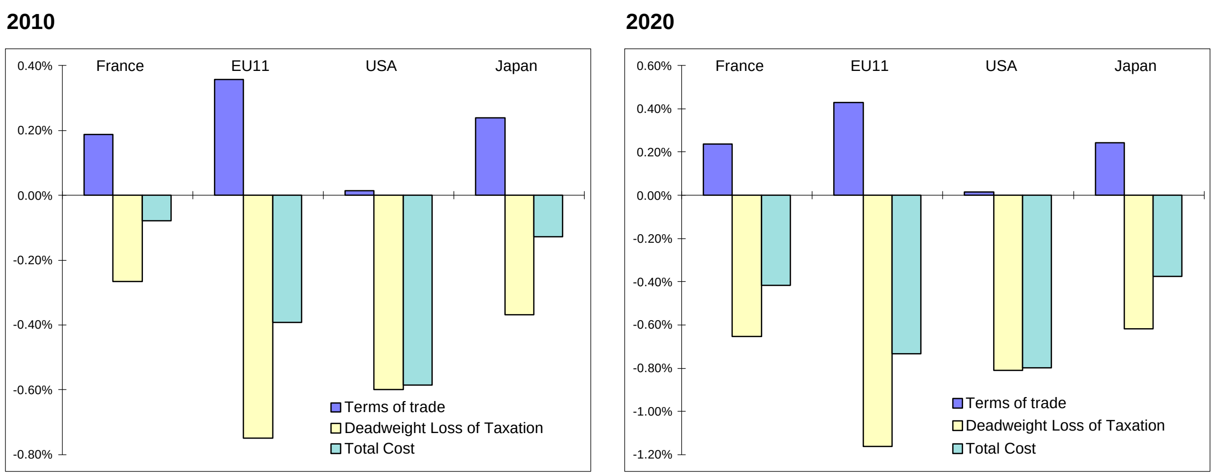
As shows Table 5 below, terms of trade benefit to European Countries and Japan, which import most of their fossil energy, and not to USA. Then, though the latter country has the smallest carbon tax and the smallest marginal abatement cost, it bears the highest total cost among OECD countries. France and Japan bear relatively low cost, and for the latter this is to be related to the assumption of lower economic growth than in other OECD countries.

Table 5 : components of total welfare cost

	France	EU11	USA	Japan
2010				
Terms of trade	0.19%	0.36%	0.01%	0.24%
Deadweight Loss of Taxation	-0.27%	-0.75%	-0.60%	-0.37%
Total Cost	-0.08%	-0.39%	-0.58%	-0.13%
2020				
Terms of trade	0.24%	0.43%	0.01%	0.24%
Deadweight Loss of Taxation	-0.65%	-1.16%	-0.81%	-0.62%
Total Cost	-0.42%	-0.73%	-0.80%	-0.38%

Breakdown of total cost between the two components is represented in Figure 5 for the years 2010 and 2020.

Figure 5 : breakdown of welfare cost



5. Implementation of Kyoto Protocol With Tradable Permits

General results of the scenarios of tradable permits are presented in Table 6 of next page.

Table 6

Results of tradable permits scenarios
(Abatement in millions T of C - Costs and Taxes in ECUs 1990)

	2010					2015					2020				
	Tax	**Abatement**	**Net sales of permits**	**MAC**	**Total Cost** (in % of HFC)	**Tax**	**Abatement**	**Net sales of permits**	**MAC**	**Total Cost** (in % of HFC)	**Tax**	**Abatement**	**Net sales of permits**	**MAC**	**Total Cost** (in % of HFC)
Permits based on taxes (OECD without HA)															
France	151	19	-2	228	-0.07%	187	22	-5	271	-0.21%	225	24	-9	316	-0.35%
EU11	151	155	-65	166	-0.40%	187	183	-74	203	-0.57%	225	209	-88	237	-0.73%
USA	151	593	71	161	-0.54%	187	691	85	198	-0.66%	225	770	107	234	-0.70%
Japan	151	71	-4	188	-0.12%	187	86	-6	227	-0.23%	225	101	-9	266	-0.35%
FSU		-10	0		-0.49%		-13	0		-0.60%		-16	0		-0.69%
Total or average		*828*	*0*	*166*			*970*	*0*	*203*			*1088*	*0*	*239*	
Permits based on taxes (OECD with HA)															
France	70	11	-9	127	-0.08%	103	16	-12	175	-0.18%	141	18	-15	226	-0.29%
EU11	70	92	-128	80	-0.27%	103	124	-133	119	-0.42%	141	155	-142	157	-0.58%
USA	70	403	-120	82	-0.55%	103	524	-81	117	-0.71%	141	628	-35	155	-0.81%
Japan	70	44	-32	99	-0.14%	103	61	-31	138	-0.23%	141	78	-32	180	-0.34%
FSU		-13	288		9.41%		-18	257		10.69%		-22	225		11.36%
Total or average		*537*	*0*	*84*			*707*	*0*	*121*			*857*	*0*	*159*	
Permits based on taxes (Annex I)															
France	35	7	-14	75	-0.03%	51	9	-18	98	-0.08%	68	10	-23	130	-0.14%
EU11	35	53	-167	37	-0.15%	51	72	-185	62	-0.24%	68	90	-207	82	-0.34%
USA	35	263	-260	41	-0.38%	51	354	-252	51	-0.53%	68	431	-231	73	-0.64%
Japan	35	26	-50	57	-0.09%	51	37	-55	82	-0.16%	68	49	-62	105	-0.23%
FSU	35	189	490		9.25%	51	235	510		11.26%	68	276	523		13.33%
Total or average		*537*	*0*	*42*			*707*	*0*	*56*			*857*	*0*	*78*	
Permits based on MACs (OECD without HA)															
France	106	15	-6	168	-0.10%	131	18	-10	202	-0.26%	158	19	-14	239	-0.41%
EU11	148	153	-67	163	-0.45%	184	181	-76	199	-0.62%	223	208	-89	235	-0.78%
USA	158	605	83	167	-0.50%	196	704	98	205	-0.61%	235	783	120	241	-0.64%
Japan	131	65	-10	165	-0.13%	164	80	-12	202	-0.25%	198	95	-16	238	-0.36%
FSU		-10	0		-0.47%		-12	0		-0.58%		-15	0		-0.67%
Total or average		*828*	*0*	*166*			*970*	*0*	*203*			*1089*	*0*	*240*	
Permits based on MACs (OECD with HA)															
France	36	8	-13	83	-0.13%	63	12	-16	119	-0.23%	90	12	-19	156	-0.35%
EU11	70	97	-123	83	-0.34%	101	128	-129	119	-0.50%	137	161	-137	156	-0.66%
USA	70	409	-113	83	-0.59%	105	532	-74	119	-0.75%	142	634	-29	156	-0.82%
Japan	55	38	-37	83	-0.18%	83	54	-37	119	-0.28%	117	73	-38	156	-0.39%
FSU		-15	286		11.47%		-19	256		12.68%		-24	223		13.11%
Total or average		*537*	*0*	*83*			*707*	*0*	*119*			*856*	*0*	*156*	

Beside the scenario « OECD with Hot Air », a scenario « Annex I » has been realized under the assumption that the same system of tradable permits (or the corresponding tax) applies in FSU[14]. This induces a specific effort of abatement, and then an additional supply of permits by FSU on the world market.

The main difference with scenarios of section 3 is that transfers related to sales or purchases of permits are now effectively implemented, and this affects the sharing of total cost between countries/regions. Related transfers are of highest importance for FSU, as the sale of permits represents a very important revenue in comparison to GDP.

5.1. Permits based on Carbon Taxes

Permits based on carbon taxes yield abatements, price of tradable permits and marginal abatement costs very close to those obtained in preliminary scenarios (Iso-Tax scenarios).

In the case of a market limited to OECD countries, USA are net sellers, mainly to Other European Countries (around 70 millions T in 2010 an 100 millions T in 2020). When FSU participates to the market, without - and a fortiori with - a specific effort of abatement, all OECD countries are net purchasers.

Permit trading does not necessarily reduces the welfare cost for all concerned countries though, as it will be shown below, it reduces total world cost. The reason is that the transfers associated with the sales of permits modify the demand in international markets of goods, and then affect the gains and losses from terms of trade[15].

Graphs below confirm the analysis by representing, for each scenario, the three components of the welfare cost : gains or losses from terms of trade, deadweight loss of taxation and net sales of permits.

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[14] However, due to the highly unreliable statistical data on households' consumption and commodity taxation, no additional carbon tax has been applied to final demand. The assumption retained is that existing subsidies on energy products are removed, and final demand taxed at the average rate of 24%.

[15] Such a result has been obtained at the theoretical level. See Bernard (1999).

Figure 6

Permits based on taxes : OECD without Hot Air

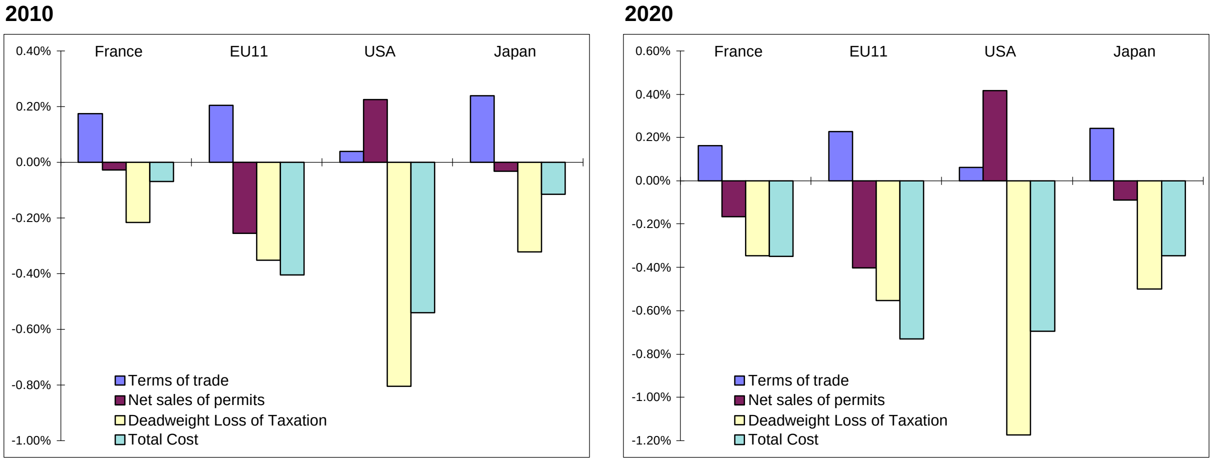


Figure 7

Permits based on taxes : OECD with Hot Air

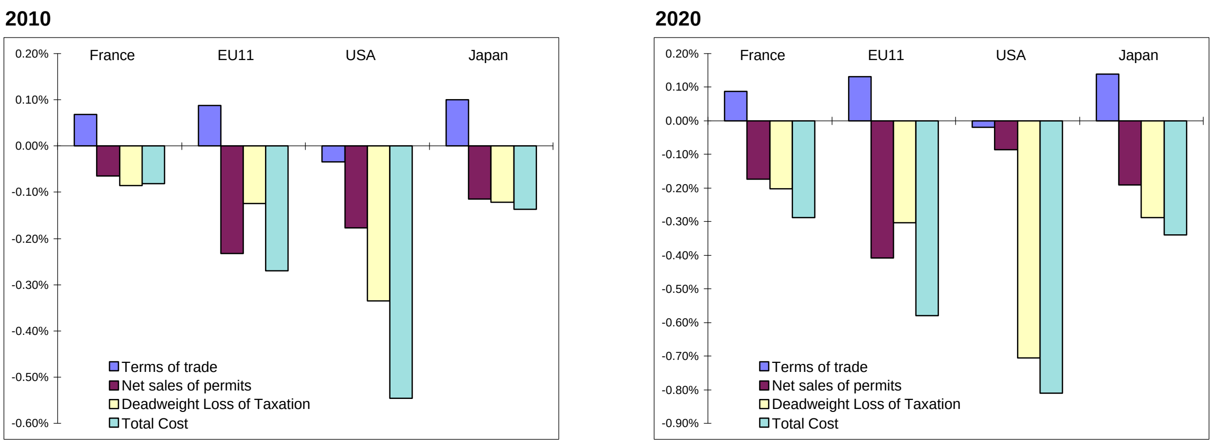
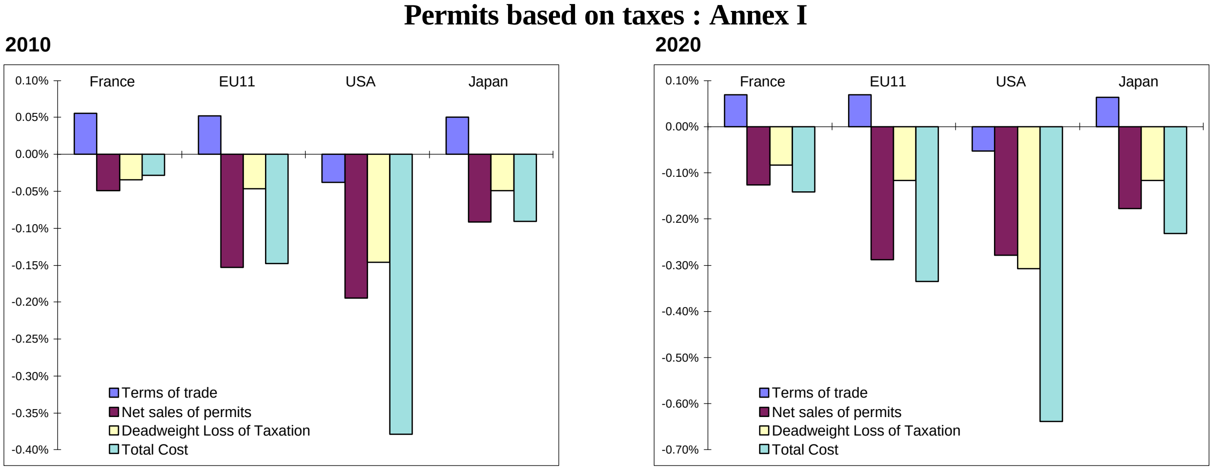


Figure 8

Permits based on taxes : Annex I



It can be noted that implementation of a carbon tax in FSU is not systematically advantageous though the deadweight loss of taxation is negative (as subsidies to final consumption of energy are eliminated). The increased supply of permits entails a sharp decline of the equilibrium market price (under the assumption that FSU has a competitive behavior) so that receipts accruing from the sales may decrease significantly. This is not an incentive for FSU to abate pollution, nor to refrain from taking advantage of a quasi-monopolistic position[16].

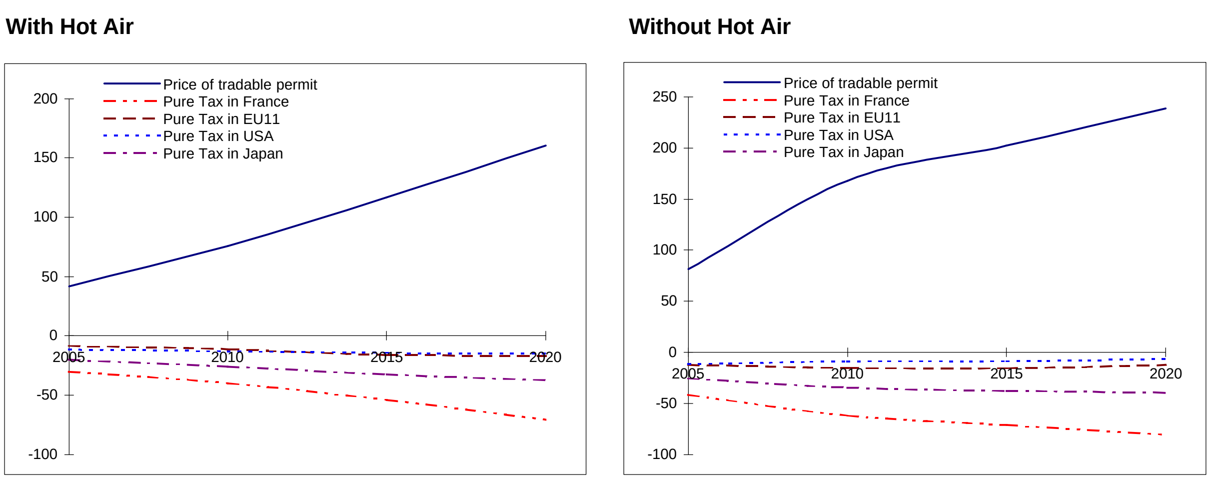
5.2. Permits based on MACs

Permits based on MACs are more advantageous to USA and less to other OECD countries than permits based on carbon taxes when trade is limited to this zone. This results from the fact that the price of permit is higher and that USA are net sellers, while other countries are net purchasers. Detailed comparison of the two types of permits is presented in sub-section 5.3.

An important aspect is the effective implementation of a market of tradable permits based on MACs (which corresponds to the optimization behavior by countries). The gap between the appropriate carbon tax in each country (differing in one from the other) and the equilibrium world price of permits requires that only governments trade in the international market. Another possibility, if private agents and in particular firms are to be the traders, is that governments set a corrective tax so that polluters pay the appropriate price.

In the present case, where MACs are systematically higher than carbon taxes, the corrective tax is negative, i. e. is a subsidy. Graphs below represent in the two concerned scenarios (without Hot Air and with Hot Air), the evolution of the price of tradable permits and of the domestic subsidies.

<u>Figure 9 : price of permit and corrective subsidies</u>



Mainly in France and Japan, where the difference between the carbon tax and the marginal abatement cost is high, subsidies are important relatively to the price of permit.

[16] See on this issue the paper by J.-M. Burniaux, 1998. « How important is market power in achieving Kyoto ? : An assessment based on the GREEN model », OECD Experts Workshop on Climate Change and Economic Modeling : Background Analysis for the Kyoto Protocol, Paris 17-18 September

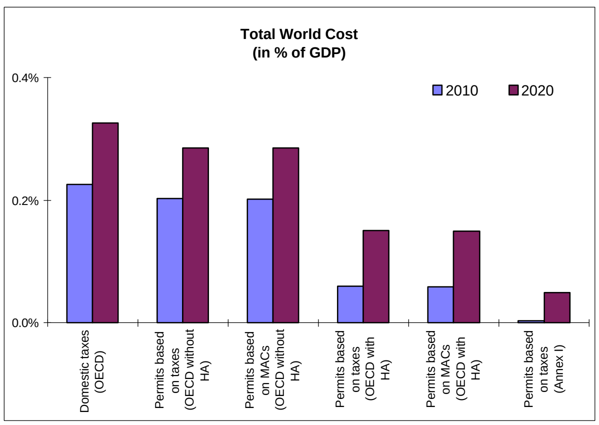
5.3. *Comparison of types of permits*

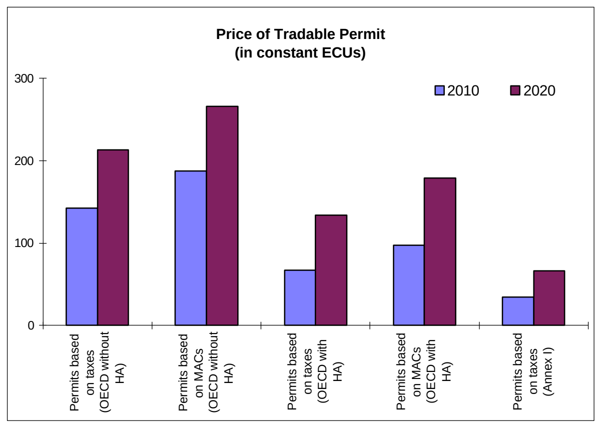
The series of graphs below gives a visual representation of the results of scenarios, mainly concerning the total cost of abatement and its sharing among counties/regions.

5.3.1. Total world cost of abatement

Total world cost is highest without tradable permits, a result which was easily expectable. Trade of permits inside OECD, either based on carbon taxes or on MACs, yield a welfare gain which is nearly identical in both cases[17], but is fairly limited.

Figure 10 : comparison of scenarios





Such a limited gain, and the very limited extent of the market (about 70 millions T in 2010 and 100 millions T in 2020) do not justify to implement a complex mechanism. At most, it may serve as a basis for rethinking the allocation of pollution rights between OECD countries.

With participation of FSU, both the extent of the market and the welfare gains change considerably. However, this is not a result of efficiency of market mechanisms, but reflects a significant difference in total world pollution abatement : industrialized countries buy from FSU rights which in any circumstance will not be used inside the Confederation.

As a result, total world abatement of CO_2 emissions is only 6% in 2010 (as compared to the baseline scenario) instead of 9% without participation of FSU. *The welfare gain results mostly from the reduced global target of abatement*.

5.3.2. Sharing of total cost between countries

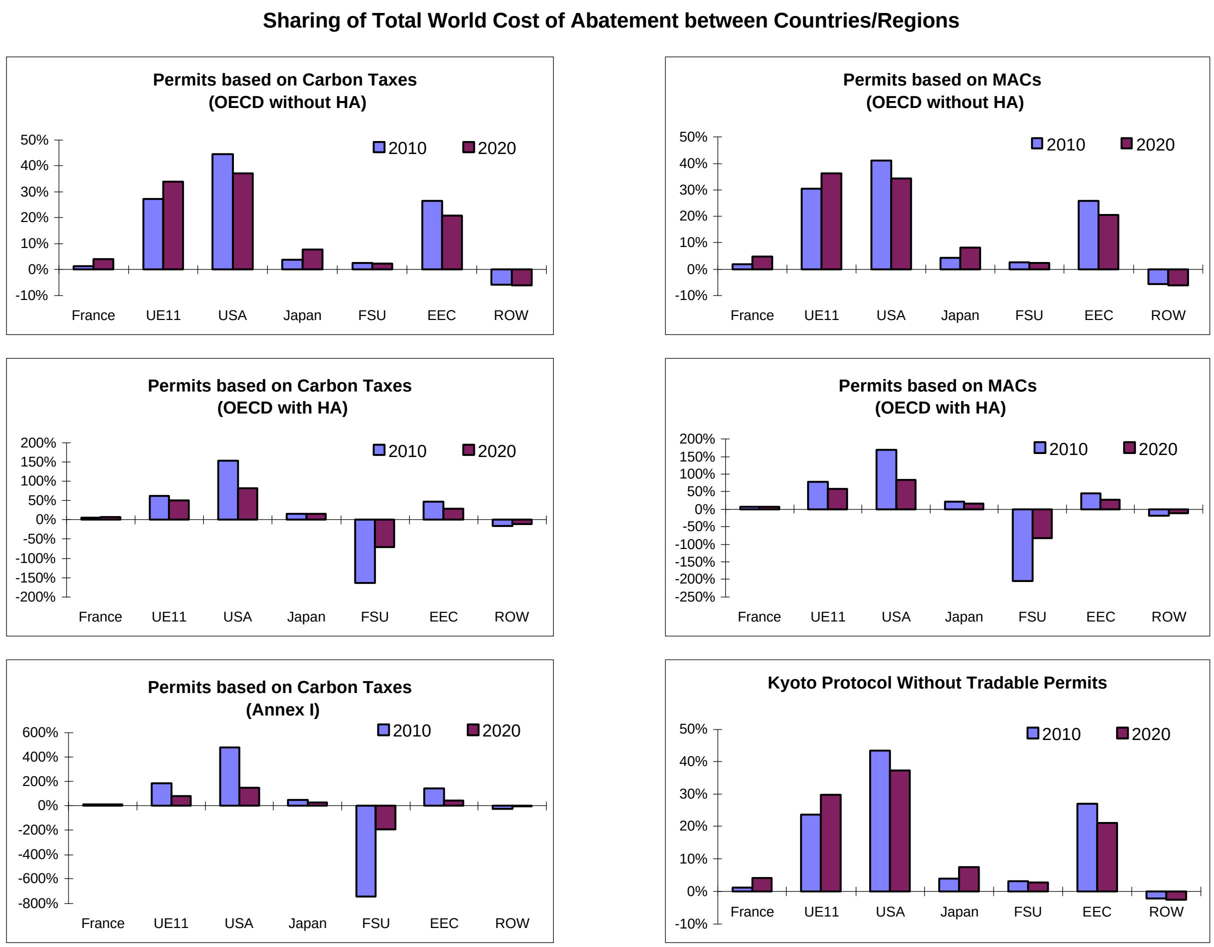
Graphs of Figure 11 represent the allocation of total cost between countries/regions. Total is normalized to 100%, with the effect that when some country/region is beneficial (case of FSU in scenarios with its participation to the market of tradable permits), the sum of shares of other countries (eventually the share of a single country) is more than 100%.

[17] This was obtained at the theoretical level (see Bernard, 1999)

All graphs show the high share borne by Energy Exporting Countries, of a size often comparable to USA and European Countries altogether. Effects of a world policy of GHG mitigation on energy markets, and in particular on the crude oil market which is highly volatile, cannot be omitted in its effective implementation.

Also enlightening is the comparison between scenarios based on marginal abatement costs and on taxes. The share of the cost is smaller (or the gain is bigger) for countries which are net sellers, and bigger for countries which are net purchasers. This concerns USA in the case of exchanges limited to OECD countries, FSU in the case of a market of tradable permits between Annex I countries.

Figure 11 : sharing of total world cost between countries/regions



Let us recall that permits based on MACs correspond to the optimization behavior of countries : though they are not necessarily more efficient at the global level, they are more likely to show off.

6. Main teachings and further developments

Main teachings of the paper are of two aspects. The first is about the technical question raised in the paper, i. e. comparison of permits based on carbon taxes versus permits based on marginal abatement costs.

Simulations realized and presented in the paper did not show a significant difference in terms of global efficiency, and this confirms a result which was already obtained at the theoretical level, in the case where there are distortions in domestic fiscal systems. There are however differences in terms of equity : as marginal abatement cost is higher than carbon tax, permits based on MACs are more favorable to net sellers and less to net purchasers.

In the present scenarios, the corresponding gain or loss for countries/regions appear quite small and the question may be considered as « of the second order ». But this may become very different in the case of a full participation of developing countries to the Kyoto Protocol. For these countries, the gap between carbon tax and marginal abatement cost may be very different from what it is in industrialized countries, eventually of the opposite sign. Simulations of tradable permits based on carbon taxes may bias significantly the effective outcome of such a market, as countries will consider their marginal cost of abatement when determining their supply or demand of permits. The question deserves a detailed examination.

The second main teaching concerns the appraisal of the Kyoto Protocol as it results from the various scenarios.

Though impressive in the reversal of past trends of energy demand by industries and households which is required, the targets of GHG mitigation set in Kyoto appear reachable at a total world cost which is fairly low : around 0.2% of world GDP in 2010,and 0.3% in 2020, not taking into account the artifact of Hot Air which is a biased way of alleviating the commitments (by approximately one third).

The total cost as measured by the model may be underestimated because costs of adjustment (i. e. transitory costs) are probably not totally taken into account. Among them are the costs of anticipated capital decay, notably in the sector of electricity generation : substituting gas to coal, in a short delay, needs to close plants which are not written off. The above-mentioned study conducted by EIA-DOE, based on detailed models of energy demand and supply, shows a significant difference between the *effective* and the *potential* decrease of GDP. In a general equilibrium model, such effects can be coped with only through vintage production functions.

As concerns efficiency, markets of tradable permits (excluding the Hot Air mechanism) alleviate the total cost, though to a very limited extent. This reflects the limited size of such a market when restricted to industrialized countries, and probably also the fact that the allocation of abatement targets decided upon in Kyoto is not too far from optimality (in the sense that the corresponding domestic carbon taxes or marginal abatement costs are not too different).

The Kyoto Protocol is, on the contrary, very inefficient relatively to other countries/regions as there is no incentive to Former Soviet Union and to Developing Countries to abate GHG emissions (or more exactly, concerning the latter, to restrain growth of energy demand).

On the one hand, the Hot Air mechanism appears rather counter-productive as effective abatement of emissions by FSU is not rewarded. On the other hand, it is politically difficult to ask countries with very low levels of energy consumption by head to restrain their demand, the growth of which is considered by them as a necessary means of economic development. It is also a question of equity.

Incentives to abate CO2 emissions by all countries, and equity among nations, would have been probably better served with an allocation of pollution rights based on population. In particular, developing countries with low levels of emissions would then benefit from transfers from industrialized countries, and would be induced to restrain the growth of energy demand in order to keep an important source of income.

At last, the specific situation of energy exporting countries deserves special consideration. Loss in the short to medium term may be counterbalanced by long term conservation and revaluation of their natural resources.

Appendix 1

The structure and calibration of model *GemWTraP*

GEMINI-E3 was the name of the first General Equilibrium Model developed in collaboration between french Ministry of Equipment and CEA (french Atomic Energy Agency). It is now the name of a family of models, including ***GemWTraP***, which is a world dynamic semi-aggregate model and GEMINI-E3 XL France, which is a static detailed one-country model (France, 88 branches are described).

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 such as, for instance, implementation of nuclear programs, the model can incorporate a technological sub-model of electric generation, better suited for comparing investments in different types of plants. It is the third version in succession and has been especially designed to calculate (social) marginal abatement costs (MAC), i. e. the welfare loss of a unit increase of pollution abatement and then to simulate tradable permits markets based either on carbon taxes or on MACs. 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 carbon taxes.

Table 1 gives an overall description and 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 coped with[18].

[18] 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.

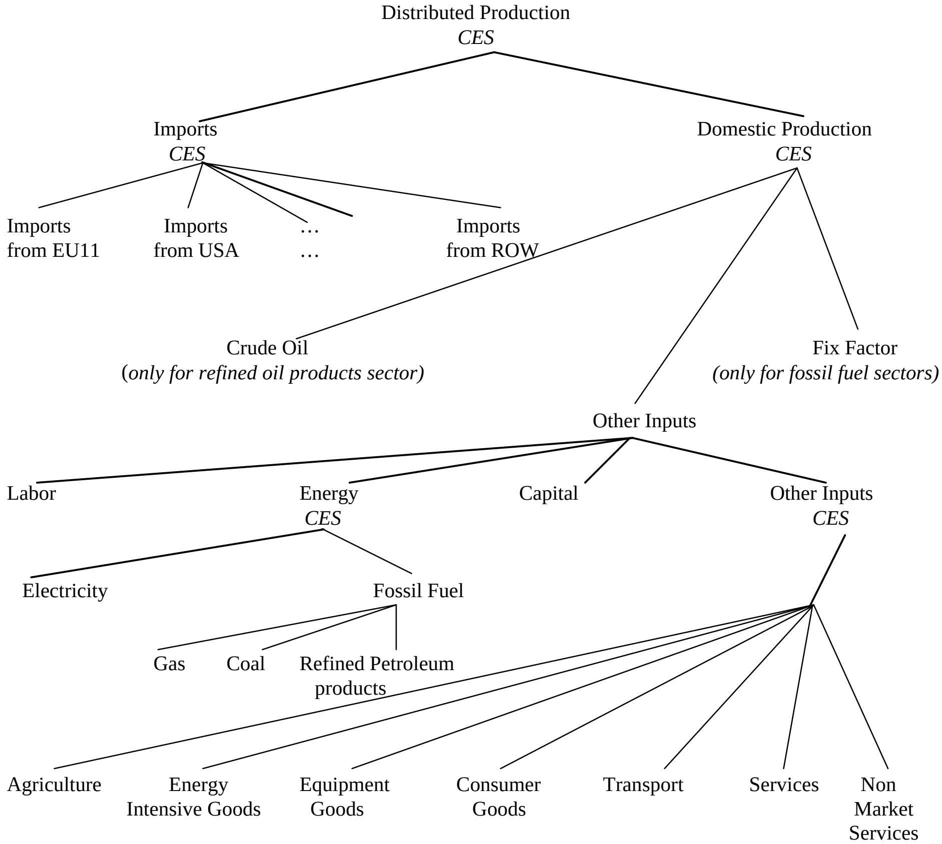
Table 1 :Identification card of GEMINI-E3/*GemWTraP*

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 Sectors (IS) : Households (incl. Private Administrations), Firms, Government
12 sectors/commodities for France and EU11 and **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 : 2020 (with yearly steps)
Production Functions : Nested CES with Fix Factors for fossil fuel sectors
Households' Demand Functions : Linear Expenditure System (Stone-Geary model)
Functions 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 costs and price of tradable permits when relevant - effective abatement of CO2 emissions, net sales of tradable permits (when relevant) - total net welfare loss, disaggregated in : 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 -sectoral data : production and factors of production (change in volume and change in price or remuneration)

1. The specification of production functions

Graph 1 represents the nesting of factors in production functions, for all sectors and all countries or regions.

Graph 1: Nesting of factors in the production function (case of France)



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. Allowing more or less easy substitutions between factors, they command much of the numerical results in scenarios : abatement of CO2 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.

Values of elasticities of substitution retained in the model were determined according to various sources and econometric estimations.

2. The specification of households' demand functions

Deriving demand by households from a utility function allows to have a relevant economic measure of the cost of abatement policies. Households' surpluses are reckoned for every year and every country/region, and 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.

Appendix 2

Design of the Baseline Scenario

Baseline Scenario is based on the International Energy Outlook (1999) prepared by the Energy Information Administration of the US Department Of Energy and for France on Scenario S2 of the Commissariat General du Plan.

1. Crude oil price in international markets

A main assumption is related to the oil price in international markets. Reflecting an average of the two above-mentioned studies, assumption is made that crude oil price is stable in real terms on the whole period and equal to 22 US dollars of 1996 per barrel.

2. Economic growth and energy demand

Assumptions relative to economic growth of the various countries/regions individualized in the model are given in table 1, which yields related growth of energy consumption and CO2 emissions.

Table 1 : Baseline Scenario : Annual Growth Rates in percent for 1995-2020

Country/Region	GDP	Energy Consumption	CO2 emissions
France	2.2	1.3	1.1
EU11	2.4	1.2	0.9
USA	2.3	1.4	1.3
Japan	1.7	0.9	0.7
FSU	2.1	1.0	0.8
EEC	3.9	3.1	3.0
ROW	4.4	3.3	3.2
Total World	3.3	2.3	2.2

Comparison of energy demand and economic growth shows that energy intensity decreases at about 0.8 to 1.0% in the various countries/regions, and a consistent rate of A.I.E.E. is taken into account in production functions of the model.

Tables 2 and 3 detail generation of electricity and the energy balance, and table 4 details emissions of CO2 by sectors.

<u>Table 2 : Electricity Generation</u>

	Share of Electricity in Final Demand		Carbon Content Electricity gr/Kwh	
	1995	2020	1995	2020
France	20%	22%	19	19
EU11	16%	18%	159	102
USA	19%	21%	164	157
Japan	22%	28%	99	83
FSU	17%	14%	236	173
EEC	12%	12%	150	114
ROW	10%	10%	190	142
WORLD	14%	13%	169	134

<u>Table 3 : World Energy Balance for 2020</u>

	Coal	Gas	Crude oil & refined oil products	Electricity
France				
Households	1	17	26	13
Industry and other sectors	8	24	78	29
Electricity	5	9	2	
Total	**13**	**50**	**106**	**42**
Growth rate 1995/2020	-0.5%	2.3%	1.1%	1.5%
EU11				
Households	6	151	181	54
Industry and other sectors	47	166	291	135
Electricity	98	142	56	
Total	**151**	**459**	**527**	**190**
Growth rate 1995/2020	-1.3%	2.9%	0.9%	1.8%
USA				
Households	2	126	333	124
Industry and other sectors	43	302	640	251
Electricity	531	299	4	
Total	**576**	**727**	**978**	**375**
Growth rate 1995/2020	0.8%	1.9%	1.9%	1.4%
Japan				
Households	0	13	72	32
Industry and other sectors	43	12	158	82
Electricity	43	77	27	
Total	**86**	**102**	**256**	**113**
Growth rate 1995/2020	0.7%	2.5%	0.5%	1.6%
FSU				
Households	24	96	32	18
Industry and other sectors	50	275	139	83
Electricity	49	268	56	
Total	**123**	**639**	**227**	**101**
Growth rate 1995/2020	-1.1%	1.7%	0.8%	0.9%
EEC				
Households	0	101	176	33
Industry and other sectors	18	87	421	76
Electricity	24	101	106	
Total	**42**	**288**	**703**	**109**
Growth rate 1995/2020	2.9%	3.0%	3.1%	3.3%
ROW				
Total	**2873**	**619**	**2423**	**767**
Growth rate 1995/2020	3.2%	2.9%	3.5%	3.6%
WORLD	**3863**	**2883**	**5222**	**1697**
Growth rate 1995/2020	2.4%	2.3%	2.2%	2.4%

Table 4 : CO2 emissions in 2020 (Millions T of C)

	Electricity	Households	Industry and other sectors	Total
France	13	33	89	135
EU11	249	255	402	907
USA	795	361	777	1932
Japan	121	68	187	376
FSU	276	116	351	744
EEC	181	213	429	823
ROW	1599	935	3108	5642
WORLD	3234	1982	5344	10559

3. Emissions abatement in energy consumption

Targets of emissions abatement set in Kyoto concern all kinds of GHG emissions, and all sources. Accounting of emissions and sinks from activities related to agriculture, land use and forestry, and expected reductions for other GHG change the targets for CO2 emissions by fossil fuels consumption to levels which are given in table 5 (intermediary column). Effective abatement, relatively to baseline scenario, then results (last column).

Table 5 : CO2 emissions abatement in energy consumption consistent with the Kyoto Protocol

Country/Region	Kyoto Protocol Abatement of total CO2 emissions (relatively to1990)	Abatement for energy consumption taking into account abatement due to other greenhouse gases (relatively to 1990)	Effective abatement in 2010 (relatively to baseline scenario)
France	0%	+1.5%	-17%
European Union (except France)	-8%	-6%	-26.5%
USA	-7%	-3%	-29%
Japan	-6%	-6%	-22%
FSU	0%	0%	+44%