Fondazione Eni Enrico Mattei

Kyoto Protocol and Emission Trading:

Does the US make a difference?

Umberto Ciorba*, Alessandro Lanza**
and Francesco Pauli*

NOTA DI LAVORO 90.2001

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CLIM – Climate Change Modelling and Policy

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SUMMARY

This paper presents an estimate of the costs of reducing CO_2 emissions as agreed in Kyoto by Annex 1 countries. Unlike most of the existing literature, this paper uses an *Almost Ideal Demand System* model for energy products to estimate the role of each country within the Annex 1 market. A major result is the provision of marginal (and total) abatement costs for each. The recent position of the US is also discussed, showing the cost of some alternative outcomes.

Keywords: Environmental policy, Kyoto protocol, international agreements, CO_2 emission, emission trading, marginal abatement cost

JEL: C13, C21, C53, Q38, Q41, Q48

CONTENTS

1. Introduction

Since its introduction, international emission trading has been the subject of extensive debate and the outcome of the COP 6 meeting in Le Hague, as well as the new US position, have added more uncertainty to the whole process. One of the major issues in the climate change debate is the GDP cost dimension related to the agreed levels of emission reduction as well as the possibility of reducing such costs through emission trading. Following a growing range of economic literature, this paper addresses this issue from a particular point of view.

Annex 1 countries signed the Kyoto Protocol in 1997, agreeing to reach a fixed level of greenhouse gas emissions by the period 2008-2012 (Table 1 in Appendix). According to the Protocol, most countries accepted a substantial emission reduction, some an emission stabilisation. A few countries were allowed to increase their emissions up to an agreed quantity.

Emissions reductions clearly involve costs. For some countries reducing emissions requires either the implementation of appropriate technological changes in energy consumption or the reduction of energy consumption itself. In any case, reducing emissions involves a social and economic price. In order to reduce the total cost, the Kyoto Protocol allows for the use of flexibility mechanisms, whereby countries can mitigate their compliance costs.

This paper focuses on emission trading and different scenarios are presented that correspond to participants in the market as well as the domestic no trade solution. For each scenario the market price as well as total abatement costs for each country is indicated. While the Kyoto Protocol considers six different greenhouse gases this paper is limited to the most relevant, i.e. CO_2 (Carbon dioxide). It is worth pointing out that not all the countries that signed the Kyoto Protocol are considered in this paper, principally due to a lack of data. However, less than 3% of Annex 1 emissions is not included in this study.

Current literature focuses on the economic implications for large aggregations of countries. The European Union, in particular, is considered as a single area, even though structural differences persist within the region. However, it is worth underlining that aggregations of countries are largely driven by different modelling approaches. For example Computable General Equilibrium Models, that require a large quantity of information, generally do not adopt a country by country approach.

This paper is divided into four sections.

Section 2 surveys the current literature, pointing out the importance of the definition of a suitable marginal abatement cost function.

Section 3 describes the econometric approach adopted, while Section 4 reports all relevant results.

Conclusions drawn from the approach adopted are outlined in Section 5.

2. Tradable permits: a general framework and survey of existing literature

The Kyoto cost for a single country can be perceived as the difference between two different scenarios. The first scenario can be labelled Business as Usual (BAU), representing a zero-cost situation. On the other hand, an Alternative Scenario (AS) is required in order to set lower emissions according to the Kyoto profile. In this context, total abatement means the difference between BAU emissions and Kyoto requirement emissions by the year 2010, central to the period considered in the Protocol, and used in this paper as a reference year.

The cost of emissions reduction is described by the marginal abatement cost (MAC). Using MAC curves for several countries, demand and supply of emission permits can be calculated. In principle, in order to minimise costs, each country's reduction will be such that the MAC corresponding to that reduction will be equal to the price of the permits. If the obtained reduction is higher than the requirement, the country will sell permits, contributing to the supply in the permits market. On the other hand, if the reduction is lower than that required, the country will contribute to the demand for permits. A market-clearing mechanism determines the market price of emission permits.

In this paper, MAC curves are calculated on the basis of country-specific demand functions for fuels and thus implicitly for carbon. A demand function for each fuel (and country) is estimated following an AIDS (Almost Ideal Demand System) (Deaton and Muellbauer (1980)) specification. A MAC for each fuel and eventually, by aggregation, a MAC curve for each country is also obtained. This approach is similar to Bader (2000) and Ciorba, Lanza, Pauli (2001).

However, an AIDS model explains more rigorously the behaviour of economic agents: demands are derived from the PIGLOG functional form that have the desirable properties of the micro demand functions and can be thought of as deriving from the behaviour of a single representative consumer.

2.1 Estimating demand functions

The final expression of a generic AIDS is:

$$w_i = \alpha_i + \sum_j \gamma_{ij} \ln p_j + \beta_i \ln\left(x/p \right) + \varepsilon_i$$

where α_i, $\gamma_{i,j}$ and β_i are parameters, ε_i is a disturbance term, p_i is the price of good j, *x* the total expenditure and P* is a price index. If we approximate P* with Stone's price index we obtain a model that is called *Linear approximate* AIDS (LA/AIDS)[1].

The model consists of a system of simple demand functions in which the expenditure rates are functions of the logarithms of prices and the logarithm of total expenditure. The AIDS model has been adopted to build a model of energy demand for the countries in Table 1. The demand system is a preliminary step towards the MAC curve for each country.

In this paper the energy system has been divided into four sectors (Households, Transportation, Electricity generation and Industry). In each sector a single representative consumer is considered. The whole model can be derived as:

$$\begin{cases} w_1 = \ln q_1 = \alpha_1 + \gamma_{11} \ln p_1 + \ldots + \gamma_{1,n} \ln p_n + \beta_1 \ln x \\ \vdots \\ w_{n-1} = \ln q_{n-1} = \alpha_{n-1} + \gamma_{n-1,1} \ln p_n + \ldots + \gamma_{n-1,n} \ln p_n + \beta_{n-1} \ln x \\ q_n = 1 - \sum_{i=1}^{n-1} q_i \end{cases} \tag{1}$$

where X/P* indicates the expenditure in real terms.

2.2 Obtaining countries MAC curves

Estimated models are used to evaluate MAC curves for each fuel; curves are then added up to obtain the MAC curve for the whole country.

First, the system (1) is used to compute the variation in carbon emission due to an increase in carbon price. Let us now consider sector *s* of country *k*. If Δp is the carbon price variation and c_i represent the carbon contents of the fuels considered (i=1,…,n), then the new prices implied by this price increase are

$$p^*_{k,s,i} = p_{k,s,i} + c_i \Delta p \, ,$$

that is, the price of each fuel is raised proportionally to its carbon content.

The estimated system (1) allows us to calculate the new quotas implied by this price structure. We only need to substitute the new prices on the right side equations and to compute the left side.

Thus, the abatement obtained in sector *s* by an increase Δp in prices is

[1] See Blanciforti and Green (1983).

$$\Delta C_{k,s}(\Delta p) = \sum_{i=1}^{n} c_i \left(q^*_{k,s,i} - q_{k,s,i} \right) Q_{0,k,s,i}$$

where $Q_{0,k,s}$ in this paper is the energy demand in 1997. By adding up sectors we obtain the carbon abatement for the country as a whole:

$$\Delta C_k(\Delta p) = \sum_{s=1}^{m} \Delta C_{k,s}(\Delta p) \quad (2).$$

Eq. (2) is repeated for different values of Δp. Fitting a simple quadratic curve between these points yields the MAC curves available country by country on request from the authors.

3. Emissions trading and abatement costs

Estimated MAC curves are different for each country. In general, the US has a MAC curve lower than those of the other industrialised countries, but still higher than those of Eastern European countries (Poland, Czech Republic, Hungary). The MAC curve for the FSU, is zero for an abatement less than 111 Mton, which corresponds to *hot air* and then grows sharply for abatements above that amount. Considering the cost of Kyoto requirements, starting from MAC curves we should evaluate first a target emission by 2010 with a zero cost scenario. In this respect, forecasts are provided by IEA (1998) for all countries except the Czech Republic, Poland and Spain for which forecasts are taken from the country's «Second national report to the conference of the parties to the United Nations Framework Convention on Climate Change» and Japan, whose forecasts are provided by EIA «International Energy Outlook 2001». The costs are compared in Table 1 where MAC and total abatement costs corresponding to Kyoto compliance are reported. According to these results Greece, France and Italy show the highest costs among EU countries in an autarkic solution. Total costs for European countries are generally higher than for other industrialised countries given the high level of energy efficiency and the important role played by energy taxes. MAC curves define a supply and a demand curve of emission permits and so can be used to determine the equilibrium price of permits and, consequently, the number of permits each country sells or buys at equilibrium price. This analysis has been performed under various hypotheses on the countries that participate in the market.

3.1 EU emission trading market.

The market price obtained using this hypothesis is US$96.5, whereas the total abatement cost is $6.7 billion, saving approximately $4 billion with respect to the no trading case. A comparison of the cost distribution within the EU shows that Greece's share of the cost is dramatically reduced (from $2.8 billion, corresponding to 27% of total EU expenditure, to $1.03 million, corresponding to 15%). In fact, Greece buys permits to cover 76.6% of the commitment. In contrast, Denmark and Luxembourg, thanks to their low MACs and commitments, are able to obtain a net income by selling permits.

To our knowledge only Bader considers a closed EU market, but the comparison between our results and his is difficult due to a difference in methodology. Bader estimates the parameters of the MAC curve for the whole of Europe, so that the same shape applies to all EU countries. This means that differences in the MACs are given only by differences in the commitments and in the starting value of the ratio C/GDP. Moreover, the forecasts for 2010 emissions are widely different, so the great differences in final results should not be a surprise. Nevertheless, the market price determined by Bader is $81/tC, less than our estimate but not dramatically different, and the same can be seen for total abatement costs.

3.2 Annex 1

Opening the market to Annex 1 countries results in a reduction of the market price of $59.9/t. Since the FSU commitment is higher than BAU forecasted emissions (Tab. 1), the MAC of this country is zero for abatement below the difference between commitment and BAU emissions. In practice, a supply of 111 Mton is introduced (the, so called, «*hot air*»), leading to an important reduction of costs as can be seen in Table 3: the FSU earns $7.2 billion from trading while the EU (except Germany and Denmark), Japan, Australia and the USA buy permits. In this market, supply is highly concentrated: the most important suppliers are the FSU (with a market share of 70.7%), the Czech Republic (14%) and Canada (6.8%). Demand is less concentrated, only USA (45.8%), Italy (11.5%), Japan (12%) and Australia (10.5%) show market shares above 10%.

Price estimates for the Annex 1 market are easy to find in literature, and our results are in line with the values obtained by other authors. In general, papers consider the European Union as a whole and do not conduct analysis on separate European countries.

3.3 Annex 1 trade without US

The refusal of US President Bush to ratify Kyoto Protocol has cast some shadows on the implementation process of the Protocol. It is still not clear whether the US intends to renegotiate targets and mechanisms of implementation or to quit the process. In the latter case, Annex 1 countries face two alternatives: reduce their emissions by the amount fixed in Kyoto for each country; or proportionally increase their commitments in order to cover the share of reductions attributed to the US in the Protocol. In both cases, a system of tradable permits should help to reduce drastically the costs of abatement.

A global trade scenario without the US and with the commitments fixed by Kyoto, produces a market price of US$38.8tC and a total abatement cost of $3.7 billion. (Table 4)

The FSU earns US$4.8 billion from trading while the EU (except Denmark with a market share of 0.37%), Japan and Australia buy permits. The supply side of the market is almost completely represented by the FSU (with a market share of 83%), the Czech Republic (13%), Hungary (2.3%) and Canada (1%). The demand is less concentrated, only Italy (15.6%), Japan (26.2%) and Australia (14.6%) show market shares above 10%.

If the US commitment is proportionally distributed between the other Annex 1 countries, in order to maintain the total reduction levels agreed in Kyoto, the market generates a price of US$120.8tC and a higher total abatement cost of US$25.05 billion (but still 30% lower than the autarkic solution). (Table 5)

The FSU earns US$15 billion from trading, the Czech Republic earns US$15 billion while the EU (except Denmark and Germany), Japan and Australia buy permits. The supply is almost completely represented by FSU (with a market share of 67.4%), the Czech Republic (17.9%), Hungary (4%) and Canada (1%). The demand side of the market is less concentrated, only Greece (10.1%), Italy (19.6%), Japan (22.8%) and Australia (18.8%) show market shares above 10%.

4 Comparison with the literature: the role of forecasts

The relevant discrepancies between our results and those that can be found in literature require some comment. In Table 6 we compare results in terms of costs and MAC. Apart from what Table 8 reveals, it should be pointed out that the behaviour of some countries is different in this paper and the prevailing literature. In particular, for Bader, Denmark and Germany are heavy buyers of permits, while in our simulation of EU trade Denmark and Germany sell permits (see table 3). We realised that these differences are mainly due to the (wide) variation in the forecasts for 2010 (the zero cost baseline). To show this result we simulate the market using our MAC curves together with the forecast proposed by Bader. In this case Austria, Denmark, Finland, France, Germany, Italy and Sweden are the suppliers, that is, the same as Bader with the exception of France, due to a discrepancy in 1990 CO_2 emissions (France in Bader has a target equal to forecasts and so clearly does not buy permits).

In the comparison with the Ellerman and Decaux results (Table 6), the surprising fact is that the role of Japan and the USA is inverted (Japan demands and the USA supplies in Ellerman and Decaux, the opposite is true for us). If we examine the 2010 forecasts we note that the forecast for the USA is quite similar (1838 v. 1800) while the forecast for Japan is quite different: 424 Mton of C in Ellermann, 310 Mton of C for IEA. Eventually, if we substitute the Ellerman forecast for Japan, the roles of Japan and the USA change and our model agrees with that of Ellerman.

More recent projections for Japan (330 Mton of C in 2010) are provided by EIA «International Energy Outlook» and are adopted in our model.

5. Conclusions

It should be noted that the results we present are no more than an indication of what might happen in a market of permits. The wide range of results that can be found in the literature on the equilibrium price of a permits market (from $20 to $177 per ton of carbon) is itself a caveat on the reliability of the numerical results. Nevertheless, general tendencies can be detected, and the fact that different studies offer similar considerations makes us reasonably confident in our conclusions.

With these considerations in mind, we observe that the empirical simulations in this report show that, without any transaction costs, a market of permits should help to reduce the individual and total costs of emissions abatement.

According to economic theory, a trading permits scheme should help to attain an efficient allocation, but is completely neutral with respect to any equity consideration. In fact, a country would be a net demander or a net supplier of permits depending on its endowment, that is, on its initial commitments. Since commitments are basically political agreements, it is useful to underline that commitments should be defined carefully: the definition of commitments may produce a redistribution of income (*via* tradable permits) from countries that have adopted mitigation measures to countries that have not. In fact, it is probable that the latter can still implement cheaper measures, whereas the former have only expensive options to reduce emissions. In this sense, Kyoto commitments seem to lead to a paradox: countries with lower levels of emissions per GDP and emissions per capita pay (through the purchase of permits) developed countries, that have significantly higher levels of emissions per capita and per GDP. The result of a tradable market

system, in fact, is that EU countries and Japan buy permits from Russia and the Czech Republic if trade is open to Annex 1 countries (see Table 4), while the Czech Republic and Russia have the highest ratios of emissions per unit of GDP and per capita (see Table 9) and those of Japan are similar to those in Europe and lower than the FSU, the Czech Republic or the US.
It should be noted that these indicators can be misleading and must be broken down by sector. Indicators are, in fact, influenced by the productive specialisation of a country and the structure of the economy will necessarily affect emissions levels. When sectors that are intrinsically polluting represent a high share of GDP, aggregate indicators are influenced by their effect, even if sector indicators show optimal performance. Moreover, the geographical aspects of each country must be taken into account. For instance, countries with a low population density will register high levels of emissions per capita in the transportation sector because of the distance that workers, goods and raw materials are obliged to travel. Climate conditions and temperature also influence the level of emissions.

Sector indicators confirm the results shown by aggregate ratios of the countries considered. With the exception of the Russian transportation sector, per capita emissions are always higher in the USA and Russia than in Europe and Japan.

Many aspects of our methodology are susceptible to improvement. From an economic point of view a primary issue is given by the role of the FSU. The market position of the FSU, which sells about 70% of permits, suggests that it may behave as a monopolist, and so its aim might not be to minimise costs, as in this model. For example the FSU could wait until the deadline fixed by the Kyoto Protocol to sell permits at a higher price to countries at risk of non-compliance. It is also true that the FSU comprises a number of countries and this may mitigate the monopoly, but there is a reasonable possibility that they may still act as a group.
The absence of transaction costs is a second main defect of our model. The market with transaction costs would allow fewer savings than the no friction market we assumed.
A more important limitation is that we consider a price variation (tax) as the only way in which countries can encourage an abatement of emissions. In fact, incentives for sensible investment may represent a valid alternative, and technological improvements would generate environmental, as well as an economic, returns.

Appendix: price and quantities of the carbon market.

Historical fuel consumption and price data (1970-1997) for the countries involved in the analysis are provided by the International Energy Agency[2]. For each country fuel consumption and price data are divided into three sectors by end use: industry, electricity generation and households, the latter is then split between domestic and transport.

Price data are always end user prices and include energy or CO_2 taxes, set at different levels in each country. These are expressed in terms of US$ PPP in order to consider differences in the general price level of EU countries.

Fuel consumption data by sector were extracted from the IEA database. The fuel classification by type considered in this database is less refined than the one used for prices.

In particular, all gasoline and diesel for motors are grouped in the household sector, and high-sulphur fuel oil (hsfo) and low-sulphur fuel oil (lsfo) are grouped in the industrial sector. The aggregate fuel oil consumption for households has been split into diesel and gasoline according to the observed ratios of gasoline/diesel consumption derived from «Energy Statistics of IEA Countries». That is, diesel consumption is $\alpha\times$(total motor fuels) where α is the share of diesel consumed as motor gasoline as well as diesel used in households. Gasoline is calculated analogously.

While quantities in the original databases are in different units (litres, tons of oil equivalent, cal), all quantities in our output are expressed in Mtoe. Conversion factors are provided by «CO_2 Emissions from Fuel Combustion» edited by the IEA. Prices in the database are in US$ PPP relative to various units of fuels. The carbon price we calculated is expressed in US$ PPP per tonne of carbon. As mentioned above, P_C depends on the prices of fossil fuels as well as their market shares.

This paper does not consider total fossil fuel consumption, but a share (in broad terms, the percentage of fossil fuels for which corresponding price and quantities are available), and, moreover, a share that varies over time. The fuels considered in the P_C calculation represent a share of total consumption[3] of about 60%, starting from a minimum value of 40% for Luxembourg, to a level of about 80% for France, Italy and Denmark. The total coverage is relatively stable from 1978 to 1997. In fact, in many countries the quantities recorded in the original database are constant over a number of years, which is a clear sign of their reliability. Apart from the share of consumption covered by the fuels, the share of carbon emissions covered by our selection can also be considered. This is the ratio of carbon emissions to each fuel (expressed as $\Sigma C_i F_i$) and total carbon emissions as

[2] IEA, Energy Prices and Taxes, several issues.

recorded in «CO_2 Emissions from Fuel Combustion» (2000). The average share of carbon emissions covered is about 70%, starting from a minimum coverage of about 40% for Luxembourg, to levels near 80% for France, Denmark, Belgium and Italy.

If we examine the coverage level of carbon emission and the coverage level of consumption for Italy we see again that the level has been essentially stable over the past 20 years and that the coverage level of carbon emission is uniformly higher. In other words 75% of the fuel consumed in Italy produces 85% of carbon emissions, this means that we tend not to use the less carbon-intensive fuels.

The lowest consumption coverage levels are registered by Sweden and France. Both countries have a percentage of TPES covered by hydro and nuclear close to 46%. In both cases a significant amount of end-use demand is not considered in our calculation, but its contribution to carbon emissions is near zero.

Analogously, the lowest emission coverage levels are registered by Germany and Greece. Both countries show 25% to 35% of TPES covered by brown coal. Since the IEA database does not contain data on brown coal, but only on bitcoal and cokecoal, we are not able to consider this substantial amount of fossil fuel end-use.

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Table 1: Kyoto commitments and domestic solutions

		Carbon Emissions (Mton)				Abatement					
		1990	1997	2010 (forecast)	2010 (commitment)	Comm (% 1990)	BAU - Target	Ab. % of 1997	MAC (US$/t)	AC (US$/t)	AC ‰ GDP
AUSTRIA	A	16.2	17.5	18.0	14.1	87.0	3.9	22.3%	154.8	0.28	1.88
BELGIUM	B	29.8	33.4	33.1	27.5	92.5	5.5	16.5%	72.4	0.19	1.03
DENMARK	DK	14.4	17.0	12.2	11.4	79.0	0.8	4.8%	21.4	0.01	0.07
FINLAND	FI	14.8	17.5	19.2	14.8	100.0	4.3	24.8%	85.0	0.15	1.70
FRANCE	FR	103.2	99.0	110.9	103.2	100.0	7.7	7.7%	210.2	0.76	0.69
GERMANY	DE	267.7	241.1	244.0	211.4	79.0	32.5	13.5%	52.2	0.79	0.55
GREECE	GR	19.7	22.0	36.8	24.6	125.0	12.2	55.4%	522.8	2.89	25.39
IRELAND	IR	9.1	10.3	12.3	10.2	113.0	2.1	20.4%	167.8	0.16	2.52
ITALY	I	111.3	115.7	132.2	104.1	93.5	28.1	24.3%	225.8	3.18	3.10
LUXEMBOU	LUX	3.0	2.3	2.1	2.1	72.0	0.0	-0.6%	-4.1	0.00	0.01
NETHLAND	NL	44.0	50.3	53.5	41.3	94.0	12.2	24.2%	139.8	0.74	2.52
PORTUGAL	PR	11.3	14.2	18.1	14.4	127.0	3.7	26.3%	83.2	0.13	1.01
SPAIN	S	58.6	69.2	77.0	67.4	115.0	9.6	13.9%	90.7	0.39	0.72
SWEDEN	SW	14.4	14.4	16.8	14.9	104.0	1.9	12.8%	153.0	0.14	0.85
UK	UK	159.9	151.3	169.0	139.9	87.5	29.0	19.2%	66.6	0.87	0.82
Tot EU-15		**877.4**	**875.2**	**955.2**	**801.7**	**91.4**	**153.5**	**17.5%**		**10.67**	**1.65**
AUSTRALI	AUS	71.7	83.5	105.5	77.5	108.0	28.0	33.6%	245.9	3.02	8.74
CANADA	C	116.9	130.2	150.1	109.9	94.0	40.2	30.9%	36.4	0.52	0.88
JAPAN	J	289.6	319.8	310.3	272.2	94.0	38.1	11.9%	36.2	0.66	0.25
NZ	NZ	7.0	9.0	10.3	7.0	100.0	3.3	36.6%	421.2	0.63	11.17
USA	USA	1339.2	1492.0	1800.5	1245.4	93.0	555.0	37.2%	76.5	17.37	2.62
Tot Non European (NE)		**1824.4**	**2034.5**	**2376.7**	**1712.0**	**93.8**	**664.7**	**32.7%**		**22.20**	**2.17**
Tot EU-15 + NE		**2701.8**	**2909.6**	**3331.9**	**2513.7**	**93.0**	**818.2**	**28.1%**		**32.87**	**1.97**
CZECH	CZ	38.7	33.0	41.7	35.6	92.0	6.1	18.6%	1.4	0.00	0.02
HUNGARY	H	18.5	15.9	19.6	17.4	94.0	2.2	13.9%	9.7	0.01	0.14
POLAND	PL	95.2	95.5	117.0	89.5	94.0	27.5	28.8%	48.9	0.57	2.33
SWITLAND	SV	12.1	12.2	11.1	11.1	92.0	0.0	0.1%	0.8	0.00	0.00
Tot Other European (AE)		**164.4**	**156.6**	**189.4**	**153.5**	**93.4**	**35.9**	**22.9%**		**0.58**	**0.89**
EU-15+AE		**1041.8**	**1031.8**	**1144.6**	**955.2**	**91.7**	**189.4**	**18.4%**		**11.26**	**1.58**
EU-15+AE+NE		**2866.2**	**3066.2**	**3521.3**	**2667.2**	**93.1**	**854.1**	**27.9%**		**33.46**	**1.93**
FSU(*)		615.5	985.1				**-111**		0	**0**	**0**

Notation: in the following scenarios, E stands for EU-15 countries; NE for Non-European countries (Australia, Canada, Japan, New Zealand, USA); AE for other European countries (Czech Republic, Hungary, Poland, Switzerland); FSU is Former Soviet Union.

Table 2: Permits market in a EU trading scenario, trading price 96.5 $/tC.

	TC(*) (billions US$)	Trade (Mton C)	Trade as % of abatement
AUSTRIA	0.25	-1.30	1.61
BELGIUM	0.17	1.67	-20.46
DENMARK	0	1.97	0.43
FINLAND	0.15	0.37	-1.32
FRANCE	0.55	-3.85	3.71
GERMANY	0.32	20.65	-317.61
GREECE	1.03	-9.32	6.47
IRELAND	0.14	-0.78	0.91
ITALY	2.14	-16.10	14.13
LUXEMBOU	0	0.17	-
NETHLAND	0.68	-2.91	4.23
PORTUGAL	0.12	0.37	-1.37
SPAIN	0.39	0.46	-1.40
SWEDEN	0.12	-0.63	0.80
UK	0.72	9.23	-151.63
Total	**6.71**	**0.00**	

(*) TC = Total Costs

Table 3: Permits market in a global (Annex 1) trading scenario, trading price 38.8 $/tC.

	TC (*) (billions US$)	Trade (Mton C)	Trade as % of abatement
AUSTRIA	0.18	-2.20	-56.48
BELGIUM	0.19	-0.90	-16.03
DENMARK	0	1.12	139.88
FINLAND	0.14	-0.89	-20.26
FRANCE	0.38	-5.22	-67.84
GERMANY	0.77	3.90	11.97
GREECE	0.67	-10.35	-84.84
IRELAND	0.1	-1.23	-58.75
ITALY	1.46	-20.66	-73.54
LUXEMBOU	0	0.07	-
NETHLAND	0.52	-5.78	-47.40
PORTUGAL	0.12	-0.72	-19.34
SPAIN	0.35	-2.62	-27.28
SWEDEN	0.09	-1.07	-56.43
UK	0.86	-2.28	-7.82
AUSTRALI	1.39	-18.91	-67.53
CANADA	0.37	12.16	30.25
JAPAN	2.87	-21.76	-18.47
NZ	0.18	-2.70	-81.74
USA	16.7	-82.29	-14.82
CZECH	-0.92	25.28	414.35
HUNGARY	-0.14	5.26	239.28
POLAND	0.55	4.09	14.86
SWITLAND	-0.02	0.66	-
FSU	-7.29	127.05	-
Total	**19.51**	**0.00**	

(*) TC = Total Costs

Table 4: Permits market in Annex 1 trading scenario w/o USA, fixed country abatement, trading price US$ 38.8

	TC (*) (billions US$)	Trade (Mton C)	Trade as % of abatement
AUSTRIA	0.13	-2.76	4.90
BELGIUM	0.15	-2.46	15.33
DENMARK	0	0.55	0.39
FINLAND	0.11	-1.78	8.78
FRANCE	0.27	-6.05	8.92
GERMANY	0.74	-7.16	-59.79
GREECE	0.45	-10.97	12.93
IRELAND	0.07	-1.52	2.58
ITALY	1	-23.29	31.67
LUXEMBOU	0	0.02	-
NETHLAND	0.38	-7.70	16.23
PORTUGAL	0.09	-1.48	7.66
SPAIN	0.27	-4.68	17.16
SWEDEN	0.06	-1.34	2.37
UK	0.73	-10.06	128.51
AUSTRALI	0.96	-21.80	32.28
CANADA	0.52	1.41	4.65
JAPAN	2.23	-39.18	212.11
NZ	0.12	-2.90	3.55
CZECH	-0.44	19.44	4.69
HUNGARY	-0.05	3.50	1.46
POLAND	0.55	-4.12	-27.73
SWITLAND	-0.01	0.43	-
FSU	-4.64	123.90	-
Total	**3.69**	**0.00**	

(*) TC = Total Costs

Table 5: Permits market in Annex I trading scenario w/o USA
total abatement constant
trading price 120.8 US$/tC.

	TC (*) (billions US$)	Trade (Mton C)	Trade as % of abatement
AUSTRIA	0.66	-3.93	-80.34
BELGIUM	0.66	-1.25	-8.15
DENMARK	0	1.80	461.52
FINLAND	0.56	-2.46	-28.06
FRANCE	1.39	-9.25	-103.65
GERMANY	2.91	3.89	-6.50
GREECE	2.46	-18.63	-144.07
IRELAND	0.36	-2.22	-85.81
ITALY	5.27	-36.08	-113.93
LUXEMBOU	0	0.35	-
NETHLAND	1.93	-11.17	-68.79
PORTUGAL	0.48	-2.07	-27.04
SPAIN	1.3	-5.60	-32.64
SWEDEN	0.31	-1.87	-78.92
UK	3.29	-7.83	-6.09
AUSTRALI	5.09	-34.64	-107.32
CANADA	2.86	2.46	52.99
JAPAN	10.47	-41.84	-19.73
NZ	0.65	-4.85	-136.66
CZECH	-2.26	32.85	700.14
HUNGARY	-0.37	7.32	500.78
POLAND	2.43	-0.10	0.37
SWITLAND	-0.08	1.26	-
FSU	-15.24	133.85	-
Total	**25.07**	**0.00**	

(*) TC = Total Costs

Table 6: Comparison of results for EU-only trading scenario.

	Bader	UE	Ciorba, U., Lanza, A., Pauli, F. (2001)	AIDS	AIDS w. EU forecasts	AIDS with Bader forecasts
TAC	3.817	16.2	10	6.7	6.85	5.7
Price	82	161.7	218	96.5	97.9	87.3

Table 7: Comparison of results (the column indicated (*) contains the results of our model implemented using Ellerman and Decaux forecasts , essentially only Japan changes)

	TAC				**PRICE**			
	Ellerman	**Ciorba, U., Lanza, A., Pauli, F. (2001)**	**AIDS**	**(*)**	**Ellerman**	**Ciorba, U., Lanza, A., Pauli, F. (2001)**	**AIDS**	**(*)**
EU+NE	101,96	42	25.8	38.76	240	147	75.3	96.9
EU+NE+FSU		40	24.9			130	73.0	
EU+NE+FSU+HA		27	17.6			100	59.0	
EU+AE			5.3				66.3	
EU+AE+NE			24.7	36.73			69.8	89.0
EU+AE+NE+FSU	69,23		24.0	35.59	150		67.7	86.4
EU+AE+NE+FSU+HA	53,96		17.2	26.78	127		55.2	72.5

Table 8: Comparison of 2010 BAU forecast of emission

	IEA	Bader	EIA	Ellerman
J	310.3		330	424
USA	1800.5		1809	1838
Tot EU-12	901.2	879.8	1040	1064

Table 9: Emissions Indicators for some Annex 1 countries (1997). Source: IEA.

Country	**Japan**	**EU**	**USA**	**CZ**	**Russia**
CO2 / GDP	0,45	0,5	0,83	4,45	2.09
CO2 / Population	9,29	8,58	20,5	11,74	9,89

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