Carbon Emissions Trading and Equity in International Agreements[°]

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1. Introduction

A fundamental theorem of the economics of welfare states that Paretian efficiency and distributive justice (relative distribution of wealth or income) can both be obtained through a market mechanisms, if there is perfect competition, absence of market distortions of any kind, and if the initial endowments are appropriately chosen. In his classic paper, Coase (1960) demonstrates that this results carries over to the case of presence of externalities, if these are internalised prior to the introduction of the market.

Indeed, the reason why externalities can be considered as market distortions is related to the fact that some markets are "missed": the internalisation of externalities (e.g. through taxation) amounts to reconstructing the missing markets, so that the theorems of welfare can continue to hold. In this sense, there is no difference - in terms of Pareto efficiency - between a situation in which "the polluter pays" for the external costs generated or a situation in which "the polluted pays" to convince the polluter to reduce the damage. The only difference regards the final distribution of wealth, which in turns depends on how the property rights on the environmental resources are initially allocated.

This argument has often be invoked by those who claim that issues of equity and issues of efficiency should be addressed separately in international agreements for the protection of the environment. For example, in the Kyoto agreement on the reduction of greenhouse gases, signing nations have agreed to keep their CO_2-equivalent emissions below some given ceilings, but with the possibility of importing or exporting "emissions permits". This means that the total volume of emissions is fixed, at least for the signatory countries, but the aggregate target of CO_2 concentration in the atmosphere can be achieved at

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a minimum cost, with a flexible market solution[1]. The individual emissions limits determine, on the basis of a comparison with actual emissions levels, how income is transferred from importers to exporters of permits. Consequently, the limits set in the Kyoto agreement should not be interpreted as rigid constraints, but as implicit cost shares attributed to each nation of the global CO_2 reduction burden.

Of course, the question of allocation of pollution rights has been much debated, before and after Kyoto (e.g. Rose and Stevens (1999)). In this context, issues of distributive justice can hardly be addresses in a scientifically neutral way, because they necessarily involve value judgements. Some authors (e.g., Helm (1999)) have identified "axiomatic criteria", on the basis of which political decisions should at least be rationally based. For example, the allocation of limits could be based on principles of fairness in the distribution of emissions rights or, instead, on principles of fairness in the distribution of reduction costs.

Also the design and implementation of an international market for emissions permits has been a much discussed topic. Critical issues include: the volume of trade, the number of countries involved, the possibility for non-signatory countries to participate in the trade, under what conditions, and the possibility of saving permits for later use. But although there are in principle several different trading schemes that could be implemented, the equity implications of the alternative options have not been analysed in depth. This can indeed be explained by the fact that the market is conceived here as an instrument to achieve economic efficiency, and in the Coasian tradition efficiency and equity are regarded as separate objectives.

It is not true, however, that relative income levels do not change when a market is introduced. Possibly, the choice of disregarding the equity effects due to trade could be justified if these effects are found to be small in comparison with those due to the initial allocation of rights, or if the different trading schemes produce comparable results in terms of equity. But in this paper we will show that both of these conditions do not hold, and therefore more attention should be paid to the equity implications of the various trading regimes.

We shall explore these issues by means of an integrated assessment model, which is a simplified variant of the model used by Nordhaus and Yang (1996). We shall consider here a set of idealised

[1] However, Martins and Sturm (1998) show, from a normative perspective, that socially optimal emissions limits (per period) may depend on the characteristics of the trade system that could possibly be adopted.

trading systems, without transaction and enforcement costs[2]. In doing this, we shall take the emissions limits cited in the Kyoto protocol as a given, and furthermore we shall assume that these limits - considered to be binding - will remain in place beyond the year 2010[3].

The paper is organised as follows: first, we shall discuss in the next section, from a theoretical point of view, how the market mechanism may affect the relative distribution of wealth, and subsequently how the measurement of equity involves the use of a social welfare function which is normally different from the function implicitly maximised in a competitive equilibrium. On the basis of this theoretical framework, we shall then present and comment some numerical results obtained by computer simulations. Finally, some concluding remarks will be drawn.

2. Implicit social welfare function maximisation

Consider the position of a country which has signed the Kyoto protocol, and has thereby agreed to reduce its emissions below a certain level. Suppose that a perfectly competitive market for emission permits is introduced, so that each country can choose, for each emission unit exceeding the threshold level, between the alternatives of paying for the abatement and paying to purchase an emissions permit from an exporting country. If cost minimisation is the guiding principle in the choice, the market equilibrium must be achieved at a point in which the marginal abatement costs in all countries are equal in each period, and equal to the price of permits as well.

An allocation in which marginal costs are equalised in each period coincides with an allocation that could be chosen by a central planner who faces a constraint on total emissions, but can distribute the abatement costs among a set of "technologies" or countries *i*, like in the case of a multi-plant producer:

$$\begin{aligned} &\min \sum_i c_i(e_i) \\ &s.t. \sum_i e_i \le \overline{E} \end{aligned} \qquad (1)$$

In the case of international agreements, the abatement costs can be stated in terms of foregone net revenue y (per-capita) in each country (or consumption), so that (1) can be also written, equivalently:

[2] Although data used in the model refer to real economies, the numerical results should be interpreted, because of the simplifying assumptions adopted, as examples providing an order of magnitude of the effects, rather than as precise forecasts.

[3] For a critical point of view on how the limits could have been differently allocated among countries and periods, see Nordhaus and Boyer (1999).

$$\max \sum_i y_i(e_i)$$
$$s.t. \sum_i e_i \le \overline{E} \qquad (2)$$

where *y (e)>0*. Although higher aggregate emissions may lower income and consumption levels in all countries, the reduction of the own emissions is usually expected to reduce a country income, because the positive effects of the reduction are shared, while the abatement costs are entirely borne by the country under consideration.

The optimisation problem (2) can also be restated as follows:

$$\max \sum_i w_i U\left(y_i(e_i)\right)$$
$$w_i = U'\left(y_i(e_i)\right)^{-1}$$
$$s.t. e_i \le \overline{e}_i + m_i \forall i \left(\sum_i \overline{e}_i = \overline{E} \right) \qquad (3)$$
$$\sum_i m_i = 0$$

where *U(.)* are utility functions with standard properties and *m* stands for net imports of permits. Notice that, although the first order conditions remain unaltered, the problem (3) can be interpreted as a total welfare maximisation, as it could emerge in the case of a cooperative agreement with the weights *w* expressing the "bargaining" power of each country.

This illustrates an interesting but well known result from general equilibrium theory, stating that a market equilibrium in a perfectly competitive exchange economy can be replicated by a single optimisation problem with appropriate weights[4]. However, because of the concavity of the utility functions (implying decreasing marginal utility of income), the richer a country is, the stronger it is in this game. Also, the solution of (3) does not depend neither on the initial income distribution[5] nor on the emissions limit set for each country. The latter can possibly be used ex-post to verify, through a comparison with the emissions level obtained in (3), whether a country is an importer or an exporter of permits.

To obtain the per-capita income of each country in equilibrium, the cost of imported permits or the revenue of exported permits should be added to the net income levels derived from (3), using the

[4] This principle turns out to be very useful for applied general equilibrium models, because it allows to avoid the computation of the equilibrium as a solution of several simultaneous optimisation problems (a Nash equilibrium), often involving lengthy iterations and convergence problems in numerical simulations.

[5] If weights in (3) would be set in a different way, emissions would be allocated in order to influence the distribution of income.

equalised marginal abatement cost as the international price of permits. The national emissions limits therefore determine the volume and direction of trade flows, and consequently the national income and utility levels, without affecting neither the total amount of emissions nor where these emissions are generated.

The optimisation problem (3) can be easily generalised to the intertemporal case, assuming that the emissions permits can be stocked and banked[6]:

$$\max \sum_{t=0}^{T} \sum_{i} \alpha^{t} w_{i,t} U\left(y_{i,t}(e_{i,t})\right)$$
$$w_{i,t} = U'\left(y_{i,t}(e_{i,t})\right)^{-1}$$
$$s.t. e_{i,t} = \bar{e}_{i,t} + m_{i,t} + s_{i,t-1} - s_{i,t} \forall i,t \qquad (4)$$
$$\sum_{i} e_{i,t} \leq \bar{E}_{t} + \sum_{i} s_{i,t} \forall t$$
$$\sum_{i} m_{i,t} = 0 \forall t$$

where s is the national stock of permits (initially zero) and α is a discount rate, equal for all countries. Here, in addition to the “horizontal” equalisation of the marginal abatement costs in all periods, the intertemporal optimisation implies a “vertical” equalisation of the marginal costs discounted at time zero. In other words, in equilibrium the world price of permits must grow at a rate equal to the world interest rate. There cannot be nations that are both saving and dissaving within each period because, once the marginal abatement costs are equalised, the whole world act - in terms of saving decisions - as a single entity.

3. Measuring equity

An equity index is often used understand which allocation of resources, possibly generated by market exchange, performs better in terms of equity. The adoption of a certain index, however, is not just a matter of purely descriptive measurement, because it always involves - implicitly or explicitly - the introduction of specific value judgements[7] (Atkinsons (1970)). These judgements can be stated in terms of choice of a particular social welfare function.

[6] Most interpretations of the Kyoto agreement rule out the possibility of borrowing permits. This would amount to disregarding the emissions constraint, with a promise of a more virtuous behaviour in the future.

[7] This is true also for purely descriptive statistics, like the Gini coefficient. Furthermore, although descriptive statistics obeys to the so-called “principle of transfer”, meaning that the index must increase if income is transferred from a rich to a poor household, they normally imply rather implausible assumptions about the social value judgements.

For example, if we assume that it would be socially desirable to have equal income levels, this would amount to choosing the following social welfare function:

$$SW = \sum_i w_i U\big(y_i(e_i)\big) \qquad (5)$$
$$w_i = 1 \forall i$$

In this case, we could say that an equity improvement is achieved when the total social welfare *SW* turns out to be higher after an income transfer has been realised between countries *i*.

An equity index can then be easily constructed by comparing the average income level in a given situation to an hypothetical income level that, if equally distributed, would have produced the same level of social welfare. The ratio between the hypothetical and the actual average income is a number comprised between zero and one, that can be readily interpreted as a measurement of equity.

Comparing the function used in (5) with that implicitly maximised in (3) or (4) one can immediately see that there exists a fundamental conflict between the egalitarian perspective and the way a competitive market operates. Indeed, if *SW* is maximised under a constraint on total emissions, the optimisation conditions would imply a distribution of marginal abatement costs among countries which would be inversely proportional to the marginal utility of income. In other words, if abatement cost functions are convex, the richer countries should reduce their emissions more than the poorer countries.

This does not mean, however, that the market is necessarily inequitable. This is because, in addition to the allocation of emissions, an income transfer is realised from importers to exporters of emissions permits. Since the exporters are typically less developed countries, this second mechanism tends to produce positive results in terms of equity. So the equity impact of a market depends on a balance between two counteracting effects: an inequitable allocation of emissions and abatement costs, and an equitable redistribution of income by means of trade revenue.

As it has been stressed in the previous section, the volume and direction of trade flows do not depend on the allocation and on the total amount of emissions, but only on the national allowance levels. As a consequence, it is possible to allocate pollution rights in order to influence the balance between equitable and inequitable effects of the market mechanism.

To see this more clearly, consider the case of two countries, where the first country is the richer one. Equity (in the egalitarian sense) would improve if, after the introduction of a trade system, the monetary gains of the second country turn out to be larger than the gains obtained by the first one. Since the gains are given by a difference between the savings (possibly negative) in emissions control costs, in comparison with a situation of no trade, and the revenue generated by the selling of permits (possibly negative), the condition for an equity improvement can be written as:

$$y_1(e_1) - y_1(\bar{e}_1) - y_1'(e_1)(e_1 - \bar{e}_1) < y_2(e_2) - y_2(\bar{e}_2) - y_2'(e_2)(e_2 - \bar{e}_2) \qquad (6)$$

where $\bar{e}$ means the imposed emission limits (binding if trade is not possible), and e stands for the emissions levels obtained in the market equilibrium. Equivalently:

$$\Delta y_1 - \Delta y_2 < y'(\cdot)(\Delta e_1 - \Delta e_2) \qquad (7)$$

Conditions (6) or (7) may or may not be satisfied, depending on the characteristics of the function linking income or cost levels and emissions. By tightening the emissions limit for an importing country, for example, both sides of the inequality are augmented, because the gains obtained from not reducing the emissions become larger but the import flow increases as well. The conditions for an equity improvement also depend on the number of trading countries. If a new country with low marginal abatement costs would enter, the right hand side of (7) would become smaller.

4. Simulating an emissions trading system for Kyoto

The simulation experiments illustrated in this section have been carried out with a simplified version of the RICE'96 model (Nordhaus and Yang 1996). In common with RICE our model maintains the regional disaggregation (the world is divided in six macroregions) and the environmental sub-model. CO_2 emissions are a by-product of the economic activity and their impact on global temperature is determined by the Schneider-Thompson model, where increases in the temperature translate in terms of GDP losses.

Exactly as in RICE the link between the economic and the environmental part is given by a particular function accounting for the fact that income is negatively affected by both the environmental damage and the environmental protection effort. This function transforms *potential* income, which is exogenously given here[8], in net income or consumption, which in turns affects the utility of the representative consumer in each region:

$$Y(t) = \bar{Y}(t)\frac{1 - \beta_1 \mu(t)^{\beta_2}}{1 + \alpha T(t)^{\sigma}} \qquad (8)$$

[8] This is different from RICE, where investments are determined by intertemporal optimisation. The FEEM research group has, however, made some experiments by introducing the emissions trading in an interteporal setting, and found that there are not significant differences in the results, whereas the solution algorithm of the model becomes substantially more complicated and less accurate.

where *Y(t)* is the *net* income of a generic region at time *t*, μ is a control variable representing the rate of emission control, $T(t)$ stands for world average temperature, and all remaining symbols are parameters whose values vary between regions and time periods.

Parameter values have been borrowed directly from the RICE model, but potential income and emissions levels has been estimated on the basis of the IPCC "A1 Marker Scenario Family" (Morita et al., 1998)[9] and a report of the White House[10].

The cases that have been considered in the simulation exercises are:

- *The imposition of constraints on emissions for signatory countries without the possibility of emissions trading*[11] (NOT). "Non-Annex I" (non-signatory) countries are assumed to act here as in the BAU scenario, without emissions abatement[12], although in this case their net income turns out to be higher because of the reduced climate change.
- *The introduction of a perfect emissions trading system including all countries which have signed the Kyoto protocol* (ETR). This amounts to set only an aggregate emissions limit for this group of countries[13], whereas other countries are modelled exactly as in the scenario NOT.
- *In addition to trading among themselves, signatory countries can save permits for later use* (ETB). Borrowing is not allowed, therefore the national stock of saved permits is never negative.
- *The trading system is extended to include all countries in the world* (GTR). Non-Annex I countries must not exceed the emissions levels corresponding to the BAU trend, but they can trade on the basis of possible emissions reductions.
- *As in ETB, banking of permits is allowed for all countries in the global trade system* (GTB).

[9] The main characteristics of the reference "business-as-usual" scenario (that is, without the imposition of emissions limits and trading) are: (1) GDP of so-called "non-Annex I countries" (countries which have not signed the Kyoto agreement) is expected to reach average 1990 GDP levels of signatory countries by the year 2030; (2) non-Annex I countries CO2 emissions are expected to become higher than signatory countries CO2 emissions between 2010 and 2020; (3) former Soviet Union countries will reach emissions levels higher than the limits imposed by the Kyoto Agreement only after the year 2020; (4) the average temperature is expected to increase by 2.7 °C in 2090, whereas with the implementation of the Kyoto agreement this increase is reduced to 2.5 °C.

[10] "The Kyoto Protocol and the President's Policies to Address Climate Change", July 1998.

[11] We consider that USA, Japan, Europe, and Former Soviet Union (our Annex 1) in 2010, as an approximation of the period 2008-2012, have to reduce their emissions of the 7%, 6%, 8% and 0% below 1990 level respectively.

[12] We tested the hypothesis of introduction of emissions constraints for Non Annex I countries assuming that these would become effective when the per-capita average income of non signatory nations reaches the 1990 average level of signatory nations. This condition, however, is not expected to be meet within the time horizon of our simulation experiments (2050).

[13] It is worth to notice that aggregate emissions are actually higher, but only for the first period, when an emissions trading is introduced. This is because one region (Former Soviet Union FSU) would be "naturally" below its threshold initially, but it could still sell - under a trading system - the difference between imposed and actual emissions levels.

Figure 1 shows the marginal abatement costs faced by each country when the Kyoto agreement is applied without trading. Substantial differences, due to both assumptions on economic growth and on control costs, indicate that significant gains should be expected from the introduction of a trading mechanism.

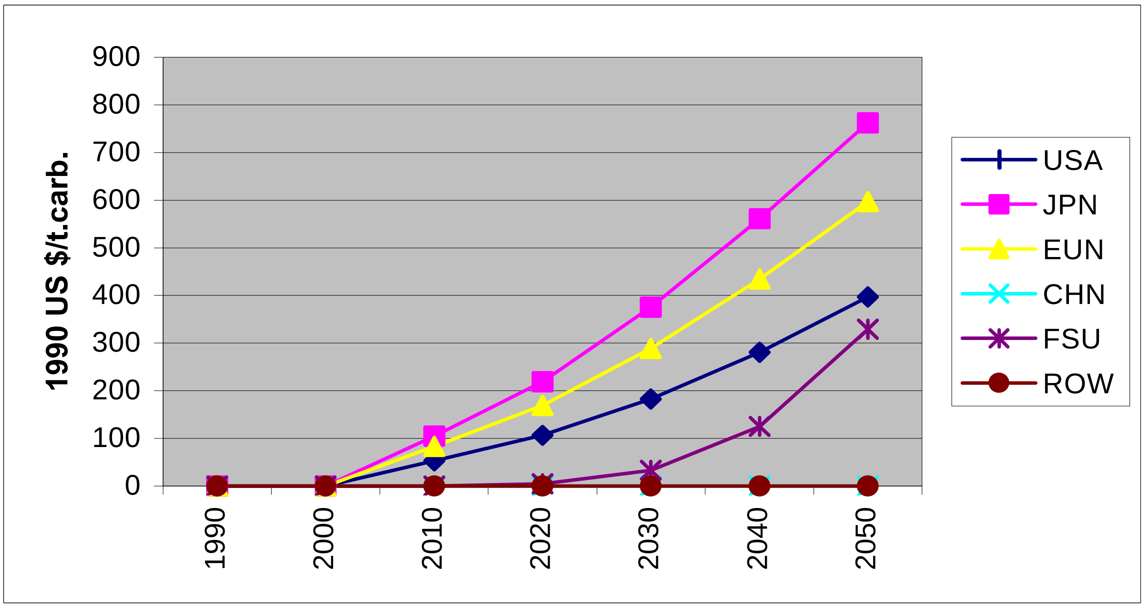

Fig. 1: Marginal abatement costs in the NOT case.

As it has been previously pointed out, trade brings about the equalisation of the marginal costs to the market clearing price of emissions permits. Figure 2 shows the evolution over time of the world price under the four trading schemes considered.

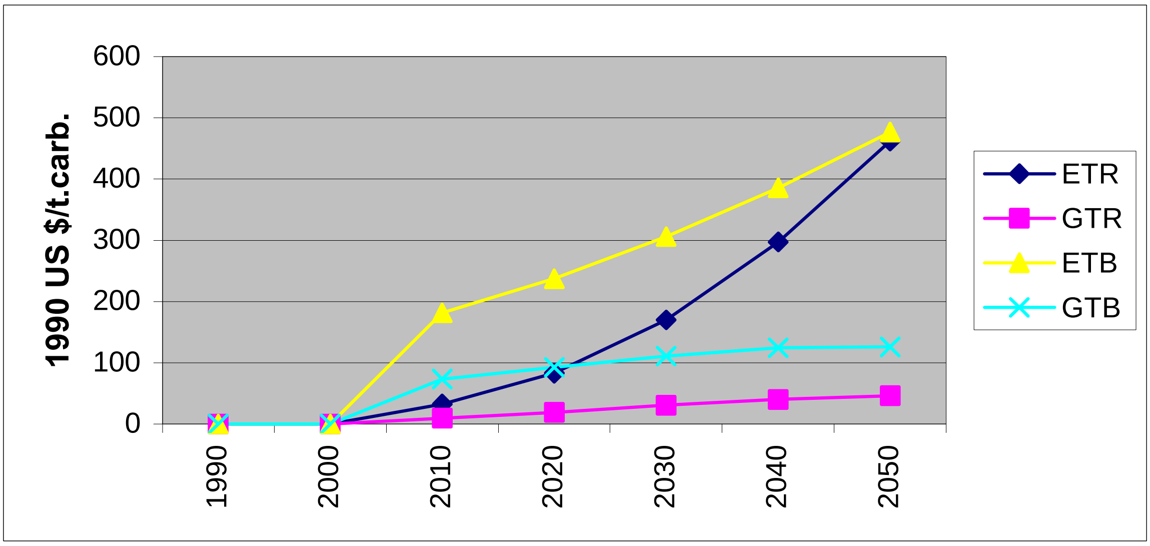

Fig. 2: Permit prices in the ETR, GTR, ETB, GTB cases.

When the Kyoto Agreement comes into play, the price is 32.72$ per ton of carbon in the ETR case, whereas in the GTR case it is only 9.2$[14]. Afterwards the prices diverge even more. When banking of permits is allowed, the price is initially higher, and then evolves smoothly according to the world interest rate. However the price remains higher than that of the corresponding situation without intertemporal transfers, because global emissions are lower[15].

As the price can be interpreted as a sort of average of the initial marginal abatement costs, the much lower price level obtained in the case of worldwide trading is essentially due to the fact that the marginal costs are significantly below the average for Non-Annex I countries. This depends on both the initial conditions considered (combination of low per capita emissions and convex abatement costs) and on the absence of emissions constraints for these regions.

Figures 3, 4, 5, and 6 show the trade patterns emerging the four trading regimes.

In the first two cases (ETR, ETB) the Former Soviet Union is initially the only exporter, but later the strong economic growth reduce its export potential, and USA also becomes a supplier of permits. Although technical efficiency does play a role here, the main driving force is the relative growth rate assumed for each country.

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[14] To allow some comparisons: RICE '98 (Nordhaus and Boyer 1999) gives a price of 57 and 17 1990 U.S. $ per ton in the case of ETR and GTR respectively; EPPA (Hellerman and Jacoby 1998) gives a price of 127 and 24 1985 U.S. $ per ton in the same cases; G-Cubed (Shackleton 1998) reports prices of 37 and 13 1995 U.S. $.

[15] This result has been obtained by running the model up to the year 2090, and cutting the last periods to avoid the effects of the terminal period. In the decades after 2050, the countries actually start consuming their permits stock, until the latter falls to zero in the last period.

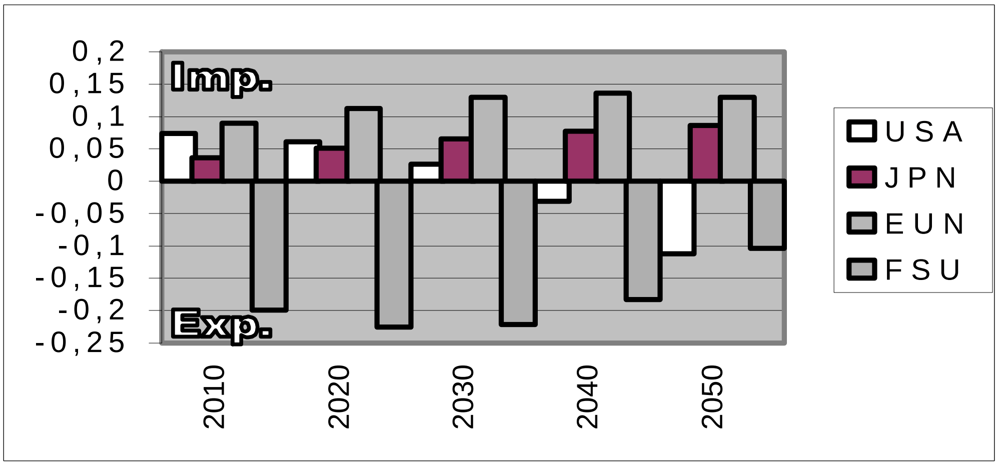

Fig. 3: ETR – Net Imports of Permits (Imp.-Exp.) in billion tons.

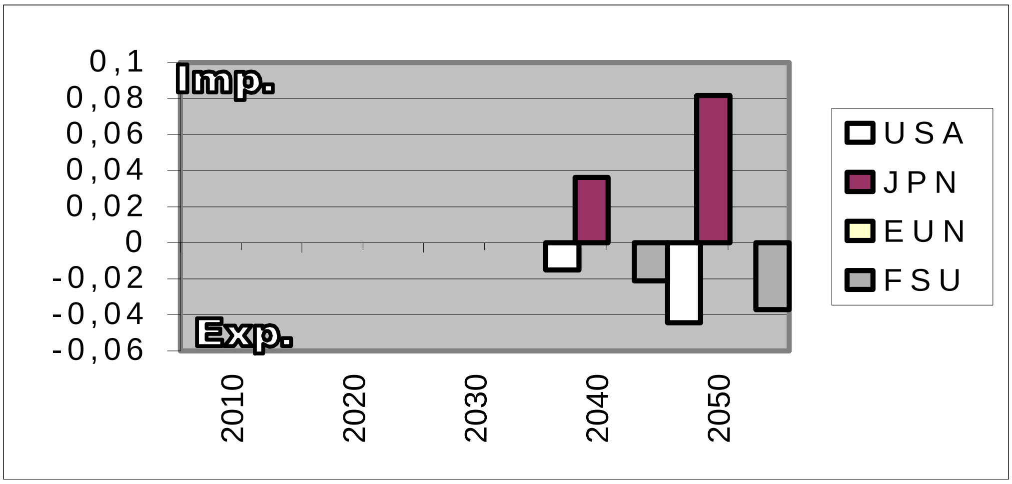

Fig. 4: ETB – Net Imports of Permits (Imp.-Exp.) in billion tons.

Because of the much lower abatement costs, China (CHN) and Rest of the World (ROW) are and remain exporters of permits in a worldwide market. Although these regions have higher than average growth rates, their emissions limits shift over time along the path assumed for the BAU scenario.

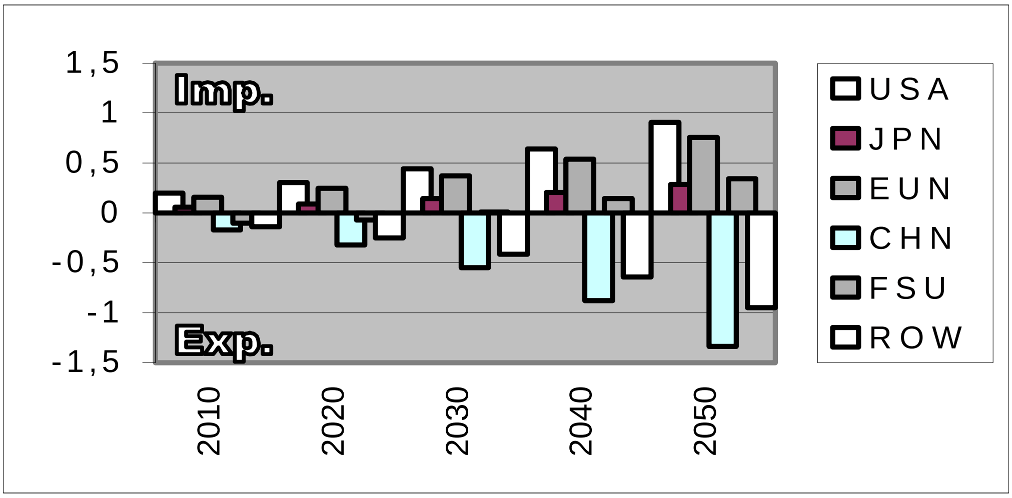

Fig. 5: GTR – Net Imports of Permits (Imp.-Exp.) in billion tons.

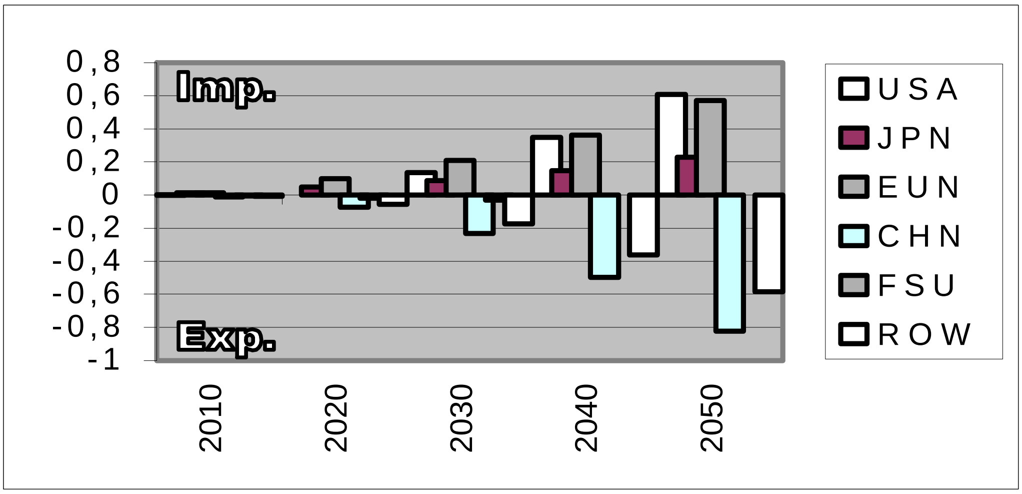

Fig. 6: GTB – Net Imports of Permits (Imp.-Exp.) in billion tons.

Some insights about the magnitude of the welfare gains expected from trade can be obtained by analysing tables 1 and 2, showing equivalent income variations differentials. Since we are speaking here of a potential Pareto improvement, every region is expected to gain in every period from the possibility of trade if global emissions remain unaltered. The amount of gain is in this case broadly proportional to the volume of trade, independently of the direction of the trade flow. If total emissions are reduced, like in the case of banking, the effects due to the higher control effort overlap to the benefits of trade[16].

[16] Of course, discounted future income levels must be higher when banking is possible than the when it is not. The exact

Tab. 1:Equivalent Variation of per capita net income, absolute terms (1): comparison ETR-NOT and ETB-NOT.

	ETR-NOT	ETB-NOT	ETR-NOT	ETB-NOT	ETR-NOT	ETB-NOT	ETR-NOT	ETB-NOT	ETR-NOT	ETB-NOT	ETR-NOT	ETB-NOT
	USA		**JPN**		**EUN**		**CHN**		**FSU**		**ROW**	
2010	2,6	-124,4	9,7	-30,6	5,1	-38,1	0	0	13,4	-96,3	0	0
2020	2,5	-161,6	26,6	-9,7	10,0	-37,3	0	0	32,2	-122,5	0	0
2030	3,5	-190,4	50,9	55,7	17,2	-12,3	0	0,2	49,9	-156,8	0	0,6
2040	3,5	-186,0	78,6	78,5	21,9	48,6	0	0,7	48,5	-156,1	0	2,4
2050	14,0	-121,6	101,8	104,4	21,8	157,3	0	1,9	20,0	-77,0	0	6,9

(1) 1990 US $

Tab. 2: Equivalent Variation of per capita net income, absolute terms (1): comparison GTR-NOT and GTB-NOT.

	GTR-NOT	GTB-NOT	GTR-NOT	GTB-NOT	GTR-NOT	GTB-NOT	GTR-NOT	GTB-NOT	GTR-NOT	GTB-NOT	GTR-NOT	GTB-NOT
	USA		**JPN**		**EUN**		**CHN**		**FSU**		**ROW**	
2010	13,9	-14,3	17,7	1,0	12,7	-0,1	0,8	-9,2	2,2	-22,5	0,2	-2,2
2020	41,1	11,7	62,0	21,4	37,3	7,0	2,8	-12,1	1,8	-23,1	0,9	-2,7
2030	105,8	34,4	160,8	91,2	98,1	43,6	7,3	-10,8	0	-18,5	1,6	-1,5
2040	231,0	96,8	351,8	243,0	213,9	128,6	15,1	-3,6	15,9	2,3	3,1	2,6
2050	471,2	278,4	677,5	535,6	416,1	305,2	25,5	6,6	118,2	138,2	5,2	12,7

(1) 1990 US $

Notice that, as the trade pattern obtained in the ET cases can always be replicated in the case of an enlarged trading system, but not vice versa, aggregate equivalent income variations must always be larger in the GT cases. In other words, the global payoff must be higher when there are more degrees of freedom (Chander et al.(1999)). However, not every country would prefer an enlarged market for

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amount of gains in terms of present value is difficult to compute exactly, however, because it depends on the terminal conditions adopted. Broadly speaking, it is nonetheless possible to say that the gains obtained by the introduction of banking are similar in magnitude to the gains achievable through the introduction of emission trading, both for restricted and global markets.

emissions permits. This is the case, for example, of the former Soviet Union which is made worse off because of a worsening of its terms of trade[17].

Figure 7 shows the evolution of the world average income, in terms of differences with the case of absence of trading and banking, over the periods considered.

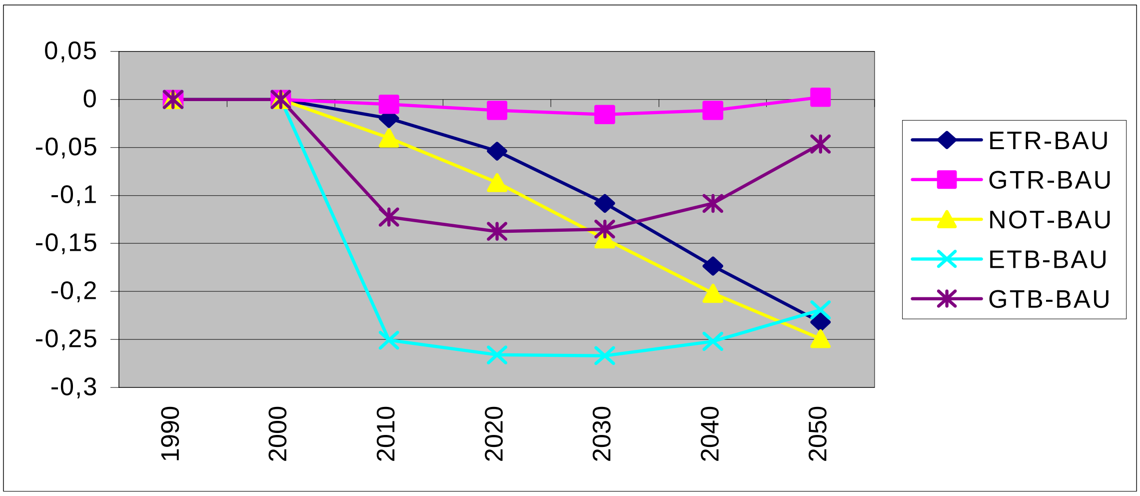

Fig. 7: Differences in world per capita average net income (percent).

Finally, table 3 shows the relative variations obtained in the egaliltarian equity index (computed as described in section three) by the introduction of the various trade regimes, in comparison with the variations obtained by the direct implementation of the Kyoto protocol without trade.

In the case NOT, equity improves - from the BAU situation -, because emissions limits and abatement costs are imposed only on developed countries. If a trade system is subsequently introduced, all countries gain, but some countries would gain more and some other countries would gain less. If the separability argument is correct, we would expect to see a relative variation in the equity index close to zero. This would mean that the impact of trade on equity is small in comparison with the effect produced by the initial allocation of allowances.

[17] This can be easily understood by considering the situation occurring in the first period, where this region sells the difference between allowances and emissions obtained without abatement effort. In this case, any price reduction, like that induced by the entry of new low-cost competitors, immediately translates in a reduction of income.

Tab. 3: Equity index - relative variations

	ETR	*ETB*	*GTR*	*GTB*
2010	-25%	334%	-17%	-558%
2020	-19%	135%	-25%	-202%
2030	-15%	52%	-38%	-79%
2040	-9%	16%	-49%	-46%
2050	-6%	-4%	-60%	-49%

However, one can see from table 3 that the relative impact on equity for all trade regimes is quite significant. Actually, in some cases the distributional effects of trading are larger than those of the emissions limits allocation.

The sign and the magnitude of the variations are due to the following effects:

- intratemporal trade tends to favour the richer countries, because savings on abatement costs are larger than the revenues obtained by exporting permits. This is true for both cases of restricted and global world trade.
- banking amounts to tightening the total amount of abatement. When this affects only Annex I countries (ETB), the positive distributional effects of Kyoto are thereby amplified. However, when all countries are involved, the bigger abatement effort turns out to cost relatively more to the low-income nations.

5. Concluding Remarks

When firing an arrow, one could - in principle - compute the exact trajectory and hit a given target if the direction and strength of the wind are known. Analogously, distributive objectives could be achieved once the equity impact of a trade system is taken into account.

The Kyoto agreement specifies in detail the amount of emissions reduction that each signing nation should reach by the year 2010, and leaves open the possibility of introducing a market for emissions permits. It is still not clear, however, how this market should actually function, and therefore we do not currently know which implications should be expected in terms of income and wealth distribution.

This is like firing an arrow without knowing how the wind will deviate the trajectory. Still, this could not be a big problem if the wind is known to be weak, that is if the effects on equity are primarily produced by the allocation of pollution rights. But in this paper we have shown that (1) changes produced on an equity index by the imposition of emission constraints are not significantly higher than those obtained by the subsequent introduction of a market mechanism, and (2) the different market regimes that could be adopted have quite different distributional implications.

Consequently, we think that these issues deserve more attention. This means going beyond the traditional research approach, which has focused, on one hand, on the efficiency gains obtainable by means of trading and, on the other hand, on the distributive effects of alternative allocations of emission limits.

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SUMMARY

An integrated assessment model is used to simulate the introduction of various emissions trading schemes based on the Kyoto protocol on the reduction of greenhouse emissions. The implications of the various systems in terms of income distribution are illustrated, and it is claimed that the issue of equity should not be regarded as independent from the issue of market efficiency.
In particular, in this paper it is shown that (1) changes produced on an equity index by the imposition of emission constraints (by country) are not significantly higher than those obtained by the subsequent introduction of a market mechanism, and (2) that the different market regimes which could be adopted have quite different distributional implications.
These results are interpreted as a direct consequence of the fact that a competitive market equilibrium is equivalent to a centralised social welfare maximisation in which the function to me maximised, however, normally differs from the social function used to define equity objectives.

Keywords: Equity/Efficiency, Emissions Trading, Banking, Flexibility mechanisms, International environmental agreements, Kyoto, Integrated Assessment Modelling.

JEL: C5, F1, F4.

NON TECHNICAL SUMMARY

The argument of separability between market efficiency and income distribution objectives has often be invoked by those who claim that equity and efficiency should be addressed separately in international agreements for the protection of the environment. For example, in the Kyoto agreement on the reduction of greenhouse gases, signing nations have agreed to keep their CO_2-equivalent emissions below some given ceilings, but with the possibility of importing or exporting "emissions permits". This means that the total volume of emissions is fixed, at least for the signatory countries, but the aggregate target of CO_2 concentration in the atmosphere can be achieved at a minimum cost, with a flexible market solution. However, there are many possible ways in which a market for emission permits can be implemented, depending on the number of countries involved, on the volume of trade allowed, on the market clearing mechanisms, and so on.
Different trading systems of course produce different effects in terms of wealth distribution. As a consequence, the possibility of pursuing distributional objectives through the allocation of rights is conditional upon the adoption of a specific emissions trading scheme. Any change in the way the market operates would require an offsetting change in the allocation of rights.
So it is not sufficient to demonstrate that a market can make everybody better off. Other relevant questions are: who will gain more and who will gain less? What determines the "weights" of the total welfare function which is implicitly maximised? Is the income inequality among countries in the world made larger by the introduction of an emission trading system?
The choice of disregarding the equity effects due to trade could be justified if these effects are found to be small in comparison with those due to the initial allocation of rights, or if the different trading schemes produce comparable results in terms of equity. But in this paper it is shown that both of these conditions do not hold, and therefore more attention should be paid to the equity implications of the various trading regimes.
These issues are explored by means of an integrated assessment model, which is a simplified variant of the model used by Nordhaus and Yang (1996). We shall consider here a set of idealised trading

systems, without transaction and enforcement costs. In doing this, we shall take the emissions limits cited in the Kyoto protocol as a given, and furthermore we shall assume that these limits - considered to be binding - will remain in place beyond the year 2010.
First, we discuss, from a theoretical point of view, how the market mechanism may affect the relative distribution of wealth, and subsequently how the measurement of equity involves the use of a social welfare function which is normally different from the function implicitly maximised in a competitive equilibrium. On the basis of this theoretical framework, we shall then present and comment some numerical results obtained by computer simulations.