Global climate change and the equity-efficiency puzzle

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Abstract

There is a broad consensus that the costs of abatement of global climate change can be reduced efficiently through the assignment of quota rights, and through international trade in these rights. But there is no consensus on whether the initial assignment of emission permits can affect the Pareto-optimal global level of abatement.

This paper provides some insight into the equity-efficiency puzzle. Qualitative results are obtained from a small-scale model, and then quantitative evidence of separability is obtained from MERGE, a multi-region integrated assessment model. It is shown that if all the costs of climate change can be expressed in terms of GDP losses, Pareto-efficient abatement strategies are independent of the initial allocation of emission rights. This is the case sometimes described as "market damages".

If, however, different regions assign different values to non-market damages such as species losses, different sharing rules may affect the Pareto-optimal level of greenhouse gas abate-

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ment. Separability may then be demonstrated only in specific cases (e.g. identical welfare functions or quasi-linearity of preferences or small shares of wealth devoted to abatement).

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1. Introduction

Global climate change is a public good problem. Rich and poor, all live in the same greenhouse. It is easy to agree on strategies under which everybody will gain. But since it is expected that we need to proceed beyond *no regrets* policies, there must be some arrangement for abatement and burden-sharing. Economic efficiency ensures the maximum potential for each participant to gain from such an agreement. This explains why efficiency, both in terms of cost-effectiveness and Pareto-efficiency, is a major issue in global climate policy.

Standard analysis suggests that the external effects of global climate change can be internalized efficiently through international trade in emission permits (see [1]). To see the rationale behind this statement, suppose for a moment that transaction costs are negligible and that information is symmetrically distributed among parties. Then the *Theorem of Coase* (see [2]) states that if trade of the externality can occur, bargaining will lead to an efficient outcome no matter how property rights are allocated. Or, since trade is a particular type of bargaining: once caps on emission rights are assigned to the individual regions, trading these rights on open international markets has the potential to let all gain from greenhouse gas abatement.

Efficiency in greenhouse gas abatement might be suggested by the Coase Theorem, but it is an open question how to place a certain Pareto-optimum into the framework of a decentralized market-economy without major changes in the allocation of conventional resources. Why? Typically, the outcome of the bargaining process depends on the initial distribution of wealth. In other words, greenhouse gas abatement will depend both on the initial allocation of emission permits and the initial allocation of conventional resources. This explains why some economists insist that the global climate problem cannot be solved without substantial international wealth transfers [3]. Some even argue that permit trade will lead to large distributional effects (see [4]) or – because of terms of trade effects – will reduce welfare and increases global pollution [5]. And it explains why the developing countries have invoked equity considerations to justify their strong opposition to cap-and-trade systems. They may be willing to accept *clean development mechanisms* for individual projects, but seem unwilling to couple these mechanisms with any limitations on their overall emission rights. Or to phrase it differently: Because of equity considerations, there is strong opposition to efficient solutions of the global climate problem through emission trading.

But what if the Pareto-efficient stock of atmospheric carbon were virtually independent of the initial allocation of conventional resources? Then it should be feasible to separate the equity conflict (who gets what?) from the issue of efficiency. The allocation of shares of the global total would not affect global emissions, but it would affect the quantities of resources available for consumption in each region. Therefore, equity could be based on allocating emission shares to individual nations, and efficiency could be achieved through trading these rights internationally without major changes in the historical ownership of labor, capital and other conventional resources.

As Manne [6] has formulated the issue, this could have far reaching policy implications. A sharp distinction could then be drawn between determining the global level of abatement and negotiating the cost sharing rules. For example, a credible international agency could set Pareto-optimal global emission targets. Thereafter, emission rights could be assigned to each region through international negotiations. This would not be an easy task, and it would depend upon the skill of the international negotiators. But it would be less complicated than negotiating simultaneously about wealth transfers, the initial allocation of emission rights and emission reduction targets. This explains why it is of more than pure academic interest if we can clarify the equity-efficiency puzzle.

In this paper, we provide two ways of obtaining some insight into this puzzle. First, we consider a small-scale and then a large-scale model of integrated assessment. Section 2 presents a simple model of a world economy that consists of several countries or regions. In each country welfare depends on the consumption of a public good and a private good. Greenhouse gases are a by-product of the consumption of the private good, and each country can contribute to the public good by investing some of the private good into an abatement technology. In the case of this small-scale model, one can obtain qualitative results. Section 3 presents results from MERGE, a large-scale integrated assessment model. Here, it is possible to obtain quantitative evidence of separability.

2. Separability: A simple analytical treatment

To clarify ideas, let us consider a simple model of the world economy, where R regions cooperate in the solution of the global climate problem. There are two commodities, a private one and a public good. The private good is traded on open international markets and can be consumed or invested in greenhouse gas abatement. The public good corresponds to the quality of the world's atmosphere. Now, since by definition the business-as-usual (BAU) level of emissions equals the sum of emissions plus abatement, this could, for example, be measured as the excess of the business-as-usual level over the controlled level of the atmosphere's carbon dioxide concentration. Therefore, the amount, Q, of the public good depends upon the sum of the regions' individual contributions to greenhouse gas abatement. This allows us to sidestep a detailed energy–abatement model by considering the following reduced-form relationship:

$$Q = \sum_r a_r, \qquad (1)$$

where a_r is the quantity of greenhouse gas abatement carried out by region r.

There are at least ways by which global climate change affects the regional economies. On the one hand, global climate change imposes costs that can, in principle, be expressed in terms of GDP losses. These are sometimes termed *market damages*. In the case of agriculture and forestry, for example, there are market prices by which we can measure the value of output losses. On the other hand, there are effects that cannot be directly expressed in terms of a national accounting system. For example, there are no market prices for valuing non-market damages such as species losses and catastrophic changes in the ocean currents. This is what we shall mean by *non-market damages*.

In the following the different types of effects will be analyzed separately. First we consider the case in which the public good only affects the regions' ability to produce private goods, net of market damages. Later, we will consider the case in which the public good also affects the utility function directly.

2.1 Abatement benefits affect net production only

We are interested in cooperative solutions of the global climate problem. For that purpose, we employ Negishi weights to characterize the international market equilibrium. These weights will depend upon both prices and quantities - the initial endowments of private goods, and the eventual assignment of emission rights.

Now, let $\omega_r > 0$, r = 1,...,R, be the Negishi weights associated with region r, and let y_r be the fraction of the world's conventional wealth that is available to region r. Each region's welfare may be measured by a continuous, strictly monotonic and strictly quasi-concave utility function, U_r. And since market damages are the only consideration here, U_r depends only on the consumption of the private good, c_r. Then for a Pareto-optimal solution, the expression

$$\sum_r \omega_r U_r[c_r]$$

is maximized subject to the constraint (1) and

$$\sum \Phi_r(Q)_r y_r - \sum_r c_r - \sum_r g_r(a_r) = 0. \quad (2)$$

Equation 2 shows how the benefits from abatement affect the regional provision of the private good. Φ_r may be called the region-specific environmental availability factor. That is, the higher the overall atmospheric quality Q, the higher is the fraction $\Phi_r(Q)$ of conventional wealth that is available to region r. Alternatively, $1 - \Phi_r(Q)$ measures the economic costs of global climate change in terms of foregone GDP. Therefore, $\sum \Phi_r(Q)_r y_r$ is called the global green GDP, and Eq. 2 describes how the world's green GDP is allocated between consumption and abatement, where g_r is the regional abatement cost function.[1]

Let us suppose that there are increasing marginal costs of abatement, $g'_r > 0$, $g''_r > 0$, and decreasing benefits from abatement, $\Phi'_r > 0$, $\Phi''_r < 0$. Furthermore, let us focus on the case where the public good is provided at positive levels, and where positive amounts of the private good are consumed. Then first order conditions imply the following optimality conditions for each region r:

$$pg'_r(a_r) = p[\sum_{j=1,\dots,R} \Phi'_j(Q)y_j], \quad (3)$$

where p is the Lagrange-multiplier that is associated with Eq. 2.

[1] Typically there are two options to affect the future: by investing in man-made capital on the one hand, and by investing in environmental capital on the other. Since this is a static framework, only the last option is taken into account. Here, investing into environmental capital is described by abatement activities.

Since prices are positive, Eq. 3 implies that regardless of the values of the Negishi weights, the amount of abatement is the same. Intuitively this is explained by the fact that the optimal abatement is the one that maximizes $\sum_r c_r$. (Recall condition (Eq. 2).) In other words, we minimize market damages plus abatement costs in order to obtain maximal aggregate consumption. (For a formal proof see the Appendix.)

Indeed, we have shown a bit more than required. Our reasoning implies that the Pareto-efficient provision of the public good is uniquely determined. Hence, independent of the distribution of conventional wealth and of carbon rights, there is only one optimal vector of global greenhouse gas abatement. Moreover, this conclusion can be generalized to a case with multiple time periods, provided that the marginal productivity of capital remains fixed over time.

2.2 Abatement benefits affect both utilities and production

Now suppose that global climate change directly affects regional production *and* utilities. This means that the public good enters into the objective function. Hence, the regional welfare, U_r, r = 1,...,R, not only depends on the consumption of the private good, c_r, but also on that of the public good, Q, with $\partial U_r/\partial Q > 0$.

Given this, the global Negishi maximand is written

$$\sum_r \omega_r U_r[c_r, Q].$$

Again this is to be maximized subject to the constraints of Eq. 1 and Eq. 2. As above we focus on the case that both the private and the public good are provided at positive levels. Then first order condition (Eq. 3) changes to

$$pg'_r(a_r) = p[\Sigma_{j=1,...,R}\, \Phi'_j(Q)y_j] + \Sigma_{j=1,...,R}\, \omega_j \frac{\partial U_j}{\partial Q}. \tag{4}$$

The Pareto-efficient internalization of the global climate damages now depends on two effects: on the aggregated losses in conventional wealth due to climate change, and on the aggregated willingness to pay for protecting the global climate. The Pareto-efficient provision of the public good therefore depends upon the Negishi weights.

What can be learned from this? Now, if utility functions are homothetic, then the Negishi weights are determined so as to be proportional to each region's wealth available for expenditure on private and public goods (see [7]). In other words, if the exogenously determined regional shares in the value of the public good are denoted by the parameter σ_r, r = 1,...,R, then the Negishi weight ω_r of region r will be proportional to

$$p\Phi_r(Q)_r y_r - \pi(\sigma_r Q - a_r), \tag{5}$$

where π is the shadow price of the quality of the atmosphere (see (Eq. 1)). The last parenthesis indicates the difference between the region's share in global abatement obligations, $\sigma_r Q$, and its actual abatement level, a_r. This quantity may be positive or negative depending on whether emission rights are bought or sold on the international market.

Now suppose for a moment that regions differ with respect to their willingness to pay for atmospheric quality. Suppose further that emission rights are redistributed from regions with high willingness to regions with low willingness to pay for greenhouse gas abatement. As Eq. 5 indicates, changing the assignments of emission rights in this way implies a redistribution of wealth. Regions which are characterized by low willingness to pay for atmospheric quality will become richer, hence will be assigned higher Negishi weights. This changes the last term in the right hand side of Eq. 4 and therefore affects optimal greenhouse gas abatement.

This observation leads to the question: Can conditions be identified under which the Pareto-efficient stock of atmospheric carbon is independent of the initial distribution of emission shares? Condition Eq. 4 suggests that we might search in two different directions: (1) for conditions which ensure that prices and Negishi weights remain (almost) unchanged, and (2) for conditions which ensure that the society's aggregated willingness to protect the world climate remains unaffected if the initial assignment of carbon rights is reallocated from one region to another.

Note that there is an important difference between these two types of separability conditions. Invariance of prices and Negishi weights depends very much upon numerical values, hence the order of magnitude by which the assignment of carbon rights influences the regions' income. This will be discussed in more detail in a general integrated assessment model (see Section 3.3). Here we will focus on structural conditions under which global greenhouse gas abatement is independent of the initial distribution of emission rights. To this end consider an instructive example. Suppose that regions are characterized by Cobb-Douglas welfare functions, $U_r = \alpha_r \ln c_r + \beta_r \ln Q$. If the elasticity of welfare with respect to the public good, β_r, is (almost) identical across regions, then Eq. 4 will simplify to

$$pg'_r(a_r) = p[\Sigma_{j=1,\dots,R} \Phi'_j(Q) y_j] + \beta Q^{-1} [\Sigma_{j=1,\dots,R} \omega_j]. \qquad (4a)$$

Since Negishi weights sum up to unity, the right hand side of Eq. 4a is independent of the specific values of the Negishi weights, and the arguments from Section 2.1 apply directly.

In other words, separability in optimal greenhouse gas abatement is observed if the willingness to pay for greenhouse gas abatement is almost identical across regions. There is, however, a further interpretation. Aggregated willingness to pay is independent of the distribution of income. This becomes more obvious through rearranging terms in condition Eq. 4. Then we obtain for each region r

$$g'_r(a_r) - [\sum_{j=1,\ldots,R} \Phi'_j(Q)y_j] = \sum_{j=1,\ldots,R} [\frac{\partial Uj}{\partial Q} / \frac{\partial Uj}{\partial cj}] \tag{6}$$

Since the marginal costs of abatement are identical across regions, Eq. 6 is nothing else than a variant of the well-known optimality condition for public goods: The sum of regional benefits from the public good has to be equal to its total marginal costs. Again Pareto-efficiency will be obtained, if we minimize market damages plus abatement costs and simultaneously maximize aggregate consumption. And if the solution to this optimization problem is unique, then there is separability in optimal greenhouse gas abatement. Or to phrase it differently: Aggregated willingness to pay for the global climate attains a maximum at the Pareto-efficient stock of atmospheric carbon. Formally, this can be expressed as follows: For any pair of Pareto-efficient levels of atmospheric quality Q and Q*:

$$Q^* > Q \text{ implies } \quad \sum_{j=1,\ldots,R} [\frac{\partial Uj}{\partial Q^*} / \frac{\partial Uj}{\partial cj^*}] \leq \sum_{j=1,\ldots,R} [\frac{\partial Uj}{\partial Q} / \frac{\partial Uj}{\partial cj}], \tag{7}$$

where c_j* is the optimal consumption associated to Q*. By repeating the arguments from Section 2.1, we can again show by contradiction that the optimal level of the public good is uniquely determined. (For a proof see the Appendix.)

What conclusions can be drawn from our considerations so far? One is that equity-efficiency separability occurs if the regions' welfare functions are not homothetic, but are quasi-linear with respect to the internationally traded private good. That is, the individual utility functions consist of a linear term in c_r plus a nonlinear term, $V_r(Q)$ (see the Appendix). Another way to interpret this is that separability is a satisfactory approximation if the distribution of emission rights leads to only small changes in real income. This is indeed what we seem to find in the case of the large-scale numerical model known as MERGE.

3. The MERGE Model

The following analysis is based on MERGE (a **m**odel for **e**valuating the **r**egional and **g**lobal **e**ffects of greenhouse gas reduction policies). MERGE is an intertemporal general equilibrium model. Like its predecessors, the version used for the present analysis is designed to be sufficiently transparent so that one can explore the implications of alternative viewpoints in the greenhouse debate. It integrates submodels that provide a reduced-form description of the energy sector, the economy, emissions, concentrations, temperature change and damage assessment (for details see [8]).

3.1 A short model overview

MERGE combines a bottom-up representation of the energy supply sector together with a top-down perspective on the remainder of the economy. For a particular scenario, a choice is made among specific activities for the generation of electricity and for the production of non-electric energy. Oil, gas and coal are viewed as exhaustible resources. There are introduction constraints on new technologies and decline constraints on existing technologies. MERGE also provides for endogenous technology diffusion. That is, the near-term adoption of high-cost carbon-free technologies leads to accelerated future introduction of lower cost versions of these technologies.

Outside the energy sector, the economy is modeled through nested constant elasticity production functions. The production functions determine how aggregate economic output depends upon the inputs of capital, labor, electric and non-electric energy. In this way, the model allows for both price-induced and autonomous (non-price) energy conservation and for interfuel substitution. It also allows for macroeconomic feedbacks. Higher energy and/or environmental costs will lead to fewer resources available for current consumption and for investment in the accumulation of capital stocks. Economic values are reported in U.S. dollars of constant 2000 purchasing power.

The world is divided into nine regions: 1) the USA, 2) WEUR (Western Europe), 3) Japan, 4) CANZ (Canada, Australia and New Zealand), 5) EEFSU (Eastern Europe and the Former Soviet Union), 6) China, 7) India, 8) MOPEC (Mexico and OPEC) and, 9) ROW (the rest of world). Under the Kyoto Protocol, the first five of these regions constitute "Annex B". The others are known as developing countries, and they have high rates of population growth. Time periods are each a decade in length, and the horizon extends through 2150. In order to minimize horizon effects, results are typically reported only through 2100. At this level of aggregation, the model contains about 20,000 decision variables and 18,000 constraints – excluding the upper and lower bounds on individual variables. With a hot start, the run time seldom exceeds half an hour on a 1000 mHz desktop computer.

Each region is represented by a single long-lived agent, and each of the agents maximizes the discounted utility of its consumption subject to an intertemporal budget constraint. Each region's wealth includes not only capital, labor and exhaustible resources, but also its negotiated international shares in emission rights. Particularly relevant for the present calculations, MERGE provides a general equilibrium formulation of the global economy. We model international trade in emission rights, allowing regions with high marginal abatement costs to purchase emission rights from regions with low marginal abatement costs. There is also trade in oil, gas and energy-intensive goods. International capital flows are endogenous. A region may have a positive or negative trade surplus in any one time period, but the present value of these surpluses must balance off to zero over the entire planning horizon.

MERGE can be used for either cost-effectiveness or cost-benefit analysis. For the latter purpose (the application presented here), the model translates global warming into its market and non-market impacts. Market effects are intended to measure direct impacts on the GDP, e.g., agricultural products and timber. Non-market effects refer to those not traditionally included in the national income accounts, e.g., the impacts on biodiversity, environmental quality and human health. These effects are probably more important than market effects – and they are even more difficult to measure.

For Pareto-optimal outcomes, i.e., those scenarios in which the costs of abatement are balanced against the impacts of global climate change, each region evaluates its future welfare by adjusting the value of its consumption for both the market and non-market impacts of climate change. The market impacts represent a direct claim on gross economic output -- along with energy costs, aggregate consumption and investment. Non-market impacts enter into each region's intertemporal utility function, and are viewed as an adjustment to the conventional value of macroeconomic consumption. There is a greater than unitary per capita income elasticity of demand for abating non-market damages. For more on the model, see our web site: http://www.stanford.edu/group/MERGE/.

3.2 Simulation results

To illustrate the separability of equity and efficiency, we will consider three different rules for the assignment of emission rights and show that these all lead to more or less the same Negishi weights – and therefore very similar levels of emissions and marginal costs of abatement. This illustration will be based on the following three alternatives:

- rights assigned in proportion to initial population – an egalitarian principle;

- rights assigned in proportion to initial emissions during the early years, and then a transition (by 2050) to an assignment in proportion to the population – a pragmatic principle, the one typically employed in MERGE; and

- rights assigned in proportion to initial emissions – a grandfathering principle.

Figure 1 compares a business-as-usual (no abatement) carbon emissions scenario with each of these three alternatives. Note that the three low emission scenarios are indistinguishable. Similarly, Figure 2 compares the three sets of prices of tradeable carbon emission permits. Again, the different burden-sharing rules lead to an indistinguishable set of efficiency prices. Similar results have been obtained in all experiments with MERGE - provided that there is free trade in emission rights.

In order to understand this result, it is instructive to examine the Negishi weights shown in Table 1. Clearly, grandfathering is favorable to the five Annex B nations, and the population criterion is favorable to the four developing regions. However, all three sharing rules lead to weights that are identical to three decimal digits. In order to detect differences, it is necessary to go to six digits. Consider the ratio of the weights implied by the egalitarian rule to that implied by grandfathering. There is only one region (India) for which the percentage change of the Negishi weight is significant. In this case the ratio differs from unity by more than 1%. That is, the initial endowments of capital, labor and exhaustible resources are the principal determinants of the Negishi weights. These far outweigh the importance of the value of each region's share in emission rights.

4. Conclusions

This paper has discussed the following question: Under what conditions is the Pareto-efficient stock of atmospheric carbon independent of the initial distribution of carbon rights? The answer differs and depends on what type of climate damages is taken into account. If all the costs of climate change can be expressed in terms of GDP losses, separability between equity and efficiency in greenhouse gas abatement strategies prevails. This is the case sometimes described as *market damages*.

If, however, different regions assign different values to non-market damages such as species losses, different sharing rules may affect the Pareto-optimal level of greenhouse gas abatement. Nevertheless, separability can also be demonstrated in this case, if income effects do not affect aggregated willingness to pay (price of the global common). In short that means, either income effects are small, or the societies' willingness to pay is independent of their income, or regions are characterized by identical homothetic preferences.

Appendix

Model equations

Abatement benefits affect net production only

From the model equation (1) and (2) immediately follows the Lagrange - function

$$= \sum_r \omega_r U_r[c_r] + p(\sum \Phi_r(Q)_r y_r - \sum_r c_r - \sum_r g_r(a_r)) + \pi(Q - \sum_r a_r),$$

where π and p are the Lagrange-multipliers corresponding to equation (1) and (2), respectively. For an interior solution first order conditions are:

$$\omega_r U'_r[c_r] = p$$

$$p[\sum_{j=1,\dots,R} \Phi'_j(Q)y_j] = \pi$$

$$pg'_r(a_r) = \pi$$

Combining the last two equations yields equation (3).

Abatement benefits affect both utilities and production

By considering both market and non-market damages the objective function changed. Therefore given the modeling framework from above, the Lagange – function is of the form:

$$L = \sum_r \omega_r U_r[c_r, Q] + p(\sum \Phi_r(Q)_r y_r - \sum_r c_r - \sum_r g_r(a_r)) + \pi(Q - \sum_r a_r).$$

For an interior solution we now observe the first order conditions

$$\omega_r \partial U_r[c_r, Q]/\partial c_r = p$$

$$[\sum_{j=1,\dots,R} \omega_j \partial U_j[c_j,Q]/\partial Q] + p[\sum_{j=1,\dots,R} \Phi'_j(Q)y_j] = \pi$$

$$pg'_r(a_r) = \pi$$

Combining the last two equation gives condition (4).

Theorem

Let the regional utility functions $U_r[c_r,Q]$, r=1,...R, be strictly increasing in the consumption of the private good, $\partial U_r/\partial c_r > 0$, as well as the public one, $\partial U_r/\partial Q > 0$. Suppose further that there are increasing marginal costs of abatement, $g'_r > 0$, $g''_r > 0$, and decreasing benefits from abatement, $\Phi'_r > 0$, $\Phi''_r < 0$. The Pareto-efficient level of atmospheric carbon Q is independent of the initial distribution of conventional wealth if

$$\sum_{j=1,\dots,R} [\frac{\partial Uj}{\partial Q^*}/\frac{\partial Uj}{\partial cj^*}] \leq \sum_{j=1,\dots,R} [\frac{\partial Uj}{\partial Q}/\frac{\partial Uj}{\partial cj}] \text{ for any } Q^* > Q. \quad (8)$$

Proof (by contradiction)

Let condition (8) is fulfilled and suppose that $(Q, c_1,\dots,c_R)$ and $(Q^*, c_1^*,\dots,c_R^*)$ are two different Pareto-efficient allocations with $Q^* > Q$. Given the assumptions imposes upon g_r and Φ_r, optimality condition (7) obviously implies for any region r

$$g'_r(a_r^*) < g'_r(a_r),$$

hence $g_r(a_r^*) < g_r(a_r)$ for all r. Therefore we get from the material balance (2)

$$\sum_r c_r = \sum \Phi_r(Q)_r y_r - \sum_r g_r(a_r) < \sum \Phi_r(Q^*)_r y_r - \sum_r g_r(a_r^*) = \sum_r c_r^*$$

which contradicts the assumption that $(Q,c_1,\dots,c_R)$ is Pareto-efficient.

Corollary 1

Suppose global climate change does affect production only but not utilities. Then separability immediately follows.

To see that let $(Q, c_1,...,c_R)$ and $(Q^*, c_1^*,...,c_R^*)$ be Pareto-efficient allocations with $Q^* > Q^*$. Since $\Phi'_j(Q) > \Phi'_j(Q^*)$ for all $j = 1,...,R$, (4) implies $g'_r(a_r) > g'_r(a_r^*)$, and the proof from above directly applies.

Corollary 2

Let $U_r[c_r,Q] = c_r + v_r(Q)$. Now, if $v'_r > 0$ and $v''_r < 0$, $Q^* > Q$ immediately implies $[\sum_{j=1,...,R} v'_j(Q^*)] < [\sum_{j=1,...,R} v'_j(Q)]$, and separability follows.

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Table 1

Negishi weights under alternative sharing rules

	Egalitarian	Pragmatic	Grandfathering	Egalitarian/ Grandfathering
USA	0.224516	0.224759	0.225367	0.996
WEUR	0.225625	0.225738	0.226022	0.998
JAPAN	0.089233	0.089272	0.089370	0.998
CANZ	0.032243	0.032280	0.032371	0.996
EEFSU	0.044120	0.044191	0.044370	0.994
CHINA	0.094155	0.094065	0.093837	1.003
INDIA	0.044032	0.043879	0.043492	1.012
MOPEC	0.047114	0.047117	0.047130	1.000
ROW	0.198962	0.198700	0.198041	1.005
TOTAL	1.000000	1.000001	1.000000	

Figure 1. Global carbon emissions

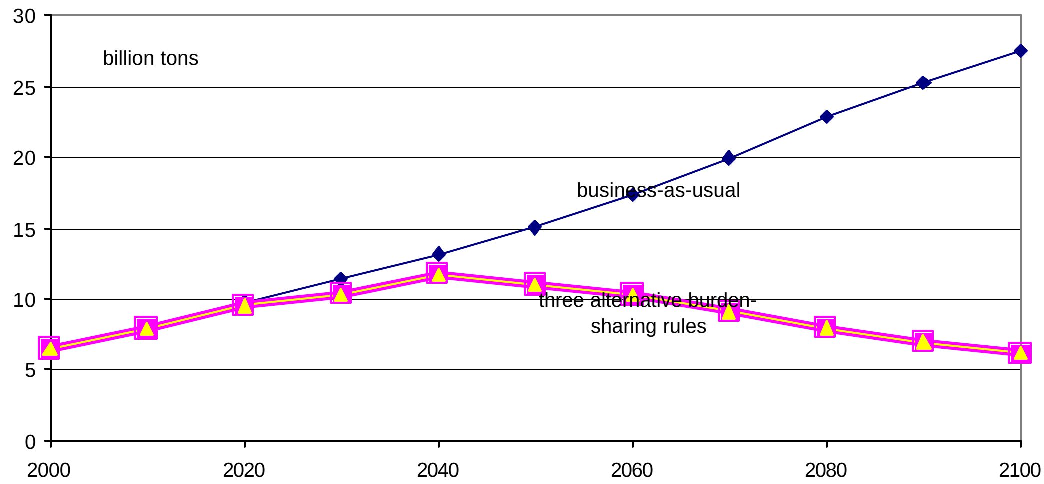

Figure 2. Value of tradeable carbon emission permits