# The use of tradeable emission permits for limiting CO2 emissions

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# The economics of limiting $CO_2$ emissions

# The use of tradable emission permits for limiting $CO_2$ emissions

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## Summary

*The substantial economic costs that must be expected to emerge from the implementation of policies to limit $CO_2$ emissions require the application of efficient environmental policy instruments. Efficient instruments permit the implementation of environmental policy at minimal costs. An efficient $CO_2$ policy can be implemented by the application of tradable emission permits.*

*The best design of a system for $CO_2$ emission permit trade is based on $CO_2$ coupons. $CO_2$ coupons are a special $CO_2$ currency.*

*$CO_2$ coupons are issued and auctioned or sold by a government agency to the general public on official exchanges. The delivery of a $CO_2$ coupon by an economic agent from the private sector back to the permit authority legitimizes the emission of a specified quantity of $CO_2$ emissions in the past. $CO_2$ coupons are thus used to pay off '$CO_2$ debt' accumulated in the past.*

*By controlling the quantity of $CO_2$ coupons issued periodically the permit authority can implement a given emission objective within an emission target corridor set by environmental policy. Within the target corridor the permit authority has a degree of freedom in fine-tuning emissions with open-market instruments. Furthermore, within the limits set by fine-tuning, polluters have a degree of freedom in distributing $CO_2$ emissions between periods. Hence, the coupon system features an important degree of intertemporal flexibility that facilitates the adjustment of the economy to temporal shifts in demand for fossil energy.*

*In order to reduce administrative costs, it is not the ultimate polluter but rather the producers of fossil energy in the permit area and firms that import primary energy into the permit area that are made subject to the permit system. To preserve an incentive for substitution of high carbon content primary energy by low carbon content or carbon free energy, the assessment base is the carbon content of fossil fuels. In order to give an incentive to develop and apply end-of-pipe technologies for $CO_2$ abatement, a compensation mechanism is applied.*

*The coupon system is the lowest administrative and organizational cost solution of all functioning tradable permit systems. It resembles a $CO_2$ tax with a flexible tax rate in which the tax rate is determined on the market for emission rights.*

*Its fundamental advantage over a $CO_2$ tax is the variability of the emission price by which a politically set emission target is attained by market processes alone. In contrast, under a tax regime, the target can only be attained by a perpetual political tax-rate-setting process of ecologically costly trial and error.*

*The EC's internal market imposes restrictions on the decentralization of $CO_2$ policies in the EC. The coexistence of the coupon system in one member country and other $CO_2$ policy instruments in other member countries unnecessarily creates substantial transaction and transportation costs. The application of the coupon system within the internal market therefore requires its application in all member countries. The instrument choice therefore needs to be harmonized.*

*Of the various options for designing an EC-wide permit system, the preferential design involves a policy body at the Community level determining the target corridor, and a single Community permit authority that issues and distributes Community coupons free of charge to national permit authorities according to a distribution key. The national authorities then supply the coupons to their domestic market and enforce the system domestically. Coupons are tradable EC-wide by the private sector. Importers and producers of primary energy settle their $CO_2$ accounts only with their respective national authority.*

*Non-member countries can participate in various ways in a Community-led coupon scheme. They can simply join the EC coupon scheme. Other possibilities include different permit systems abroad, the application of other market instruments or even the implementation of quotas by command and control. However, a prerequisite for each and all of these options is that non-member countries do not violate their respective emission quotas.*

*A major roadblock on the path to extending a permit/quota system beyond the EC is country sovereignty. Country sovereignty relates to a sovereign nation's degree of freedom in factually violating an international $CO_2$ agreement.*

*Although a skilful design of initial quotas can resolve the problem of country sovereignty in theory, a careful approach to international environmental cooperation suggests that the entire burden of contract stabilization should not be placed on quota allocations alone. Additional stabilization instruments are available. Amongst them are conditional preferential trade agreements, contract indexation and cross-default clauses.*

## 1. Introduction

Tradable emission permits have been discussed by economists since Dales first introduced the idea in 1968. It is simple: a governmental permission to emit environmentally harmful substances is made transferable between polluters. Hence, instead of investing in expensive abatement technology, a polluting firm may buy emission permits from other polluters whose abatement costs are lower. By so doing, the polluter reduces his own cost of compliance as well as overall abatement costs.[1]

By limiting the number of available emission permits, government authorities can predetermine the quality of the environment.[2] Under ideal circumstances, a market for emissions develops in which emission permits are traded at the going equilibrium market price. Since this market price applies to every polluter and in market equilibrium is equal to the marginal abatement costs of each source, the outcome is economically efficient. It is a least-cost solution.

In practice, however, this outcome is not automatically guaranteed. Problems with respect to market creation may occur, and non-existent or deficient markets reduce the efficiency of emissions trading.

Deficient markets may result from a number of shortcomings. For instance, market deficiency is caused by insufficiently guaranteed property rights with respect to emission permits, high search and transaction costs, monopolistic structures in commodity markets, problems of administration and enforcement of the permit system, a segmentation of permit markets, the lack of experience and acceptance on the side of potential traders in permit markets, and the like.[3] Many of these problems can be solved by a careful design of the tradable permit system, which makes use of the characteristic features of the $CO_2$ problem. In this respect, $CO_2$ emissions appear to be an almost ideal case for the application of tradable permit systems.

It is the objective of this paper to describe a feasible concept of emission permits for $CO_2$ (section 3), to apply this concept to the European Community (section 4), to assess the possibilities of a tradable permit scheme for energy in general (section 5), to extend the idea of tradable permits to the international sphere (section 6) and to provide a framework of evaluation criteria for choosing between a permit system and a $CO_2$ tax (section 7).

## 2. Some basic facts on $CO_2$ emissions

The growing concentration of $CO_2$ in the atmosphere is closely connected with the increasing exploitation of fossil carbon deposits (coal, petroleum, natural gas) since the beginning of the nineteenth century, which prompted the rapid economic development in industrial countries during the last 200 years. Table 1 reflects this. Western Europe, North America, Eastern Europe and the Soviet Union alone emitted 13 371 million tonnes of fossil $CO_2$ in 1986, which amounts to 65 % of global $CO_2$ emissions. With the exception of China, developing countries play as yet a relatively small but increasing role.

**Table 1**

**$CO_2$ emissions by region, 1986**

| Region | Emissions (million t) | Share of world-wide emissions (%) |
|---|---|---|
| Western Europe | 3 156 | 15,4 |
| North America | 5 761 | 28,0 |
| South and Central America | 939 | 4,6 |
| Africa | 565 | 2,8 |
| Near East | 518 | 2,6 |
| South-East Asia, Australia | 2 471 | 12,0 |
| Eastern Europe, Soviet Union | 4 454 | 21,6 |
| China | 2 674 | 13,0 |
| Total | 20 583 | 100,0 |

*Source:* Heister and Michaelis et al. (1991), p. 28.

In industrialized countries, roughly one-half of all man-made $CO_2$ is released by large combustion facilities (industry, electricity generation). The remaining half originates from smaller sources (skilled trades, households, traffic). Table 2 shows a breakdown of total $CO_2$ emissions by sector for the Federal Republic of Germany. The relative importance of minor sources suggests that a concentration of $CO_2$ reduction measures on large sources is not sufficient to adequately exploit the existing reduction potential.

[1] See, for instance, Tietenberg, 1985.

[2] In the case of regionally/locally effective pollutants, transferability of emission permits must be spatially restricted in order to fix environmental quality. This, however, is of no importance in the case of $CO_2$ emissions.

[3] See, e.g. Hahn and Hester, 1989, on experience with emission trading programmes and market-like compensation solutions in the United States.

**Table 2**

**Average annual $CO_2$ emissions in the FR of Germany by sector, 1980-85**

| Sector | Emissions (million t) | Share of total emissions (%) |
|---|---|---|
| Households and other small-scale consumer | 180 | 24,2 |
| Traffic | 127 | 17,2 |
| Industry | 100 | 13,5 |
| Energy conversion | 336 | 45,1 |
| Total | 743 | 100,0 |

*Source:* Heister and Michaelis et al. (1991), p. 33.

Measuring $CO_2$ quantities directly and continuously at their source is relatively expensive and only justifiable for large combustion facilities. However, the $CO_2$ quantity generated in combustion can be determined by the specific carbon content of the fuel used, which is different with respect to its energy potential for different kinds of fuel. Since end-of-pipe technologies for $CO_2$ emissions do not (yet) exist, the total amount of carbon in fossil fuels is released into the atmosphere. This linear relationship between carbon content and $CO_2$ emissions makes it possible to calculate emission coefficients that indicate the quantity of $CO_2$ released into the atmosphere per unit of fossil fuel.[1] Hence, $CO_2$ output can be calculated on the basis of fuel input.

$CO_2$ is a natural component of the atmosphere. In contrast to many other pollutants it is neither possible nor necessary to control the spatial allocation of $CO_2$. Possible differences with respect to climate change between regions have complex meteorological causes, but do not depend on the location of the $CO_2$ source. The crucial problem with respect to global warming is the intertemporal allocation of the $CO_2$ emissions. It is estimated that an average increase in surface temperature of 0,1°C in 10 years is the maximum to which flora and wildlife can adjust (Jäger, 1988). This is much less than the temperature increase presently expected. Although in the short and medium term some flexibility of emission quantities can be allowed, it is crucial that in the long run $CO_2$ emissions and their distribution over time will be safely controlled.

1 Determining $CO_2$ emissions by using emission coefficients presupposes complete combustion of the fuel, which is assumed here.

# 3. A tradable permit scheme for $CO_2$ emissions[2]

## 3.1. $CO_2$ coupons as the tool of $CO_2$ control

Theoretical permit concepts usually stipulate that the holder of an emission permit is entitled to discharge a certain quantity of the pollutant in question per unit of time during the period of validity of the permit. In contrast to this traditional approach, the system proposed here embodies tradable emission permits in the form of $CO_2$ coupons. Such coupons have only one dimension: they are solely defined in quantities of $CO_2$, and they are valid for an unlimited period of time. $CO_2$ coupons have two functions. As an entitlement, they permit the emission of the stated quantity of $CO_2$, but only once although at any point in time. As a means of verification, $CO_2$ coupons that have been used must be submitted to the coupon authority, which withdraws and invalidates them. Hence, $CO_2$ coupons can be interpreted as a kind of money: a specific $CO_2$ currency, which exclusively serves for the settling of $CO_2$ emissions with the coupon authority. This approach has a number of advantages compared to traditional emission permits (see Table 3):

(a) Traditional emission permits may differ from each other, for instance with respect to the emission quantity per unit of time, temporal and spatial validity of the permit and possibly further criteria. In contrast, $CO_2$ coupons represent perfect substitutes and are fully divisible. This guarantees that a homogeneous market and thus an efficient market price for $CO_2$ emissions will develop. And this ensures the optimal spatial allocation of the total admissible quantity of $CO_2$ emissions. As perfect substitutes, $CO_2$ coupons can easily be traded on an exchange. This reduces transaction costs substantially and increases market transparency considerably.

(b) In the case of traditional emission permits, permanent supervision is inevitable. It is necessary to keep track of a permit in order to make sure that only its present holder uses the permit to justify his present emissions. Contrary to this, in the case of $CO_2$ coupons, all supervision requirements are met if those economic agents who assume the coupon liability are obliged to submit the required number of $CO_2$ coupons to the coupon authority, which are then invalidated. The required number of coupons must correspond to the quantity of $CO_2$ emissions caused by each agent during the settlement period. The $CO_2$ emission quantity itself can be determined and supervised independently of the coupons

2 This section is based on Heister and Michaelis, 1991, and Heister and Michaelis et al., 1991. For a comparison of different instruments to reduce $CO_2$ emissions, see Heister, 1992.

held by the owner of the source. Furthermore, it is not necessary to furnish proof of the possession of coupons for prolonged periods of time in the past, during which $CO_2$ was released.

(c) When employing $CO_2$ coupons, the control of $CO_2$ emissions over time can be implemented by issuing a limited number of new coupons periodically in order to replace those coupons which have been used up (see below). There is no need to depreciate or limit the validity of $CO_2$ coupons as is necessary with traditional permit systems. Hence, property rights are more certain.

(d) A system of $CO_2$ coupons has a high degree of reversibility and adaptability. This is important since there is practically no experience with tradable permit markets for emissions in Europe yet. Reversibility could not be assured if traditional permits were introduced, which are property rights with an unlimited validity in the extreme case. Contrary to this, $CO_2$ coupons in circulation will be permanently used up. Hence it is, if the occasion arises, possible to let the permit system expire without having to expropriate those emission permits that have already been granted. They could, for instance, be accepted as payment against $CO_2$ tax obligations if the permit system were to be replaced by a $CO_2$ tax.

**Table 3**

**Comparative advantage of coupons over traditional permits**

| | Traditional permits | $CO_2$ coupons |
|---|---|---|
| Transaction costs | substantial | minimal |
| Supervision costs | high | low |
| Property rights | risky | certain |
| Reversibility of system | difficult | simple |

## 3.2. Controlling $CO_2$ emissions over time

From a theoretical point of view, it would be conceivable to leave the intertemporal allocation of $CO_2$ emissions completely up to the market. On introducing the system, the total amount of $CO_2$ emissions that would be admissible in the long run — in the extreme case indefinitely — would be privatized and put on the market in the form of $CO_2$ coupons. This stock would then be used up under the responsibility of the private sector similar to the extraction of a nonrenewable resource.

Such an approach, however, does not seem to be advisable and is not recommended here. For reasons of intertemporal externalities which would not be accounted for in the market price of $CO_2$ coupons and on grounds of possible discrepancies between the individual and social decision parameters (e.g. time horizon, discount rate), it is not guaranteed that an ecologically justifiable and a politically acceptable reduction path will result. Furthermore, given the present state of scientific knowledge, the total quantity of $CO_2$ emissions that would be admissible over time cannot be fixed definitively when initiating the system.

For these reasons, the $CO_2$ reduction path has to be fixed at the political level. This means for the system in question that in each period of time only that number of additional $CO_2$ coupons which correspond to the $CO_2$ emissions assigned to that very period may enter the market. For reasons of flexibility, however, it may be of advantage if the emission target aimed at by the government is fixed in the form of a target corridor. Within this corridor the coupon authority can independently determine the number of $CO_2$ coupons that are to be issued annually.

Apart from issuing $CO_2$ coupons within the bounds of the target corridor, the coupon authority has additional means at its disposal. With these instruments, which will be described below, a fine tuning can be implemented which does not influence the number of $CO_2$ coupons available in the long run.

Since the economically optimal reduction path is neither known to the political decision-makers nor to the coupon authority, the emission path finally realized should be allowed to deviate to an ecologically and politically acceptable extent from that path which is predetermined by periodical issuance of new $CO_2$ coupons. The system presented here takes this requirement into account in two different ways.

First of all, it is possible to save $CO_2$ coupons for later use, since their validity is not limited. Stockpiling $CO_2$ coupons is equivalent to transferring part of the $CO_2$ emissions assigned by the authorities for the current period to future periods. Contrary to that, it is not possible to take a credit on future emission possibilities in the present because the necessary $CO_2$ coupons are not yet on the market. Thus the emission path is sealed off asymmetrically with respect to time.

Second, to resolve this asymmetry, those economic agents who are obliged to settle their $CO_2$ account with the coupon authority may be allowed to carry forward a proportion of their $CO_2$ emissions. That is, they may postpone submission of a part of the $CO_2$ coupons due for the present period until the next period. Since paying for today's $CO_2$ emissions only in the next settlement period has virtually the same effect as a bank credit, a fee has to be charged. The fee must be at least as high as the interest on the implicitly given bank credit. To limit the accumulation of this $CO_2$ debt, the fee may become prohibitive at a certain level of debt.

Based on these built-in intertemporal flexibility mechanisms, the coupon authority has fine-tuning instruments at its disposal with which it can influence the coupon market temporarily without changing the number of carbon coupons that are available in the long run.

The coupon authority itself may keep a stock of carbon coupons and may carry out an open-market policy by buying and selling coupons on the coupon stock exchange.

It may pursue a discount-rate policy by changing the fee that is charged for postponing payments with carbon coupons.

It may lengthen or shorten the settlement period, thus allowing for more or less automatic intra-period flexibility.

It may demand periodic anticipatory payments of coupons on the basis of the expected total payment, due at the end of the settlement period.[1]

Apart from the flexibility mechanisms already introduced, it could be of advantage for the economic agents concerned if they were able to increase the certainty of their operational planning by securing $CO_2$ coupons for future operations ahead of schedule. This can be made possible by already issuing a proportion of those $CO_2$ coupons that have been assigned to future periods in the form of dated $CO_2$ coupons. These coupons will become valid for the settlement of $CO_2$ emissions only after the imprinted date. The determination of the time path of emissions is summarized in Table 4.

**Table 4**

**The determination of the time path of emissions**

| | |
|---|---|
| Political authority: | Determination of the target corridor |
| Permit authority: | Supply of coupons within the bounds of the target corridor |
| | Open market operations |
| | Discount-rate policy |
| | Change of settlement period |
| | Demand for anticipatory coupon deliverance |
| | Issuance of dated coupons |
| Private sector: | Release of emissions |
| | Coupon saving |
| | Coupon credits |

## 3.3. Initial distribution of $CO_2$ coupons

There are two basically different procedures for the initial distribution of tradable emission permits: the allotment, free of charge, to the existing sources on the basis of their current real emissions (grandfathering), and the sale to the highest bidders in an auction.[2]

In the literature it is often suggested that the vested rights of existing polluters be protected by supplying emission permits to them free of charge at least for a transitional period. This approach is to be rejected (see Table 5). The protection of acquired rights can also be ensured by announcing the permit system sufficiently in advance of its going into operation. This would render any grandfathering of $CO_2$ coupons unnecessary, which, in the case of $CO_2$ emissions, would give rise to serious distributional problems: since there are not yet any legal provisions for the limitation of $CO_2$ emissions, it is to be taken that to date everybody has a right to emit any quantity of carbon dioxide. If total $CO_2$ emissions were to be restricted now and allocated by tradable emission permits, it would not be justifiable that scarcity-induced profits would accrue only to those who made use of their right to emit $CO_2$ in the past, but not to those who held the same right but simply did not make use of it. Instead, the public at large, represented by the State, may be considered the natural beneficiary of any scarcity-induced profits arising from the privatization of a common right.

There are other important reasons favouring the initial sale of emission rights. Auctioning of $CO_2$ coupons guarantees immediate access to the market for any new firm. The signalling effect of the true scarcity price emerges as early as possible. And problems that relate to the establishment of a particular distribution formula can be avoided. A formula based on current real emissions would, for instance, provide an incentive to increase short-term emissions in order to

1 Note that neither the settlement period nor the date of payment need be equal for all firms concerned.

2 The option of combining the allotment with a charge is only gradually different from a free-of-charge distribution of $CO_2$ coupons since additional criteria for discriminating between potential buyers have to be applied (unless the charge happens to equal the unknown market price).

**Table 5**

**Comparative advantage of a sale of coupons over grandfathering**

| | Grandfathering | Sale of coupons after sufficient announcement period |
|---|---|---|
| Rights of active polluters | protected | protected |
| Rights of dormant polluters | violated | protected |
| Market entry | potentially restricted | open |
| Information | available only when 'grandfathers' start selling | immediately available |
| Incentive problems | adverse incentives during announcement period | none |

obtain as many permits as possible. Any distribution formula would have to comply with some notion of distributional justice and would certainly be disputed by the pressure groups concerned.

## 3.4. Choosing fossil carbon as assessment base

Due to the constant ratio between the carbon content of fossil fuels and the $CO_2$ emissions caused by incineration, the coupon liability can either be based directly on the measured $CO_2$ emissions or indirectly on the weighted fuel input. Deciding between these two options implies a choice between conflicting goals (see Table 6). On the one hand, the innovation processes induced are most substantial if the financial burden is put directly on $CO_2$ emissions measured at their source. On the other hand, the existing substitution potential can only be fully exploited if all sources of $CO_2$ emissions are included in the coupon system. The latter, however, is not possible if directly measured $CO_2$ emissions are chosen as the coupon base, since a considerable share of the emissions are caused by minor sources for which an adequate and economically justifiable measuring technology does not yet exist. This means that, at present, only those systems that either do not include smaller sources or do not opt for directly measured $CO_2$ emissions as the coupon base can be realized.

Since neglecting minor sources seems to be economically unjustifiable and since the disadvantages of choosing fuel inputs as the coupon base can be compensated by adequate

**Table 6**

**Comparative advantage/disadvantage of choosing $CO_2$ emissions or fossil carbon as assessment base**

| | $CO_2$ emissions | Fossil carbon |
|---|---|---|
| Incentive to develop end-of-pipe technologies | present | absent |
| Coverage of all sources | expensive | inexpensive |

supplementary mechanisms (see below), the system developed here proposes determining the quantity of $CO_2$ emissions for which $CO_2$ coupons have to be submitted to the coupon authority, by weighting the fuel input with fuel specific $CO_2$ factors. Hence, fossil carbon should be chosen as the relevant assessment base. This warrants the inclusion of almost all man-made $CO_2$ emissions into the coupon system as these emissions need not be directly measured at their individual source.

However, some modification seems to be necessary in the case of $CO_2$ emissions. These are related to burning waste products in waste incineration plants. These products contain either non-fossil or fossil carbon. The emission of non-fossil carbon quantities resulting from burning wood and other organic materials should not be included in a coupon system since these quantities are a part of the natural carbon cycle and do not add to global warming. However, $CO_2$ emissions resulting from burning products which contain fossil carbon (plastics and the like) should, in principle, be included in the coupon system. But since it is hardly possible to measure these $CO_2$ quantities separately in waste incineration facilities and since these quantities account for a relatively unimportant proportion of total $CO_2$ emissions it is reasonable not to include them in the $CO_2$ coupon system.

## 3.5. Placing the coupon liability on fossil fuel producers and importers

If fuel inputs are chosen as the assessment base, it is not necessary to place the coupon liability directly on the operator of a $CO_2$ source. This opens up an additional degree of freedom when allocating the coupon liability, a factor that can be used to reduce administrative costs. These costs depend mainly on the number of individuals or firms which bear the coupon liability and with which the coupon authority has to deal. Hence, the coupon liability should be placed on that commercial level which has the fewest market participants. This is the level of importers and producers of fossil fuels. This minimizes administrative costs.

In order to fulfil the coupon liability, those firms which produce or import fossil fuel must procure emission coupons. At the end of each settlement period, they must transfer the required number of coupons back to the coupon authority. In principle, the total $CO_2$ face value of the coupons to be handed in is equal to the quantity of fossil carbon supplied by a firm to the markets during the settlement period.

The coupon costs will be passed on to the consumers as a component of the price for fuel. This results in a differentiated price increase, which is in direct proportion to the carbon content of the fossil fuel. This price increase is a signal to the consumer. It indicates the scarcity of permissible $CO_2$ emissions and induces energy savings and substitution effects.

Placing the coupon liability on the first commercial level may, however, impede the proper functioning of the coupon market. The number of firms assuming the coupon liability may not be sufficiently large to guarantee competition. This can be a problem for small economies and for countries in which monopolistic structures in the energy markets prevail. Fifty to 100 firms should be the minimum to constitute an active market for $CO_2$ coupons. The number of potential market participants can, however, be much larger since anyone is permitted to buy and sell $CO_2$ coupons. Opening coupon markets to others than licensees has an important advantage. Market participants which hold $CO_2$ coupons as part of their portfolios will ensure that the coupon market operates under conditions of perfect competition whatever the number of licensees involved.

Generally, any attempt by large companies or by cartels to dominate the permit market in order to push competitors on commodity and labour markets out of business would have no chance of success. Since $CO_2$ coupons can be purchased, stocked and resold by anybody, the market for $CO_2$ coupons is contestable. A cartel would therefore have to fight against an arbitrarily large number of potential market participants, which have only small transaction and information costs. Furthermore, anyone who attempted to abuse the coupon market would undoubtedly have to reckon with open-market intervention by the coupon authority and countermeasures by the exchange supervisory board.

## 3.6. Compensation payments with $CO_2$ coupons

Basing the $CO_2$ coupon system on the fossil fuel sales by producers and importers of fossil fuel gives rise to three major problems for which a solution must be found if the coupon system is to be applied successfully.

(a) If the fossil carbon input is the relevant assessment base, then industry has no incentive to develop end-of-pipe technologies for holding back $CO_2$, since there would be no remuneration for installing such devices. Furthermore, if end-of-pipe devices were nevertheless applied, the coupon authority would, in all, extract more $CO_2$ coupons from the economy than would be justified by total actual $CO_2$ emissions. The $CO_2$ target would then be undercut: it would actually become tighter than was politically intended, and $CO_2$ emitting activities would have to be reduced by more than is required in order to reach the emission objective. Hence, $CO_2$ quantities held back by end-of-pipe devices must be exempted from the coupon liability.

(b) Similarly, fossil fuel quantities that are not used in combustion processes and therefore do not release $CO_2$ into the atmosphere would be unduly covered by the coupon system. This is a problem which mainly occurs in the chemical industry that uses oil to produce plastics and other carbon-containing durables. Non-energetic use of fossil fuel causes a targeting problem which is similar to the one described above. Therefore, these fuel quantities must also be exempted from the coupon liability.

(c) The same problem arises if fossil fuel products are (re-)exported, since any related $CO_2$ emissions will not occur in the home country, which is therefore not liable for them. Hence, these quantities should, in principle, not be subject to the domestic $CO_2$ restriction and they must therefore be exempted once they have crossed the border. This is easily achieved in the case of fuel exports by firms at the first commercial level since the calculation of their coupon payment due is based on their domestic sales. But a different solution must be found for fuel exports by retailers.

A solution for these problems cannot be found by exempting the fossil fuel quantities concerned from the coupon liability already at the first commercial level, since there a differentiation of fuel quantities with respect to their final use is impracticable, if not impossible. All three problems can, however, be solved at the level of fuel consumption. A mechanism which supplements the coupon system must compensate those who have to bear costs for $CO_2$ emissions that they have not caused (see Table 7). This mechanism must neutralize the associated loss of $CO_2$ coupons to the economy.

$CO_2$ coupons can be interpreted as a kind of money. Hence, they can be used for compensatory payments. Those firms or individuals that have finally paid for $CO_2$ quantities that

**Table 7**

**Advantages of a compensation mechanism**

| | Coupon system | |
|---|---|---|
| | without compensation mechanism | with compensation mechanism |
| Incentive to develop end-of-pipe technologies | absent | present |
| Exemption of non-energetic uses of fossil fuel | not possible | possible |
| Exemption of fuel exports at the intermediate or retail level | not possible | possible |

have not been emitted are entitled to receive an equivalent amount of $CO_2$ coupons. They are free to use these coupons as they wish. They may, for instance, use them to pay their fuel supplier or exchange them for cash on the coupon market, and thus they are remunerated for their investments in end-of-pipe technology. At the same time these newly issued compensatory $CO_2$ coupons bring the total $CO_2$ emissions allowed and the number of coupons in circulation back into balance.

It is a precondition for the functioning of this compensation procedure that the quantity of $CO_2$ or of fossil carbon that has not been released to the atmosphere inside the country can be determined. This is easily achieved in the case of fuel exports since export data are either already available or are easy to collect at the border. The exporting firm will be granted $CO_2$ coupons for free equivalent to the quantity of fossil carbon that it has exported.

In the case of non-energetic usage of fossil fuel, the firms concerned must determine and declare the quantity of fossil carbon that has been bound in solid products and is sealed off from the atmosphere. After checking their declaration, if necessary on the spot, the firms concerned receive the number of $CO_2$ coupons to which they are entitled.

The availability of end-of-pipe technologies will probably not become relevant for some time. But when it does, the measurement of the $CO_2$ quantity held back should be easy to achieve, since this $CO_2$ must exist in some storable and disposable, possibly solid, form. As an innovation incentive, all large $CO_2$ sources should be entitled to compensatory $CO_2$ coupons as soon as the system is implemented. In the case of small sources, private firms may act as an intermediary between source operators and the coupon authority and thus reduce transaction costs. They would measure (maybe also collect and dispose of) the $CO_2$ held back and deal with the coupon authority on behalf of their clients.[1]

## 3.7. Institutional requirements

The particular design of the above described tradable permit system allows for a relatively simple institutional and administrative setting. This does not, of course, imply that institutional and administrative aspects are of minor importance. First, a correctly functioning $CO_2$ coupon system requires reliable political decisions. Second, enforcement must be ensured by a public institution, the coupon authority. Third, coupon trading must be organized, preferably by a coupon exchange. These three institutional aspects will briefly be discussed in what follows.

### 3.7.1. The political level

The coupon market can only function properly and cushion the insecurities that prevail in the energy markets and with respect to unknown $CO_2$ reduction potentials if the respective political terms of reference are sufficiently certain. This means that political plans and decisions concerning the reduction target and the proposed reduction path must be known in public for a sufficiently long time in advance. Any political revisions of the $CO_2$ targets once they have been fixed must be made as unlikely as possible. The allowable $CO_2$ emission quantities must not be a political variable with which other (economic) factors are influenced in order to reach other political goals (e.g. growth rate, unemployment, etc.).

Therefore, national $CO_2$ reduction targets that are to be achieved by means of a national $CO_2$ coupon system should not only be decided upon by the government but should formally be laid down in $CO_2$ legislation, binding not only the present but also future governments. The public administration's, and particularly the coupon authority's, competence and responsibilities should be fixed clearly in formal legislation, especially with respect to their ability to influence the coupon market, as described above.

This idea of a fixed and reliable $CO_2$ coupon supply policy slightly changes if international trade in $CO_2$ quotas is an element of the system.[2] In this case, the import (or export)

1 A model for this arrangement could be the measuring of individual heating consumption in private homes and flats by specialized firms in the Federal Republic of Germany.

2 International trade in $CO_2$ emissions is, of course, indispensable if a quota system is to be efficient. The possibilities and problems of international $CO_2$ trade are discussed in sections 4 and 6.

of $CO_2$ quotas may lead to a domestic supply in $CO_2$ coupons that deviates from the previously announced supply paths. This, however, need not obstruct markets if $CO_2$ trade takes place only between those countries in which similarly strict requirements for the reliability of $CO_2$ policies (possibly on the basis of an international $CO_2$ agreement) hold.

### 3.7.2. The coupon authority

The $CO_2$ coupon system requires the creation of a new bureaucracy: the coupon authority. It has two main tasks. First, it must create and market $CO_2$ coupons as well as survey and, if necessary, influence the coupon market. Second, it must check upon individual $CO_2$ (or carbon) quantities for which firms are responsible, keep individual $CO_2$ accounts, settle these accounts and pay compensation with $CO_2$ coupons where required.

The second task is of a technical nature and does not need much examination and explanation here. But it should be mentioned that placing the coupon liability on importers and producers of fossil fuel allows it to take recourse to existing institutions like customs and tax authorities and readily available statistical and business data. Hence, the data requirements for enforcing the coupon system can easily be fulfilled.

The first task is more delicate, since the behaviour of the coupon authority can directly influence the coupon market. For this reason, the coupon authority's decisions should be insulated against political influence. This is particularly important for decisions on coupon marketing strategies and on the employment of fine tuning instruments.

### 3.7.3. The $CO_2$ coupon market

A number of standard procedures which are used in financial and equity markets can be employed for placing $CO_2$ coupons on the market. Among these, sale by tender seems to be particularly suited, since the number of $CO_2$ coupons that are to be auctioned is fixed, but not their price. A sale by tender should take place regularly (e.g. once every week). All interested individuals and firms are requested to submit tenders to the coupon authority or to a private institution that takes over this task. Such tenders consist of a request for a number of $CO_2$ coupons and a proposed price, which reflects the willingness to pay for the requested coupons. On the basis of all tenders submitted an equilibrium price which clears the market will be established. The requested amount of $CO_2$ coupons will then be sold to those who had offered to pay at least the established equilibrium price for this quantity.

The trade in $CO_2$ coupons between private owners, in principle, need not be governed by State authority, since $CO_2$ coupons can be regarded as an ordinary commodity. Establishing a coupon exchange would, however, be an advantage for trade in $CO_2$ coupons, since this reduces transaction and information costs considerably. $CO_2$ coupons can and should in the beginning be traded at a single exchange. There are several methods of organized trade. In the beginning, it seems advisable to determine regularly (e.g. once a day) a spot price on the basis of limited orders for $CO_2$ coupons. Such daily fixings should then be published together with other data that describe the $CO_2$ market.

It should be mentioned that neither the creation of $CO_2$ coupons nor trade in such coupons require that such coupons be actually printed out on paper. Electronic $CO_2$ coupons which may be deposited on accounts at the coupon authority itself or at a private institution will serve the same purpose and make coupon transactions less expensive.

It is likely that, on the basis of regular $CO_2$ coupons, a private market in options and futures on $CO_2$ coupons develops.[1] Such derivative products help to reflect market expectations and reduce uncertainty. A certain standardization of these products by the relevant stock exchange seems to be advisable in order to limit market segmentations.

## 3.8. Extending the coupon system to other greenhouse gases

The system presented so far covers only emissions of $CO_2$. However, there exist several other man-made pollutants which also contribute significantly to global warming. Hence, there is no reason to believe that a tradable permit system that aims exclusively at the reduction of $CO_2$ represents the most efficient way to sustain the desired climatic conditions. Such a one-dimensional policy with respect to $CO_2$ can only be efficient if abatement costs for other greenhouse gases are sufficiently high — a condition that cannot be expected to be fulfilled in general.

Moreover, a financial burden levied solely on $CO_2$ may lead to substitution effects that are highly problematic from an ecological point of view. If, for example, waste incineration becomes more expensive due to a $CO_2$ coupon system, there will be a substitution effect in favour of direct waste deposition. However, landfills represent a major source of meth-

1 Futures and options for $CO_2$ coupons would probably only cover shorter time periods. Therefore, they are not in direct competition with the dated $CO_2$ coupons (introduced above in section 3.2) that are issued by the coupon authority.

ane emissions, which substantially contribute to the greenhouse effect. This example shows that a policy directed solely at $CO_2$ may lead to a substitution of pollutants that may even speed up global warming.

From this it seems desirable to extend the system to other greenhouse gases. The basic idea of this extension is to redefine the emission coupons discussed above in terms of $CO_2$ equivalents; i.e. they permit the emission of the stated quantity of $CO_2$ or of a quantity of another trace gas that is equivalent in terms of its greenhouse effect. However, as will be seen, such an extension leads to a number of problems. These can only be touched upon in this paper.

Besides $CO_2$, the main greenhouse gases are methane ($CH_4$), nitrous oxide ($N_2O$), tropospheric ozone ($O_3$) and the chlorofluorocarbons $CFC_{11}$ and $CFC_{12}$. However, not all of these gases are suitable for inclusion in a tradable permit system.

First of all, there seems to be no straightforward way to include tropospheric ozone. This greenhouse gas is not directly emitted from anthropogenic sources, but is created by highly complex and non-linear photochemical reactions in the atmosphere that involve nitrogen oxides ($NO_2$) and several other trace gases. Therefore, an unambiguous assignment of tropospheric ozone to an individual polluter is not possible and hence nobody can be made subject to provide permits.

The case of chlorofluorocarbons (CFCs) has to be judged differently. Here it seems to be possible, at least in principle, to identify the responsible polluters, or at least the suppliers of CFCs. Nevertheless, CFCs are not candidates for inclusion in a permit system either. According to international agreements, there will be a medium-term phasing out of CFCs anyway. Therefore, it does not seem worthwhile to include these greenhouse gases in a permit system.

As a consequence, only methane ($CH_4$) and nitrous oxide ($N_2O$) remain potential candidates for an extension of the $CO_2$ coupon system. For these two trace gases it seems (at least in principle) to be possible and worthwhile to identify the responsible polluters and to include them in the group 'liable agents'.[1] In such an extended system, the specific global-warming potential of methane and nitrous oxide (which is defined as the warming effect of an emission of one tonne of these gases relative to that of $CO_2$) may serve as a kind of 'exchange rate' between the pollutants. According to estimates based on a time-horizon of 100 years[2] and published by the Intergovernmental Panel on Climate Change (IPCC), the global-warming potential of one tonne of methane amounts to 63 tonnes of $CO_2$, whereas the figure for nitrous oxide is 290 tonnes of $CO_2$ (IPCC 1990). Therefore, emission coupons may be defined that permit the emission of one tonne of $CO_2$ or 1/63 tonnes of methane or 1/290 tonnes of nitrous oxide.

This approach would enable the market mechanism to identify the most efficient way to reduce the emissions of green-

1 At present, $CH_4$ and $N_2O$ contribute approximately 20 % to the greenhouse effect, and this share will increase considerably after the phasing out of CFCs. Main sources of $CH_4$ and $N_2O$ are energy use, agricultural activities (use of fertilizers, cattle) and waste deposition.

2 The global-warming potentials mentioned above are calculated in such a way that they already include the different atmospheric lifetime of $CO_2$, $CH_4$ and $N_2O$. Therefore, the resulting figures are dependent on the time horizon used in the calculation.

**Table 8**

**Coverage of other greenhouse gases on the basis of $CO_2$ equivalents**

| | Methane ($CH_4$) | Nitrous oxide ($N_2O$) | CFCs ($CFC_{11}$, $CFC_{12}$) | Ozone ($O_3$) |
|---|---|---|---|---|
| Sources | Bovid lifestock<br>Fossil gas leakage<br>Anaerobic decay of organic waste | Nitrogen fertilizers | Aerosols<br>Coolants<br>Cleansing in electronics | $NO_x$ and others |
| Problems | Assessment base<br>Costs of covering all sources<br>Greenhouse gas substitution<br>Institutional design | | To be phased out shortly | Assignment of ozone to individual polluters impossible |

house gases to a predetermined level in terms of $CO_2$ equivalents.[1]

However, many unsolved problems remain. They include, for example, the definition of the assessment base, the choice of the licensee base and the general institutional setting. A summary of the scope of extending the coupon system to other greenhouse gases is given in Table 8.

## 3.9. Possible effects of the $CO_2$ coupon system

The basic $CO_2$ coupon system as described above has several effects, which shall be summarized here. First of all, a $CO_2$ coupon system ensures that the political $CO_2$ target will be reached. Furthermore, it will be reached efficiently, i.e. at the lowest possible costs to the economy as a whole. The administrative requirements and transaction costs are much reduced.

However, the price for $CO_2$ coupons is and remains unknown in principle, although the market will generate information. This fact makes it almost impossible to assess the economic consequences of political $CO_2$ reduction targets *ex ante*. This, in turn, implies a certain degree of economic uncertainty which may be politically unacceptable. It should, however, be taken into account that, in the long run, the economy may be more easily adaptable than the environment. If this is so, the application of a $CO_2$ coupon system is rational. It features enough flexibility in the short and medium term, allowing the economy to adapt itself to the ecological necessities, and at the same time the system can accommodate sustainable development in future generations. Of course, in a situation which is characterized by a trade-off between economic and ecological uncertainty, it is the task of the policy-maker to decide which kind of uncertainty is most easily borne, and to choose the policy instrument accordingly.

Several studies have recently been undertaken which estimate the possible costs of $CO_2$ reductions and related permit prices or tax rates.[2]

These studies apply widely differing modelling concepts and baseline scenarios, and their results differ accordingly. A survey of the literature, which shall not be repeated here, has recently been presented by Hoeller, Dean and Nicolaisen, 1990.

**Table 9**

**Percentage increase in output prices of German production sectors, 1988, on the basis of a coupon price of DM 10 and DM 50 per tonne of $CO_2$**

| | DM 10/t $CO_2$ | DM 50/t $CO_2$ |
|---|---|---|
| Coal mining and manufacturing of coal products | 18,2 | 91,1 |
| Crude petroleum and natural gas production | 16,0 | 80,0 |
| Refining and distribution of gas | 7,4 | 37,1 |
| Petroleum products | 4,0 | 20,1 |
| Production and distribution of electricity, steam and hot water | 3,2 | 15,9 |
| Iron and steel products | 2,3 | 11,6 |
| Structural metal products | 0,6 | 3,2 |
| Railroad services | 0,6 | 3,1 |
| Production and distribution of water | 0,6 | 3,1 |
| Mining of non-metallic minerals, manufacturing of construction materials | 0,6 | 2,9 |
| Casting products | 0,5 | 2,7 |
| Pulp, paper and paper board | 0,5 | 2,3 |
| Others | < 0,5 | < 2,3 |

*Source:* Heister and Michaelis et al. (1991), p. 130.

As can be shown by a simple input-output analysis, even a high $CO_2$ tax (or permit price) does not significantly affect the many sectors of the economy which are not particularly energy intensive. Table 9 gives an example applying 1988 data of the German economy.

A study on the impact of a climate convention of the Norwegian economy by Brendemoen and Vennemo, 1991, shows that possible distribution effects of a $CO_2$ tax between households remain very limited. In any case, distributing $CO_2$ coupons by auction and entering the revenue into the general budget allows tax breaks to be introduced elsewhere. Such tax breaks should, however, not be granted on the basis of individual burdens imposed by the permit scheme, because this would again destroy the efficiency property of the coupon scheme.

1 Note that another way to ensure efficiency in the case of multiple greenhouse gases may be the implementation of an efficient charge system. For a formal and empirical treatment of this topic see Michaelis, 1992.

2 See, for instance, Manne and Richels, 1990, Whalley and Wigle, 1989. Permit prices and tax rates represent the marginal reduction costs, and they must be the same if they are to produce the same $CO_2$ reductions.

# 4. An analysis of the main options for using tradable $CO_2$ quotas/permits in the Community context

## 4.1. Decentralized instrument choice

In view of the theory of institutional competition and considering the principle of secondary liability, it would be of advantage if the decision on what kind of environmental policy instruments should be applied (command and control, charges, tradable permits) could be made at the level of individual countries and thus could be decentralized.

However, the decentralized application of policy instruments will be a serious problem in the future EC internal market. Goods, including fossil fuel, and services coming from all countries of the Community may be imported and sold in any other EC country without any restrictions. Thus the country-of-origin principle is in force. This will be so even with respect to product-related charges and directives and other environmental regulations. But this freedom of markets throughout the Community imposes restrictions on the decentralized choice of policy instruments. For the case of the $CO_2$ coupon system, it will be shown below that under conditions of the internal market, a carbon dioxide policy with different instruments applied in different countries of the European Community is not sustainable (see Table 10).[1]

Assume that one Member State implements the $CO_2$ coupon system as described above whereas another EC partner intends to fulfil his abatement obligations by employing adequate command and control regulations only (e.g. minimum effectiveness standards for power stations, etc.) In this situation, market prices for crude fossil energy (including coupon costs) would be higher in the coupon country than in the 'command-and-control country', since the costs of command-and-control measures would only affect the conversion and use of fossil energy but not the price of imported or domestically produced unrefined energy products. After the lift-off of the EC's internal market, arbitrage would commence, i.e. retailers in the 'coupon country' would buy their supplies in the command-and-control country thus evading the coupon liability and all related costs (except transportation costs). Such arbitrage would continue until the price for $CO_2$ coupons would be equal to the additional per unit transportation costs of purchasing fossil-fuel carbon in the command-and-control country. The coupon system would be undermined by the command and control system.

[1] For reasons of simplicity, the analysis is restricted to the two country case, but results hold in the multicountry Community setting.

The coupon policy would become ineffective and the emission target in the coupon country could not be met. Furthermore, EC-wide fossil-fuel transportation costs would be excessive.

**Table 10**

**Effects of foreign $CO_2$ policies on the domestic coupon instrument in the EC single market, if trade in $CO_2$ emissions between Member States is not provided for**

| Foreign $CO_2$ policy | Domestic coupon instrument |
|---|---|
| Command-and-control measures | Ineffective |
| $CO_2$ charge on measured emissions | Ineffective |
| Fossil fuel tax | Tax rate determines coupon price, $CO_2$ target missed |
| Coupon system | Inefficient fossil energy markets in the EC |

Basically the same market arbitrage would occur if one country decided on a $CO_2$ charge on individually measured real emissions or a $CO_2$ tax on fossil fuels. This charge or tax would initially most likely differ from the price for $CO_2$ coupons. In the case of a charge on directly measured emissions, the above analysis holds. In the tax case, the price for $CO_2$ coupons would adjust to the fixed tax rate by the transfrontier arbitrage process as described above. The coupon system would thus degenerate to a tax solution, where the coupon price would *de facto* be determined by the 'tax country's' tax rate. The single price for $CO_2$ emissions that would develop in the two countries would be economically efficient as all polluters would be charged the same price for $CO_2$ emissions. However, the quantity target in the coupon country would be missed. Furthermore, transportation costs would be excessive.

## 4.2. Tradable $CO_2$ quotas/coupons for each Member State

Consequently the coupon policy would only make sense under conditions of the single European market if the remaining EC partner countries were also to adopt a similar coupon strategy on the basis of fossil fuel sales. If this were the case, further problems would arise.

At first glance, it does not appear to be necessary that national $CO_2$ coupons or national $CO_2$ quotas be mutually tradable in the whole Community in order to exploit the cross-country substitution potential necessary to minimize overall abatement costs: the prices for national $CO_2$ coupons would adjust to each other throughout the Community through trade in fossil fuel. This would, in the first place, imply additional and unnecessary transaction and transportation costs. Additionally, the problem arises that some EC partners themselves are large producers of oil, coal and gas and sell these to other EC countries. These quantities would, according to the country-of-origin principle, be subject to the coupon system of the extracting country, although they cause emissions of $CO_2$ in the recipient country. Fixed national $CO_2$ limits on the basis of the fossil carbon quantity that is imported from outside the Community or extracted by the country in question would thus impede the export opportunities of the fuel producing countries concerned. And this would result in inefficient fossil energy markets in the European Community (Table 10).[1]

This problem can be countered in two ways. First, by making national $CO_2$ quotas tradable between the Member States, i.e. between the respective $CO_2$ authorities. Second, by extending the validity of national $CO_2$ coupons to the entire Community so that coupons, and implicitly national quotas, can be traded Community-wide on a private basis and be used to settle $CO_2$ accounts with all national coupon authorities. Unfortunately, both alternatives have serious disadvantages in the single market, as will be shown below.

### 4.2.1. Quota trading between Member States

Trading of $CO_2$ quotas between Member States of the Community requires that each Member State possess a share of overall Community-wide allowed $CO_2$ emissions. Each Member State may then sell part of its $CO_2$ stock to other Member States or buy $CO_2$ emission shares accordingly. Similarly to the case of tradable permits, $CO_2$ quotas must be clearly defined so that compliance can be guaranteed. National $CO_2$ emissions seem not to be an appropriate basis for tradable quotas in the Community for two reasons. First, it will be impossible to determine total national $CO_2$ emissions by directly measuring them at the emission source. Second, it will be difficult and costly to calculate total domestic $CO_2$ emissions on the basis of total fossil fuel use inside an EC member country, since the country-of-origin principle allows the free flow of goods and traffic, and consequently border controls between Member States will be abolished. Reporting procedures and controls inside each country may replace border controls to some extent. However, fuel imports by private individuals (car traffic) can hardly be measured and, in the case of different domestic fiscal levies on fuel (excise taxes), there is an incentive not to report cross-border fuel trades to the authorities. Hence, it is questionable whether sufficiently accurate data can be generated in order to determine domestic $CO_2$ emissions. Instead, it is suggested to define tradable $CO_2$ quotas in terms of domestic fossil fuel production or import from outside the Community, no matter where in the Community these fuel quantities will finally be consumed and their carbon content emitted.

Furthermore, such national $CO_2$ quotas would have to be fixed and agreed upon by all Member States with respect to national carbon quantities and with respect to time (e.g. x million tonnes of carbon per year). This means that national authorities will have no competence any more to decide independently over national $CO_2$ quantities and their intertemporal allocation.

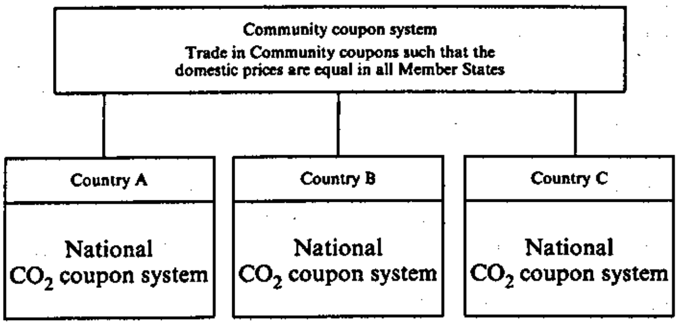
In general, the design of a system of quota trading between EC Member States has to solve the same fundamental problems that were encountered when designing the tradable permit system for $CO_2$ at the national level. Hence, it is not surprising that the most flexible system of organized quota trading between Member States is a $CO_2$ coupon system at the Community level. It would encompass the European Community as the supplier of Community $CO_2$ coupons and the Member States who would have to assume the Community coupon liability for fossil carbon imported or extracted in the area of their respective authority. Only in this case can the positive features that the coupon system offers with respect to emission trading and intertemporal flexibility be made available for $CO_2$ quota trading between EC Member States. In fact, for each country, the possible intertemporal flexibility would be similar to the flexibility described above for individuals and firms in the case of a purely national $CO_2$ coupon system. For this reason, it would also be easier to agree on mutually reducing national $CO_2$ quotas: the resulting reduction path would be allowed to deviate from presupposed reductions.

Quota trading between Member States would lead to a two-stage $CO_2$ coupon system (Table 11). In the first stage, Member States would engage in trading Community $CO_2$ coupons and settle their $CO_2$ accounts with the Community coupon authority. In the second stage, national coupon authorities would create national $CO_2$ coupons, which would only be valid inside the country. The possible number of such national coupons is restricted by the ability of the country in question to settle its national $CO_2$ account with the Community coupon authority by paying the Community either with originally received or with traded Community coupons.

[1] It would, of course, be possible to channel fuel exports through non-member countries, thus making use of the compensation procedure described above. This would, however, imply unnecessary transportation and transaction costs.

## Table 11

**Two-stage coupon system in the EC**




If such a system is to be efficient, it would be the task of the national $CO_2$ authorities to trade Community $CO_2$ coupons among themselves and continuously adjust the national coupon supply in such a way that the domestic coupon prices on all national $CO_2$ coupon markets become and remain equal throughout the Community. If national authorities do not achieve such an equalization of national coupon prices, incentives for cross-border arbitrage trades in fossil fuel remain present. This is obviously a very demanding task, since authorities will have to react quickly to market developments in order to wipe out the arbitrage margin, thus minimizing costly arbitrage trades and energy market inefficiencies that would otherwise occur. Generally, national coupon authorities would have to act faster than the markets in order to balance external influences on the national coupon price, including influences from shifts in currency exchange rates.

Furthermore, adjusting the national $CO_2$ coupon supply in order to guarantee a common price level would require the existence of a reference price. This reference price would most likely be the coupon price on one of the national coupon markets. To this extent, the problem is equivalent to the fixing of currency exchange rates in the European Monetary System, in which a single currency serves as a point of reference. The complication arises, however, that this reference price depends on the availability of Community $CO_2$ coupons, which in turn is influenced by all national coupon markets. It is obvious that these interdependencies are very difficult to handle by political and bureaucratic procedures unless one single country sets the guidelines and all other EC partners follow suit.

Another problem arises with respect to trading in Community coupons between the 12 Community Member States, of which only four (France, Germany, Italy, and the UK) are responsible for over three-quarters of all $CO_2$ emissions in the Community. In this situation trading will most certainly not be free of political and strategic considerations and a functioning competitive market for Community $CO_2$ coupons is unlikely to develop. Hence, it is also unlikely that the market price reflects the true shadow price for Community $CO_2$ coupons. It will, therefore, most likely be inefficient.

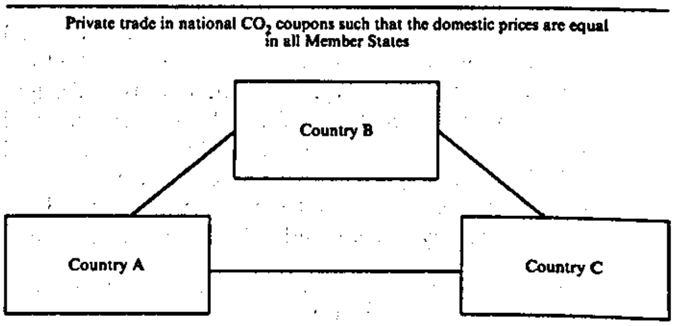
One is therefore bound to conclude from the above discussion that a two-stage $CO_2$ coupon system, in which the EC Member States trade Community coupons on the first level whereas individuals trade national $CO_2$ coupons on a second level, is hardly practicable under the conditions of the future single market. Therefore, it seems necessary to consider a one-stage system. Such a system is conceivable in two versions: as a system in which national $CO_2$-coupons are valid throughout the Community, or as a single, genuine Community-wide $CO_2$ coupon scheme under European Community legislation.

### 4.2.2. Community-wide validity of national $CO_2$ coupons

The idea behind a system of national $CO_2$ coupons that are valid throughout the Community is rather simple. Each Member State introduces its own $CO_2$ coupon system and issues national $CO_2$ coupons, but these national coupons must be accepted by all national coupon authorities for the settling of $CO_2$ accounts. As a consequence, anyone may procure $CO_2$ coupons anywhere in the Community and use them for $CO_2$ payments due at home. The explicit trading of $CO_2$ quotas between Member States would in this case not be necessary. The prices for national $CO_2$ coupons would converge through cross-border private trade in coupons. A Community-wide $CO_2$ coupon market would *de facto* result (Table 12).

## Table 12

**Multilateral one-stage coupon system in the EC**



Under this system, Member States and national coupon authorities would, in principle, have some freedom of choice with respect to their national $CO_2$ coupon policies. They need not equalize diverging national $CO_2$ coupon prices by market interventions. This task is taken up here by the private sector, and the market outcome will always be efficient whatever a national coupon authority does. But the Community-wide validity and private trade in national $CO_2$ coupons also means that a country cannot pursue its own $CO_2$ coupon policy without affecting all other national coupon markets. Hence much of the effectiveness of a country's own policy options is lost. Consequently, purely national $CO_2$ policies cannot exist.[1] In order to avoid possible negative impacts by independent national coupon policies on Member States and the whole Community, a system of national $CO_2$ coupons that are valid throughout the Community would indeed require a close harmonization of national $CO_2$ coupon policies. This would at least comprise binding rules for the supply of national markets with national $CO_2$ coupons and for interventions in $CO_2$ coupon markets by the coupon authority.

But if such a close harmonization of $CO_2$ policies is indispensable, a substantial difference between the decentralized $CO_2$ coupon system discussed above and a centrally organized Community coupon system would hardly exist.

**Table 13**

**Advantages/disadvantages of different coupon systems for $CO_2$ trading between EC Member States**

| | |
|---|---|
| Trading in Community coupons (two-stage coupon system) | Trade between national bureaucracies not fast and flexible enough<br>One national coupon price not practicable as reference price<br>Strategic trading possible |
| Trading in national $CO_2$ coupons (multilateral one-stage coupon system) | Interdependence of national $CO_2$ policies<br>Close harmonization of national $CO_2$ policies necessary<br>Not practical |
| A single EC-wide $CO_2$ coupon system (unilateral one-stage coupon system) | Mainly identical with a national $CO_2$ coupon system<br>Feasible |

[1] Note that an adjustable exchange rate between national $CO_2$ coupons does not exist if each $CO_2$ coupon is to represent a given amount of $CO_2$. The situation is similar to that of a monetary system, in which national currencies are permanently linked to each other by fixed exchange rates, but national central banks may act independently.

Hence, it appears reasonable to explore the possibility of a single $CO_2$ coupon system for the European Community, which would function on the basis of a single $CO_2$ emission quantity for the whole Community. Table 13 summarizes these three options.

## 4.3. A single Community-wide $CO_2$ coupon scheme

In the case of a single Community-wide $CO_2$ coupon system, the entire European Community would be treated as one single country. Hence, such a European system would essentially be identical to the one described above for an individual country. A political decision on the proposed $CO_2$ reduction would have to be found at the European level. This reduction would then be implemented by a European coupon authority in the way described in section 3. Some adaptations would, nevertheless, be necessary.

### 4.3.1. The institutional setting

In view of the federalist structure of the Community, a reallocation of responsibilities between the European coupon authority and corresponding national authorities seems to be advisable. According to the rules of the European Community, the $CO_2$ policy in a single EC coupon system would have to be decided upon by the European Council of Environment Ministers.[2] The Council would have to fix a proposed reduction path several years in advance, and it would have to create a European coupon authority. This authority could, in the beginning, be established within the planned European Environment Agency.

The European coupon authority would create the required quantity of European $CO_2$ coupons. The European coupon authority itself could then sell these coupons by auction to the general public or assign them to the respective national coupon authorities on the basis of a distribution key, which would have to be established (see section 4.3.2 below). In a federalist Europe, the second alternative is probably preferable. It would require that the marketing of the European $CO_2$ coupons be left to the national coupon authorities. They would, of course, have to act in cooperation and accordance with the rules of the European coupon authority. This second approach would ensure that the revenues resulting from coupon sales would remain under national control. However, the coupon policy would be controlled at the Community level.

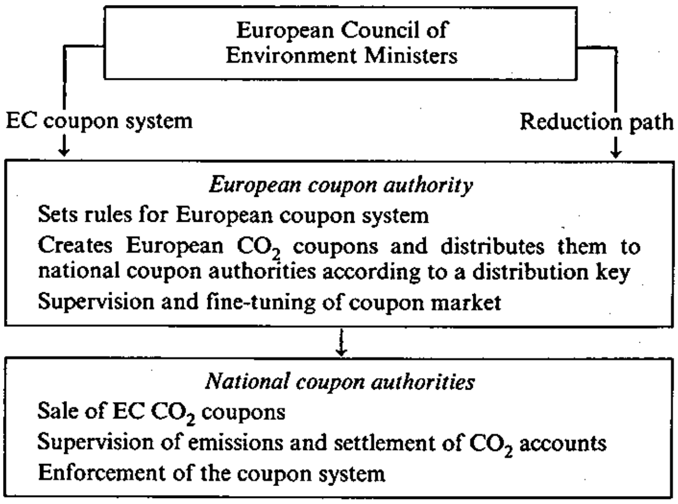
[2] In line with the argument put forward in section 3.7.1, it would be desirable to have some formal $CO_2$ legislation by the European Parliament as soon as this becomes feasible.

The supervision and settlement of emission accounts would quite naturally have to remain the responsibility of the national coupon authorities. Not only would they be better able to establish and maintain close contacts with the firms concerned, but the enforcement of the system would also have to rely on national sovereign powers.

Trade in EC $CO_2$ coupons would take place in a single European coupon market, which would develop automatically. In the beginning it could be sufficient to use only one European exchange for quoting European $CO_2$ coupons. It would have to be adequately equipped in order to deal with orders coming from all EC countries. The location of the coupon exchange is then a question of minor importance. In the long run, it can be left to the markets to decide whether the listing of EC $CO_2$ coupons on other (national) exchanges would be advantageous. Table 14 summarizes the institutional set-up of an EC-wide $CO_2$ coupon system.

**Table 14**

**Institutional set-up of the EC-wide $CO_2$ coupon system**




### 4.3.2. The distribution of $CO_2$ coupons to Member States

Allocating EC coupons to the national coupon authorities requires an agreement on a distribution key. Such a distribution key would have the same function as an agreement on $CO_2$ quotas or an agreement on the distribution of revenues from coupon sales by the European coupon authority itself. The design of the distribution key is not a question of efficiency. Rather, it is equity and distributional considerations that matter. The distribution key can thus incorporate the role of side payments to some EC Member States. This may be politically unavoidable in order to ensure cooperation.

In principle, a distribution key can be based on several factors (see Grubb, 1989). For instance, current $CO_2$ emissions, GNP, land area, population, costs of reducing $CO_2$ emissions, availability of alternative energy sources (hydropower etc.) and climate conditions could be taken into account.[1]

## 5. Applying the tradable quota philosophy to energy in general

Since $CO_2$ emissions are strongly related to energy generation and consumption, a general energy tax (on top of existing excise taxes) is currently being discussed as an alternative to $CO_2$ levies. This would induce reductions in energy consumption and hence in $CO_2$ emissions. The following arguments are put forward in favour of such an approach (see Table 15).

The use of energy has a much broader environmental impact than the $CO_2$ problem alone. These effects should be taken into account. Substitutions away from $CO_2$-intensive forms of energy may, for instance, favour other forms of energy generation, particularly nuclear energy, which may incur additional environmental damage and risks. In the case of nuclear energy, the related risk structure is to a large extent not reflected in its production price, and a pure $CO_2$ tax, based on $CO_2$ content, would worsen this negative externality, since it would leave nuclear energy unaffected.

It is claimed that the supply security of natural gas, which is likely to be a winner in the case of a pure $CO_2$ tax, is lower than that of other sources of energy, particularly domestic coal, since increasing quantities of natural gas would have to be imported from non-EC countries (USSR, Algeria, Norway). Incentives for energy substitution should therefore not increase the share of natural gas to such an extent that it would render energy supply undesirably insecure from a political point of view. In general, differences in supply security should be accounted for and the necessary

[1] For a discussion of these criteria see Grubb, 1989.

policy adjustments should be made, when reducing $CO_2$ emissions. Taxing energy in general is allegedly one possible solution.

A pure $CO_2$ levy would have distributional consequences. For instance, for countries with a relatively high share of $CO_2$-free nuclear energy, reductions in $CO_2$ emissions would be particularly inexpensive. On the contrary such reductions would be particularly expensive for those EC Member States which do not possess, or possess only to a very limited extent, nuclear energy. It is claimed that a general energy tax would impose more equitable reductions for all countries.

In the context of the present study, the question arises of whether adjustments that are claimed to be necessary with respect to the abovementioned arguments can be made by applying the tradable permit philosophy to energy in general. Taking the abovementioned arguments as given, the following paragraphs will mainly focus on technical aspects of the proposition. However, the proposition will be analysed for internal consistency.

## 5.1. Basic considerations

The concept on which tradable permit schemes are based is to ration the use of the environment quantitatively by rationing the output of the pollutant in question. Although this concept is not a formal condition for the functioning of a tradable permit scheme, it should be shown that rationing is, at least, a reasonable approach with respect to the objectives in question. This proof cannot be furnished for energy in general as the policy object. There is no obvious reason why the consumption of energy as such should be rationed. The use of energy as such is not environmentally harmful and, depending on technology and the energy mix, different levels of pollution may relate to the same level of energy consumption and vice versa. Hence, regarding the basic concept of tradable permits, energy in general appears to be the wrong target for the application of a tradable permit scheme. Put differently, the rationing of energy consumption and hence a tradable permit scheme for energy is the wrong instrument for tackling the abovementioned issues, namely the complexity of environmental problems, supply security and equity.

Technically, the coupon system described above can easily be applied to energy in general, since this would only require a redefinition of the assessment base: the coupons (energy coupons) would only have to be defined in terms of fuel energy content, for instance in the physical measure of joule, which can be applied to any kind of energy source. Issuing a fixed number of energy coupons would thus imply that only the admissible amount of joules may be consumed in any given period of time. The energy coupon liability would equally fall on producers and importers of fossil fuel and, in addition, on nuclear energy plants.[1] All other aspects of the $CO_2$ coupon system can easily be translated into a system of energy coupons including those that relate to the question of a decentralized or a single coupon system in the Community.

## 5.2. An inappropriate instrument

The effects of an energy coupon system would differ greatly from a pure system of $CO_2$ coupons. First of all, a uniform coverage of all forms of energy irrespective of their carbon content, would wipe out the substitution effects that would otherwise contribute to total $CO_2$ reductions. Thus, a given

[1] Sources of renewable energy (hydropower, solar and bioenergy, etc.) may be included, but with increasing administrative costs, since these sources are typically small. They are not included in EC plans for an energy tax.

**Table 15**

**Alleged advantages of a levy on energy in general compared with a levy on $CO_2$**

| | Energy levy | $CO_2$ levy |
|---|---|---|
| Complexity of environmental problem | Taken into account | Concentration on $CO_2$ problem |
| Energy supply security | Higher | Lower due to unfavourable energy substitution |
| Equity considerations | Easier to meet due to national differences in fuel use | Harder to meet due to national differences in fuel use |

$CO_2$ objective can only be attained at higher costs. Additional costs arise because of the two available buffers, energy conservation and energy substitution, the policy takes the luxury of relying exclusively on one. Lacking any incentive for energy substitution, cuts in energy use need to be excessively high, and this implies that the $CO_2$ reductions are achieved at relatively higher costs. These additional costs are probably modest in the short run, since energy saving can be realized faster than energy substitution. In the long run, however, energy substitution can become a powerful option for cost savings, which will be exploited by the private sector if price incentives are properly set.

The costs of a system of energy coupons compared to $CO_2$ coupons will be even higher if one considers that end-of-pipe technologies, which eliminate $CO_2$ from exhausts, may become technically feasible. Energy coupons carry no incentive whatsoever to develop and install such equipment. Therefore, possible cost savings that could be harvested from advances in abatement technology will be foregone or too small if energy coupons are applied.

Hence, measured against a pure $CO_2$ levy, the loss of efficiency induced by an energy coupon system and the related increase in costs in the long run can be expected to become enormous eventually, since public and private investment in energy equipment as well as in research and development will be misled such that the 'wrong' energy supply and demand structure and the 'wrong' technical outfit is perpetuated or will emerge.

Obviously, the absolute level of these additional costs also depends on political decisions concerning the protection or promotion of certain sources of energy (e.g. hard coal, nuclear energy). If the additional costs of an energy coupon system are measured against a $CO_2$ coupon system that is accompanied by subsidies or other political arrangements in favour of certain sources of energy such that the $CO_2$ coupon system cannot fully bring to bear its substitution potential, then the measured additional costs will, of course, be lower. In this case, a proportion of the inefficiency must be attributed to certain political preferences, but it does not disappear. If a dual system of $CO_2$ coupons and energy coupons is applied, the real loss in substitution effects may be reduced. However, it will persist in general.

Furthermore, existing excise taxes on energy must be taken into account. These differ between different kinds of fuel and between member countries. Hence the total effect of a uniform energy levy with respect to $CO_2$ reductions becomes increasingly unclear. This is so, in particular, because member countries may be bound to accept the uniform energy levy (a coupon price or an EC energy tax) but remain free to change all the other national taxes and levies on energy as they think fit. Effective levies on energy are therefore likely to differ across countries despite a uniform price for energy coupons (or a uniform EC tax on energy).

A system of energy coupons (or of an energy tax) would probably have no effect, or very limited effect, on the supply of nuclear energy. Whether nuclear power plants be built or not is a political decision. Market forces play an inferior role at most: therefore a market based instrument (taxes or permits) will not be able to affect the share of nuclear energy.[1] Hence, since substitution towards more (or less) nuclear energy is steered directly by the political process, the application of energy coupons is redundant here.

Whether the objective of supply security, particularly with respect to natural gas, can be achieved by a system of energy coupons is, at least, questionable. Other instruments, for instance a risk tax on natural gas imports into the European Community or stockpiling obligations on the side of the importing companies, are certainly more easily targetable and less distorting, and therefore cheaper.

**Table 16**

**Objections to energy coupons**

| |
|---|
| Rationing of energy consumption is unreasonable. |
| Considerably more expensive in the long run, since energy substitution is eliminated or reduced and end-of-pipe equipment will not be developed and installed. |
| Conflicts with national excise taxes on fuel. |
| Redundant, since share of nuclear energy (and hard coal in some countries) is politically determined. |
| More effective and better targetable instruments for complex environmental problems are available. |
| Cheaper means to ensure supply security are available. |
| Less distorting instruments to secure fairness and equity are available (side payments, initial coupon distribution). |

[1] Unsuccessful privatization efforts in Great Britain have shown that electricity generation in nuclear energy plants is considerably more expensive than alternative forms of electricity generation (National Power, 1989, see Kraemer and Rüdiger, 1990). These empirical observations suggest that nuclear energy is not accepted in a competitive energy market. Although market valuation of nuclear energy facilities must be expected to greatly depend on the political climate itself, this failure of the 'market experiment' suggests that, under existing political reservations, market forces alone are most unlikely to affect the share of nuclear energy.

A similar argument applies to the equity considerations mentioned above. Balancing costs of $CO_2$ reductions between rich and poor Member States or between countries that use nuclear energy and those that do not can be achieved with other instruments in a suitable way. It could, for example, be accommodated under a $CO_2$ coupon system by an appropriate initial distribution of emission rights.

Table 16 summarizes the abovementioned objections to a coupon system for energy in general. The application of energy coupons and any combination of energy and $CO_2$ coupons makes $CO_2$ reductions more expensive than a pure system of $CO_2$ coupons. The fact that other externalities are connected with the consumption of energy is, from an economic point of view, not a valid argument for implementing a system of energy coupons. Instead, other ecological problems as well as risk and distributional problems can be tackled more successfully with separate and more easily targetable instruments. These include differentiated excise taxes, additional tradable permit schemes for other pollutants and side-payments.

## 6. Extension of the tradable permit scheme to the international sphere

### 6.1. The problem

A country-wide $CO_2$ policy could at best be a starting point for a successful endeavour to limit global warming. To have a chance of success, other countries must follow suit. Emerging evidence even suggests that a successful policy hinges not only on the participation of industrialized countries or the OECD as a whole: to meet the more ambitious greenhouse targets at all or to achieve the less ambitious targets at reasonable costs, it is considered necessary that developing countries also participate (e.g. Grubb, 1989). It is therefore important to ensure that a Community-wide policy can accommodate this. In particular, it should be initially designed such that it can be simply extended to a situation in which non-members of the Community participate.

### 6.2. Technical options

An extension of the permit scheme beyond the EC has to accommodate two features, which set it apart from the design of EC-internal permit trade:

(a) Checks at the external border of the EC are possible. Hence the country-of-origin principle with respect to external permit relations is not in force.

(b) The heterogenity of countries outside the EC which could be potential participants in an EC-led greenhouse gas convention is large.

The first implies that there exist more options in designing an EC-external permit scheme than in the EC-internal case. The second feature suggests that this additional freedom in system design is to be welcomed in order to accommodate the country-specific necessities likely to emerge when taking on other countries. It also suggests that in the EC-external case there is likely not to exist a design which could be favoured over its alternatives for all non-EC countries under consideration. Table 17 summarizes the main options for EC-external permit schemes. Table 17 presumes the adoption of the first-best EC-internal scheme outlined in section 4.3, that is of a single Community-wide $CO_2$ coupon scheme.

A precondition for the functioning of all alternatives is the existence of a hard $CO_2$ budget constraint in all external participating countries. That is, external governments must abstain from 'printing' additional $CO_2$ permits or allowing excessive emissions in response to a transfer of emission rights to the EC. This needs verification, which in the case of some countries may be difficult or costly to achieve.

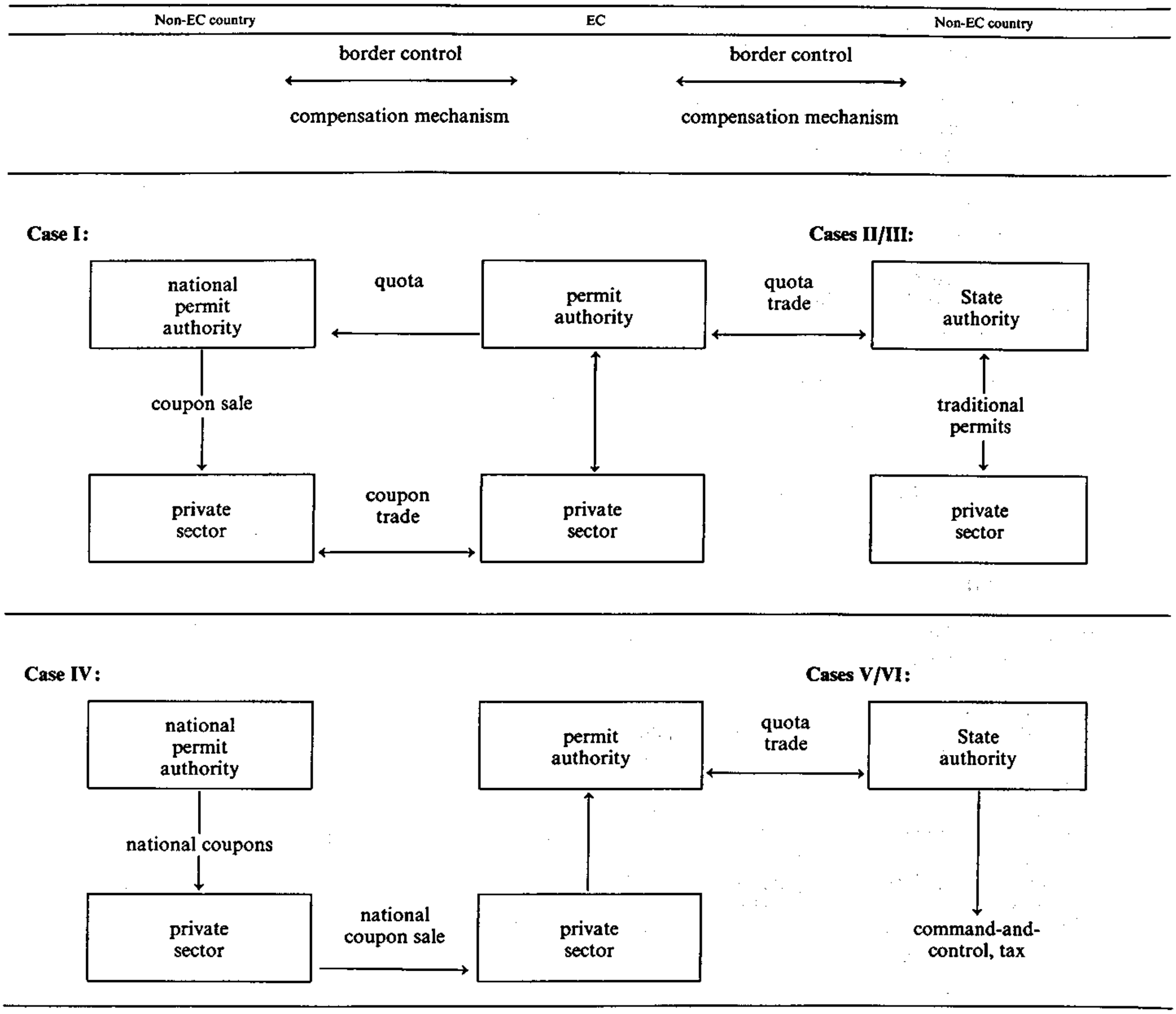
Case I is simply the adoption of the EC coupon scheme by an outside country. It includes a quota allocated to the country by the EC, negotiated beforehand, the domestic issuance of the permitted quantity of EC $CO_2$ coupons and private coupon trade across borders. This option is the most promising for countries which are sufficiently similar to EC members to take over this EC infrastructure.

Under cases II and III, the non-EC member opts for a traditional permit scheme. Nevertheless, the EC permit authority, or authorized national permit authorities, trade quota with that country. These cases differ from one another with respect to the routine of quota trade. While in case II quota trade takes place on an institutionalized and routine basis, in case III quota trade takes place more on an *ad hoc* and irregular basis, comparable to open-market operations.

In case IV, the non-member opts for a coupon system similar to the EC system. However, it sets its own $CO_2$ objective and does not accept EC coupons as payment against the domestic private sector's $CO_2$ obligations. However, given the hard budget constraint condition, EC permit authorities can accept that country's $CO_2$ coupons as perfect substitutes for their own. A one-way trade in permits gives the result that the EC coupon price is the lower bound on the non-member's coupon price. Such a system is suitable for countries which want to set looser emission limits dom-

**Table 17**

**Main options for EC-external permit trade**



estically than those which they would have to accept under an EC-led system.

Finally, cases V and VI represent the option of enforcing a national quota by command and control or by a $CO_2$ tax. The former solution seems particularly suited to LDCs which do not possess the institutional punch to run a sophisticated system domestically. Again cases V and VI differ in the routine of quota trading.

An extension of the coupon scheme beyond the EC could simultaneously include more than one or even all of these cases. Border controls and the application of the compensation mechanism (see section 3.6 above) at EC external borders ensures that distortionary arbitrage is prevented and that the quantity of internal $CO_2$ emissions is identical to the quantity of coupons turned over to the EC authority.

## 6.3. The problem of country sovereignty

Tackling the problem of cooperation of non-members, one has to come to grips with how to treat non-members conceptually. One approach would be to presume that non-members exhibit the same behaviour as members with respect to the $CO_2$ policy. In a sense, this amounts to the tacit presumption that non-members are more cooperative than members because the latter are subject to Community law and the former are not. Although one cannot exclude this possibility in the case of non-members which have a reputation of high environmental concern, in designing a $CO_2$ agreement one should not rely on it.

Countries are sovereign. A sovereign country can join an agreement as it thinks fit. It can also leave an agreement again which it decided to join in the past. The Community therefore faces not only the problem of how to get non-members into an agreement but also how to keep them in. Problems go even deeper: apart from a straightforward exit from the community of environmentally concerned nations, a sovereign country has available an array of other non-cooperative options. This is best illustrated by the wide experience with sovereign international debt.[1]

In designing an agreement the European Community should therefore follow the most pessimistic hypothesis which presumes that a non-member will violate the $CO_2$ agreement whenever it is to its own advantage to do so and in a manner which it considers best suited to further its self-interest.[2]

The emergence and stability of cooperation under the most pessimistic hypothesis can be best analysed applying game theory. It is standard knowledge in game theory that continued cooperation is possible in a situation in which all can benefit from cooperation. In such a situation, adequate side-payments from 'winners' to 'losers' can ensure that actually all benefit. Hence side-payments can bring about cooperation. However, in the real world we do not observe side-payments.[3] Continued cooperation is therefore not trivial to achieve.

If a system of tradable permits is envisaged, there is a straightforward theoretical solution to how to entice the emergence of cooperation. Countries simply need to be allocated an appropriate initial quantity of tradable permits such that those which otherwise would stay outside the $CO_2$ agreement are lured into it and kept inside by the prospect of revenue from the sale of excessive permits (e.g. Grubb, 1989). In theory, the problem therefore consists of finding such an initial endowment for the set of countries for which an agreement shall be designed.

Although in theory a judicious design of the initial allocation of tradable permits can ensure the emergence and stability of cooperation, one must nevertheless be very careful not to rely too much on it when designing a tradable permit scheme for the exigencies of the real world. To be precise, although a certain endowment with permits may be necessary and sufficient to lure a particular country into a $CO_2$ agreement, a number of real world problems can cause the country to violate the contract afterwards.

Environmental agreements to fight global warming are not designed by game theorists alone. Furthermore, the blueprints prepared by scholars will be extensively revised and modified in the political process leading up to an agreement. Hence the most straightforward obstacle to a smooth func-

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1 For an analysis of the history of international debt see, e.g. Berg and Sachs, 1988; Eichengreen, 1988; Jorgensen and Sachs, 1988. For a particularly revealing example, see Winkler, 1933.

2 More technically, the most pessimistic presumption is that a country compares the net benefit of sticking to the letter of the $CO_2$ agreement with the net benefit accruing from each possible contract violation. It makes this comparison in each state of nature and whenever in the course of time it can decide whether to honour or breach the agreement. It acts in accordance with that strategy which maximizes its net benefit. In the language of game theorists such strategies are called subgame-perfect.

3 One explanation for this is that side-payments frequently require payments from pollutees to polluters. Side-payments therefore carry the stigma of bribes and blackmail and hence have little chance to survive the political process.

tioning of a permit scheme is an initial allocation of permits which is simply inadequate due to restrictions imposed by the political process.

A second obstacle is the degree of uncertainty which surrounds the economics and ecology of global warming. For example, if estimates of abatement-cost functions or of the impact of warming on living conditions in a country turn out to be false, the initial endowment with permits may fail to ensure continued cooperation. Furthermore, a country may falsely believe that it is not in its own interest to continue with cooperation.

Third, a $CO_2$ agreement must necessarily be designed for the long term. Economic growth of developing countries may change the conditions under which they operate. Joining an agreement therefore does not guarantee that a country is cooperative for ever.

Fourth, even if a country is better off under an agreement compared to the case when it stays outside, the country may want to renege in order to become still better off. It is a frequently used and sometimes successful strategy to buttress such a request by the arm-twisting of minor or major violations of the agreement.[1]

In sum, there are good reasons to presume that problems are not solved once and for all if an endowment with permits is found which entices a country to join a $CO_2$ agreement. A practicable permit scheme should therefore be able to contain and cope with the pathology of non-cooperative members of a $CO_2$ agreement.

## 6.4. Symptoms of the pathology

In practice, the pathology of non-cooperative members of an international $CO_2$-abatement club can erupt with many symptoms of contract violations.

One symptom is a unilateral termination of membership. Although this is the most severe violation of an agreement, it is perhaps the least likely to occur. In any case, one must expect that it will be preceded by more subtle contract violations.

If the permit system is of the traditional type, i.e. if permits entitle it to a flow of emissions, then a country can simply produce, or import from outside the permit area, primary energy in excess of the permits it holds. Similarly, if the permit system is based on a $CO_2$ currency, a country can deliver fewer $CO_2$ coupons to the international permit authority than required on the basis of energy production and energy imports. Although in the permit system developed in this paper this is permitted for some time under the rule which permits the accumulation of '$CO_2$ debt', the country may decide to exceed the upper bound on its $CO_2$ debt or refuse to retire old $CO_2$ debt altogether.

Another symptom of the pathology would be if a country formally accepts its liability to deliver $CO_2$ coupons or hold traditional permits but declares a moratorium.

A different violation can accrue if the licensees are individuals within participating countries rather than the participating countries themselves. In this case a government may simply fail to enforce the scheme domestically.

The above violations are observable and very likely to be verifiable in international courts. Other violations of an international permit scheme are harder to verify, or it is harder to judge whether a country can be made responsible for a violation which is observable.

The ability to honour a $CO_2$ agreement depends on a number of factors. Some are intrinsically uncertain. Hence a country can blame phenomena like an especially cold winter for the 'necessity' to declare a temporary moratorium on the $CO_2$ agreement. To other members of the $CO_2$-abatement club, it may therefore be difficult to distinguish admissible violations from violations which occur simply because some violations are difficult to verify.

Another point in case is the balance of payments. A country may justify a moratorium on the deliverance of coupons due to balance-of-payments problems. Although in this case a moratorium may be considered permissible, a problem arises because the balance of payments can hardly be considered exogenous to a country.[2] Rather it must be seen as a potential policy variable. Balance-of-payments problems can therefore be created in order to slide out of a $CO_2$ agreement.

## 6.5. Sources of the pathology

As has already been pointed out, a basic fallacy of a $CO_2$ agreement is an inadequate initial international allocation

[1] Back in the sphere of theory, a further obstacle arises. Voluntary international trade (in permits) must be to the mutual advantage of individuals involved in trade. Voluntary international trade (in permits) is also welfare-improving in countries which are small. However, if countries are large such that participation in trade affects the parameters under which individuals operate, international trade need not be (see e.g. Buiter, 1981).

[2] Niehans, 1985.

of permits. This potential source of violations of an agreement is exogenous to an individual country or at least is not under its exclusive control after an agreement has been reached or after it has joined an agreement on terms negotiated beforehand. There exist, however, other sources of the pathology which are endogenous to individual countries participating in a $CO_2$ agreement. That is, a country may not only be responsible for a violation of an agreement, it may also be responsible for the emergence of the pathology which makes contract violations a potential problem (see Table 18).

**Table 18**

**Sources of the pathology**

| Source | Responsibility |
|---|---|
| False initial allocation of permits | Designers of international agreement |
| Sale out of initial quota | Home-made |
| Capitalization of lease income or future allocation of coupons | Home-made |
| Borrowing against flow of lease income or against net exports of coupons | Home-made |

If growth is uncertain, a country may end up in a situation in which it has to buy back traditional permits it had sold when growth projections were lower. In this situation, it is possible that the country finds it sufficiently attractive to violate the agreement, whereas under the initial allocation it would have not.

However, such home-made sources of the pathology also exist if traditional permits can only be leased or if the permit scheme is based on a $CO_2$ currency. A country can capitalize the future lease income or the future allocation of $CO_2$ coupons on international capital markets. If future markets exist, future coupon allocations can be sold today. Alternatively, a country may be able to place future coupon allocations as collateral for accumulating debt. At least, a country can borrow against the flow of lease income or the income from the net export of $CO_2$ coupons.

After capitalization of the future income stream accruing from a $CO_2$ agreement, a country is left exclusively with the burden of meeting the obligation imposed by the agreement. The country holds the bag of 'obligations only'. Hence international capital markets have a potentially destabilizing effect on a tradable permit scheme.

Therefore, even if by any chance the initial allocation of permits is adequate, actions taken by a country in the course of time may nevertheless thwart prolonged cooperation.

Country sovereignty is therefore likely to pose a serious problem for the implementation of a $CO_2$ agreement. Of course, in theory, one can imagine the existence of an initial allocation which supports continued cooperation as a perfect equilibrium in a game in which all these real world complications are taken into account. However, the chances seem small enough that such an allocation can ever be found. In any case a careful approach to global-warming policies suggests that one should not put all the burden of stabilization on the initial allocation alone.

## 6.6. Remedies

Fortunately there exist a number of remedies which can prevent or contain violations of an international tradable permit scheme. The list summarized in Table 19 must not be considered exhaustive. Rather it is a first sample out of a potentially rich tool-chest of stabilization instruments. Further research in this direction is certainly needed.

**Table 19**

**Stabilization instruments**

| Instrument | Property |
|---|---|
| Use of $CO_2$ coupons | Allows a flexible response to minor contract violations |
| Exclusion of the private licensee | Facilitates monitoring of participating governments |
| Conditional preferential trade agreements | Gives incentive to join and disincentive to violate agreement |
| Contract indexation | Allows a flexible response to random events |
| Cross-default clauses | 'Recruits' additional sanctions |
| | Stabilization effort is undertaken by private sector |
| | (Superior?) information generation of private sector exploited |
| | Increases net-permit exporters creditworthiness |

### 6.6.1. The superiority of $CO_2$ coupons

Under a system of traditional permits, an agreement can be easily violated and countermeasures are difficult to implement. If a country temporarily produces or imports primary energy in excess of the number of permits it holds, there is no straightforward countermeasure available to the international permit authority. This is different if the permit scheme is based on $CO_2$ coupons. In this case, the international permit authority simply needs to count a country's $CO_2$ deficit against the number of coupons the country is supposed to receive in the following period. If the buffer of admissible $CO_2$ debt is exceeded, the difference between actual coupon-debt and maximally admissible coupon-debt could simply be withheld by the international permit authority. Just as in the case of admissible coupon-debt, the authority must charge interest on the delayed 'supply' of coupons. In order not to soften the admissible coupon-debt constraint, the interest rate on excessive coupon-debt must exceed the interest rate on admissible debt. Moratoria on the supply of $CO_2$ coupons could be treated similarly.

### 6.6.2. The exclusion of the private licensee

An international $CO_2$-permit system must be designed to accommodate a heterogeneous set of countries. Cultural, economic and ideological differences need to be accounted for. An agreement should therefore not require participating countries to impose a permit system domestically. Rather (non-EC) countries must be allowed to implement the agreement with instruments as they see fit (see Table 17 above).

This, however, allows for a system in which a country chooses the tradable permit option domestically. For those countries it would in principle be possible to require that domestic licensees deliver coupons directly to the international permit authority.

There are, however, straightforward cost arguments that can be put forward against the participation of private licensees in an international permit scheme. Furthermore, the exclusion of private licensees from the international permit scheme would make it more difficult for a government to hide behind the domestic private sector by simply failing to enforce the delivery of coupons to the international authority. An international permit scheme should therefore be constructed such that, from an international perspective, the national governments or the national permit authorities are the sole licensees with which the international permit authority has to deal.

The judicious design of an international $CO_2$-currency system therefore helps to alleviate problems arising from country sovereignty. However, it cannot resolve these problems altogether. It therefore needs to be buttressed by further stabilizing instruments.

### 6.6.3. Preferential trade agreements

Cooperation in an existing agreement can be further increased by the imposition of economic sanctions upon a violation of the agreement. The threat of sufficiently severe sanctions can entice a country to honour an agreement that it would otherwise violate. There are, however, a number of problems arising from the imposition of economic sanctions.

First, in order to be effective, the threat of sanctions must be credible. That is, it must be in the interest of other countries to execute a threat after a violation. A threat which is not credible has no impact at all. Second, a threat of economic sanctions in response to a contract violation by a member to an agreement can create a disincentive to becoming a member in the first place.

A solution to these problems could be the introduction of economic sanctions in the form of preferential trade agreements. If a country joins an EC-led $CO_2$ agreement it could be offered and entitled to a preferential trade status. As a part of the $CO_2$ agreement, the newcomer would automatically lose its preferential trade status again after it has violated the $CO_2$ agreement. Such an arrangement would not create a barrier to entry to the $CO_2$ agreement. Beyond that, the threat of retiring the preferential trade status after a violation is likely to be considered credible.

### 6.6.4. Contract indexation

In a situation of uncertainty it is not straightforward whether a country has deliberately broken a $CO_2$ agreement. A tradable permit scheme should therefore feature excusable contract violations which do not trigger countermeasures by other countries.[1]

Such excusable contract violations can be institutionalized by indexation. For example, the quantity of coupons which has to be delivered to the international authority could be indexed to variables important to a country's readiness to cooperate. Such indexation must permit sufficient leeway when times are 'bad'. Excusable $CO_2$-debt accumulation could be treated similarly as regular $CO_2$ debt. When times are good indexation would require a country to pay off $CO_2$ debt.

[1] For similar proposals to stabilize international debt contracts, see Grossman and van Huyck, 1988, and Worrall, 1988.

A tradable permit scheme could be indexed, for example, to seasonal variables such as the average air temperature during winter, world market prices for natural resources and the like. In order not to run into an array of incentive problems, a country's obligation to cooperate should be indexed to variables which are exogenous to the country.[1]

#### 6.6.5. Cross-default clauses

Capitalization of the permit allocation is a potential source of contract violation. Capitalization takes place on the world capital markets. In this sense, capital markets have a destabilizing effect on a $CO_2$ agreement.

The resolution of this problem is difficult, notably because command and control instruments which can prevent capitalization on credit markets would cause efficiency costs both on international debt and permit markets.[2] Hence the problem must be resolved by reducing the incentive to capitalize in the first place or violate the $CO_2$ agreement for a given degree of capitalization.

Such incentives could be triggered by economic sanctions imposed upon violations of the $CO_2$ agreement. After such sanctions have been imposed, the country's general ability to service debt will have declined. Rational lenders will anticipate this when making a loan. Consequently, the overall creditworthiness of a country declines if a threat of credible sanctions in response to violations of a $CO_2$ agreement is imposed. Consequently, starting from any given level of total indebtedness, the country receives a smaller additional loan on the given future income from permit exports if a credible threat of sanctions is imposed. Hence sanctions imposed after the violation of the $CO_2$ agreement reduce a country's incentive to capitalize its permit income.

Although the rational anticipation of economic sanctions by lenders mitigates the destabilizing effect of capitalization, it is not guaranteed that violations of a $CO_2$ agreement due to capitalization never occur. Cross-default clauses can overcome this problem (Mohr, 1991b).

In finance, a cross-default clause is a contract amongst several or all of a debtor's creditors such that the debtor cannot violate one contract and preserve good credit relations with other lenders. For the problem at hand, such a cross-default clause would be an agreement between those countries which advance the permit scheme for environmental reasons (the EC and other net importers of permits) and the community of international lenders (banks). Under the cross-default clause, banks would hold a title to the net permit export income should debt contracts be violated. In turn, net permit importing countries would hold a title to a country's debt service payments in order to purchase permits the country fails to take up under the permit scheme.

If under this cross-default clause a country violates the $CO_2$ agreement, it also violates its debt contracts with lenders. Hence a country either honours both debt and the environmental agreement or it violates both. This creates an additional incentive to honour the $CO_2$ agreement if a violation of debt contracts is associated with costs to the country. Such costs arise from sanctions imposed by lenders, such as seizure of goods in transit or a credit embargo. Stabilizing environmental agreements by way of cross-default clauses is attractive for a number of reasons.

First, the public sector problem of keeping an environmental agreement running in the long term is solved by letting the private sector undertake the necessary stabilization. This is achieved because under cross-default clauses rational international lenders will impose such a credit limit on a country that it will honour the $CO_2$ agreement. This is optimal to do because lenders receive full payments on debt outstanding only if the $CO_2$ agreement is honoured in full. A tradable permit scheme can thereby do without the administrative overhead and interventions which would otherwise be necessary.

Second, perhaps the private sector possesses a comparative advantage in generating and using information relevant for contract stability. And third, a cross-default clause not only benefits the public sector but also the lenders in the private sector. Under a cross-default clause, they immediately gain additional titles against a net permit exporting country. This increases the net permit exporter's creditworthiness. Under cross-default clauses a country can therefore raise more debt than it could otherwise. Cross-default clauses therefore benefit all. Their introduction into an international $CO_2$ agreement will therefore not vitiate its voluntary nature.

1 For an analysis of such incentive problems in the case of debt indexation see for example Krugman, 1988; Froot, Scharfstein and Stein, 1988.

2 For an analysis of the emergence of efficiency costs in the wake of stabilizing a $CO_2$ agreement by a restriction of permit trade, see Mohr, 1991a.

## 7. Evaluation criteria for choosing between taxes and tradable permits for limiting $CO_2$ emissions

The scope of market-based policy instruments for limiting $CO_2$ emissions includes price-based instruments (i.e. taxes) and quantity-based instruments (i.e. tradable permits). Instruments can be further distinguished according to their assessment base. In principal, the tax burden or the required amount of permits can be based on the carbon content of fossil fuels or on energy use in general. This leads to four basic policy options:

a $CO_2$ tax on fossil fuels that is based on the respective carbon content of fuels,

a general tax on energy use,

a system of tradable $CO_2$ permits on fossil fuels that is based on the respective carbon content, and

a system of tradable permits on energy use in general.

In the present section, a set of evaluation criteria will be developed, which can be used as guide-lines in choosing between these policy options. However, three qualifications should be noted:

(i) Some of the following criteria are relevant only for the choice between taxes and permits, while others are only of importance for the decision on the appropriate assessment base.

(ii) The criteria cannot be used in a quantitative sense, i.e. it is not possible to quantify a degree of accomplishment.

(iii) Since it cannot be expected that one single instrument is superior to all other options with respect to every criterion, it is necessary to assign relative weights to the importance of individual criteria. This, however, is the responsibility of the political decision-maker and cannot be done here.

Table 20 gives an overview of the criteria discussed below and relates them to the appropriate questions.

**Table 20**

**Criteria for choosing between taxes and tradable permits**

| | Criterion is mainly related to: | | |
|---|---|---|---|
| | Choice between taxes and permits | Choice of assessment base | General instrumental design |
| Ecological effectiveness | * | * | |
| Economic efficiency | | * | |
| Transaction and administration costs | | * | * |
| Compliance with the polluter-pays principle | | * | |
| Incentives for technical progress | | * | |
| Information requirements | * | | |
| Predictability at the macro-level | * | | |
| Reliability at the micro-level | * | | |
| Transition problems | | | * |
| Compliance with the existing legal framework | | | * |
| Compliance with national energy policies | | * | * |
| Experience with the performance of the instrument | * | | |
| Reversibility and adaptability | * | | * |
| Openness for an extension to other greenhouse gases | | * | |
| Effects on competition | * | | |
| International extendability | * | | * |
| Incentives for cooperation | * | | * |
| Sensitivity with respect to strategic behaviour | * | * | * |

### Ecological effectiveness

The main goal of the instruments in question is to reduce annual $CO_2$ emissions to an exogenously (politically) given level. Therefore, ecological effectiveness in the sense of accurate target accomplishment is an important evaluation criterion. It relates not only to the principal choice between taxes and permits, but also to the choice of the assessment base. In general, a system of $CO_2$ permits based on the carbon content of fossil fuels seems to be best suited to meet this criterion, whereas it will hardly be possible to guarantee a certain level of emissions by means of a general energy tax.

### Economic efficiency

The reduction in $CO_2$ emissions will impose considerable abatement and adjustment costs on society. Consequently, economic efficiency — i.e. reaching the desired level of $CO_2$ emissions at minimal costs — is an important evaluation criterion. This criterion cannot be met if the policy instrument aims only at a general reduction of energy use and does not induce substitution processes between different energy sources, because the required total reduction in $CO_2$

emissions would have to be reached solely by a reduction in energy consumption.

Transaction and administration costs

Although $CO_2$ taxes and $CO_2$ permits lead to the same efficient allocation of overall allowable $CO_2$ emissions, the latter instrument may induce higher transaction and administration costs. However, as has been shown above (see section 3), transaction and administration costs associated with tradable permits can be minimized by a skilful design of the permit system. If the design outlined in section 3 is chosen, the transaction and administration costs of taxes and permits will differ only moderately.

Compliance with the polluter-pays principle

This principle ensures that the respective economic agents take into account the social costs of their decisions. With respect to the problem at hand, it requires that there should be a price for the emission of $CO_2$ which reflects the scarcity of overall allowable $CO_2$ emissions. This requirement cannot be met by the use of a general energy tax or a permit system on energy use, since in these cases there would be no direct relationship between the individual financial burden and the actual $CO_2$ emissions.

Incentives for technical progress

The chosen instrument should not only ensure an efficient allocation for the given state of technology (static efficiency), but it should also provide incentives for the development of new technologies (dynamic efficiency). This requirement is of particular importance for the problem at hand, since the development of new energy techniques may lead to a significant reduction in abatement and adjustment costs. The accomplishment of this criterion is independent of the principal choice between taxes and permits but depends on the appropriate assessment base. A general energy tax or a permit system on energy use would promote only the development of energy-saving technologies but not the search for low-carbon or carbon-free energy sources. The latter can only be accomplished if the assessment base is linked to the carbon-intensity of the respective energy sources. However, even in this case there remains the problem of missing incentives for end-of-pipe technologies which has to be solved by additional measures (see section 3).

Information requirements

Since the gathering of information is costly and some information is simply not available, information requirements (i.e. the information that is needed for the application of the instrument) are important for the valuation of policy options. As a rule, price-based instruments (taxes) require more information about substitution costs than quantity-based instruments (permits) because the latter automatically guarantee the accomplishment of the desired emission target.[1] Moreover, while the application of a tax system requires comprehensive knowledge about the substitution costs in advance, a system of $CO_2$ permits is able to generate this information since it reveals the true market price for the emission of $CO_2$.

Predictability at the macro-level

Since the generation of $CO_2$ is related to energy use and since there exist no end-of-pipe technologies as yet for the elimination of $CO_2$, any attempt to accomplish a significant reduction in $CO_2$ emissions would impose a serious strain on the economy as a whole. Therefore, the predictability of the macroeconomic impacts induced by the intended policy measure is of importance. In this respect, price-based instruments (taxes) are generally superior to quantity-based instruments (permits): whereas the economic effects of a tax can be predicted with relative certainty when the tax rate is known, the impact of a permit system can be predicted only with considerable uncertainty because the market price of the permits is not known *ex ante*.[2]

On the other hand, quantity-based instruments are superior with respect to the accurate accomplishment of the desired emission level. Therefore, the use of permits instead of taxes implies a partial relocation of uncertainty from the ecological system to the economic system. Whether such a relocation is advantageous depends on the adaptability of the two systems. As a general rule, the uncertainty should be shifted to that system which possesses a higher degree of adaptability with respect to the problem at hand.

Reliability at the micro-level

At the microeconomic level, the agents involved (taxpayer/licensees) are interested in having a reliable basis for their planning process. Price-based instruments are superior to quantity-based instruments in that respect because the market-price of permits is not known *ex ante*. However, these shortcomings of permit systems can be reduced significantly by trading in futures and options for permits.

1 This, of course, is only true with an appropriate definition of the assessment base.

2 Of course, it is possible to simulate permit markets by means of computable equilibrium models (see, e.g. Hoeller et al., 1990). However, at present the results of such simulations have to be viewed merely as illustrations of possible outcomes.

Transition problems

The implementation of stiff policy measures for reducing $CO_2$ emissions will bring about fundamental changes in the economic institutions and induce transition problems. It has to be asked how transition problems can be resolved or mitigated by different instruments.

Compliance with the existing legal framework

Experience in environmental policy shows that existing command-and-control structures can hardly be replaced but at best be complemented by market instruments.[1] Therefore, compliance with the legal framework is an essential criterion for the evaluation of policy options. However, in contrast to some other highly regulated pollutants (e.g. $SO_2$, $NO_x$), this criterion seems to be rather unimportant in the case at hand because up to now no legal provision exists for the limitation of $CO_2$ emissions.

Compliance with national energy policies

Compliance with national energy policy is important in evaluating alternative policy instruments because any attempt to accomplish a significant reduction in $CO_2$ emissions would severely affect the energy industry. In particular, a system of $CO_2$ taxes or $CO_2$ permits would not only induce a general cutback of energy consumption but also a substitution of carbon-intensive energy inputs. This process would primarily be to the detriment of hard coal and to the advantage of natural gas and carbon-free energy sources (e.g. nuclear power). Such effects can be in contradiction with existing national energy policies.[2]

Experience with the performance of the instrument

The implementation of taxes or permits for reducing $CO_2$ emissions involves an institutional innovation which — in contrast to technical innovations — cannot be tested on a laboratory scale. Consequently, experience with the performance of taxes and permits in related applications should be used as guide-lines for evaluation. This implies in particular that the performance of the emission trading policies used in the United States (see, e.g. Hahn and Hester, 1989) should be taken into consideration.

Reversibility and adaptability

The basic conditions and objectives of environmental policy do not remain unchanged over time but are subject to an ongoing evolutionary process. This is particularly true for the problem at hand because scientific knowledge about global warming is quickly evolving over time. Consequently, policy instruments for reducing $CO_2$ emissions should possess a high degree of reversibility and adaptability. This criterion will affect the concrete instrumental design. If, for example, emission rights are privatized by permits with indefinite validity, then the criterion of reversibility can hardly be met without expropriation. This possibility would in turn discourage the trade in permits. However, this problem can be avoided by the use of a coupon system as described in section 3.

Openness for an extension to other greenhouse gases

Although the recent discussion on measures against global warming concentrates almost exclusively on the reduction of $CO_2$ emissions, there exist several other man-made greenhouse gases (e.g. $CH_4$, $N_2O$). Hence, one must not expect that a $CO_2$ policy alone will ensure efficiency in terms of overall abatement costs. In order to sustain a desired level of mean temperature it may be less costly to refrain in part from $CO_2$ reduction and to reduce the emissions of, for example, $CH_4$ by an amount that is equivalent in terms of the prevented greenhouse effect.[3] Therefore, the chosen instrument should be open for future extensions to other greenhouse gases (see section 3.8). This criterion can be met by a tax system as well as by a permit system as long as there is an appropriate definition of the respective assessment base.

Effects on competition

Taxes and permits may have different effects on the competitive environment. In particular, under the use of tradable permits, large companies could try to corner the permit market in order to push competitors out of business. However, any attempt to dominate the market for permits on fossil fuels (or on energy in general) would require enormous financial resources.[4] Moreover, as shown above (see section 3), it is possible to design a contestable market where market power can hardly emerge.

[1] A well-known example for this observation is the German effluent charge, which serves only as an instrument to speed up the enforcement of the abatement requirements stated by the Water Management Law (Wasserhaushaltsgesetz). See, e.g. Meyer-Renschhausen, 1986.

[2] An example of such problems is the German policy to subsidize the extraction and consumption of domestic hard coal.

[3] On the problem of efficient policies against global warming in the case of several pollutants, see Michaelis, 1992.

[4] For example, in the FR of Germany (without the new States) the annual market volume based on a price of DM 50/tonne $CO_2$ would amount to more than DM 30 billion.

It should be noted that the importance of the above criteria also depends on the implementation of the policy at a national or an international level.[1] Moreover, in the context of an international agreement to reduce $CO_2$ emissions, there are some additional criteria which have to be considered:

International extendability

In view of the problems discussed in section 6, it is not to be expected that all major $CO_2$ emitting countries of the northern and the southern hemispheres will participate in the international $CO_2$-abatement club right from the beginning. Therefore, it is of particular importance that the institutional setting of the chosen policy option should easily facilitate the inclusion of additional countries in the course of time. To that end, it would be advantageous to leave the policy choice up to individual countries[2] (see also section 6).

Another important fact influencing the international extendability of the $CO_2$ agreement is the chosen instrument's robustness against changes in currency exchange rates. With respect to this criterion, a licence scheme is clearly superior to a tax system because an international $CO_2$ tax would require the fixing of a uniform tax rate in terms of a particular key currency (e.g. ecu).[3] As a result, the tax rates in terms of national currencies would be subject to changes whenever shifts in exchange rates occur. Furthermore, non-convertibility of currencies raises the problem that tax rates cannot easily be compared (Bohm, 1991). Non-convertibility, however, poses no problem under a tradable permit scheme.

1 For example, the criterion of compliance with national energy policies may be much harder to meet if the $CO_2$ agreement includes a large and heterogeneous number of countries.
2 Note, however, that this kind of decentralization is not feasible for the members of the European single market (see section 4).
3 The choice of an appropriate key currency could trigger a conflict between potential parties of the $CO_2$ agreement.

Incentives for cooperation

As discussed in section 6, the incentive to join and to stick to an international scheme of tradable emission rights depends crucially on the initial allocation of permits. In the case of an international $CO_2$ tax the same argument is true with respect to the redistribution of the collected tax revenue (see e.g. Proost and van Regemorter, 1990).[4] Nevertheless, there seems to be an important difference between these two options: in the case of a $CO_2$ tax the potential members of the agreement will be in a better position to anticipate the gains from and costs of cooperation because the tax rate is known *ex ante* whilst the market price of the permits can only be assessed with considerable uncertainty. Therefore, the use of taxes may — at least in the presence of risk-aversion — induce a stronger incentive to join the agreement than a permit scheme would do.

Sensitivity with respect to strategic behaviour

In section 6 a number of stabilization instruments were discussed which are intended to prevent violations of the $CO_2$ agreement. Although some of these instruments are applicable both in the case of a permit scheme and under a tax system, it is possible that some stabilizing instruments differ with respect to their suitability under either regime. A choice between these policy instruments should therefore also take into account the feasibility of stabilization measures. However, these issues are in need of further research.

Non-observable violations of an agreement are a special problem. The instrumental choice should therefore aim at reducing the scope of non-observable violations.

4 In particular, this implies that it may be possible — at least in theory — to ensure the emergence and stability of cooperation by a judicious redistribution of the tax revenue.

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