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Designing markets for CO₂ emissions and other pollutants

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Working Paper No. 490

Designing Markets for CO₂ Emissions and Other Pollutants

by Johannes Heister and Peter Michaelis
September 1991

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Designing Markets for CO₂ Emissions and Other Pollutants

1. Introduction

According to scientific evidence the increasing concentration of carbon dioxide and other greenhouse gases in the earth's atmosphere will lead to a warmer climate and a change in life conditions on the planet in the decades to come. The primary cause for this global problem is the use of fossil fuels as a source of energy, such as coal, mineral oil and natural gas, which contain large proportions of solid carbon. The burning of these fuels leads to the emission of their carbon contents in the form of carbon dioxide, which contributes to global warming via the greenhouse effect.

Based on these findings, there is a growing consent among political leaders world-wide on the principal necessity to curb carbon dioxide emissions. But as yet, there is no clear conception of possible national and international policies by which such a goal can be reached. One problem is the design of appropriate emission control instruments which translate the political aim of reducing CO₂ emissions into a corresponding behaviour on the level of households and firms. Adequate individual incentives and, consequently, efficient pollution control cannot be ensured by command-and-control measures, which are widely applied in the case of other pollutants by many OECD countries (see, for instance, Opschoor, and Vos, 1989). Particularly in the case of carbon dioxide, market-based instruments, such as emission charges and emission permits, have a much greater potential to minimize the overall costs of emission control and to induce an incentive for technical progress.

The objective of this paper is to show how to initiate a market for carbon dioxide and other greenhouse gases by introducing a feasible system of tradeable emission permits, which can be applied as an efficient instrument of environmental policy in single countries and in the whole European Community after the EC internal market is in force.¹ Part one of the paper summarizes the relevant framework conditions of the CO₂ problem and briefly reviews possible instruments for CO₂ control. Based on this, part two develops an alternative to traditional permit systems. It describes the notion of tradeable emission coupons and applies this concept to CO₂ emissions. It deals with the intertemporal allocation of CO₂ emissions, opts for the initial distribution of CO₂ coupons by auction, stipulates the carbon content of fuel as the assessment base, selects importers and producers as the appropriate addressees of the coupon system for CO₂ and solves the (system's initial) problem with end-of-pipe technologies. Finally, it shows how to extend the coupon system to other greenhouse gases. Part three of the paper studies the performance of the system in the framework of the EC's future internal market. And finally, part four deals with a possible application of the emission coupon system to pollutants other than greenhouse gases.

¹ The paper is based in part on Heister, Michaelis (1991a), (1991b).

1.1 The background of controlling CO₂ emissions

Total man-made carbon dioxide emissions can mainly be attributed to two kinds of sources. In industrialized countries roughly half of the total quantity of CO₂ emissions is released by large combustion facilities (industry, energy conversion). The remaining half originates from smaller sources (skilled trades, households, traffic).² Under these conditions a reasonably sufficient exploitation of the reduction and substitution potential will only be achieved if possible policy instruments for CO₂ control do not focus only on major sources but include sources of minor CO₂ emissions as well. Unfortunately, measuring CO₂ quantities directly and continuously at their source — as would normally be necessary for the application of emission control instruments — incurs great expenses and would only be justifiable for large combustion facilities. However, the amount of CO₂ generated in combustion can be calculated on the basis of the specific carbon content of the fuel. And, since there is no end-of-pipe technology available yet or even in sight, the total quantity of CO₂ generated in combustion is also released into the atmosphere. Hence, there is a linear relationship between the carbon content in fossil fuels and the related CO₂ emissions, which allows emission coefficients to be established that are independent of the combustion technology and that indicate the quantity of CO₂ released per ton of fuel.³ This makes it possible to do without directly measuring CO₂ emissions and instead calculate emission quantities indirectly on the basis of fuel input.

It is a great ecological advantage that carbon dioxide is a non-toxic and natural component of the atmosphere. Hence, the prevention of dangerous spatial concentrations (hot spots) is — in contrast to the cases of e.g. SO₂ or NO_x — of no importance here. As a consequence, a delineation of regions for CO₂ control is not required ecologically and the spatial allocation of total permissible CO₂ emissions can be left to the market. This, however, is not possible in the same manner when it comes to the long-term intertemporal allocation of CO₂ emissions. In this case, a clear and yet flexible steering mechanism must be invented (see part 2).

With respect to environmental policy, carbon dioxide is an ideal case for the application of economic instruments. As CO₂ is a non-toxic and globally effective natural gas, the advantage of command and control measures, which consists in their ability to tackle individual hazards selectively, becomes irrelevant. Hence, there is room for the application of globally effective economic instruments of environmental policy. Moreover, direct regulations concerning CO₂ emissions have not yet been established in most countries. This should facilitate the adoption and implementation of economic instruments considerably, because, as experience has proved in the case of other pollutants, it is usually politically impossible to replace existing command

² For example, in the Federal Republic of Germany (excluding the former GDR) about 740 Million tons of CO₂ are emitted annually, roughly 60% by large combustion facilities and 40% by smaller sources.

³ Determining CO₂ emissions by using emission coefficients can only be done correctly under the condition of complete combustion of the fuel, which is assumed here but may not always be fulfilled in reality.

and control regulations by economic instruments.⁴ They can, at best, be complemented, and there remains little scope for economic instruments in cases that are already under command and control rule. This is particularly true when dynamic emission standards are applied, as for instance in the German air quality law. The requirement to adjust critical quantities and technical provisions to the state of the art as defined by the administration can in no way be reconciled with the application of economic instruments.

1.2 Possible instruments for CO₂ control

There are basically four different instruments that may be applied for emission control, namely direct regulations, subsidies, charges and tradeable permits.⁵ Their suitability for controlling CO₂ emissions can be judged on the basis of four major criteria.

- Instruments of emission control should be ecologically effective, i.e. they should reach the political target in terms of emission quantities as accurately as possible, and,
- they should be economically efficient, i.e. emission abatement should be accomplished at minimal costs on the whole, including administration costs.

Additionally, the severe economic impact of CO₂ reductions suggests two further criteria.

- CO₂ policy instruments should feature a high degree of economic security, i.e. their macroeconomic impact should be predictable and they should provide a reliable planning basis for firms and individuals.
- And last, but not least, CO₂ instruments must be politically feasible, i.e. they must comply with a country's legal and institutional system, be adaptable to new situations, allow for a solution of related distributional problems etc.⁶

Due to the linear relationship between fuel input and CO₂ emissions, most measures of direct regulation will have to be some kind of energy efficiency standards for production and, in the form of product norms, for commodities. Even if applied in the form of dynamic energy efficiency standards, which require the application of state-of-the-art technologies, it is obvious that the ecological effectiveness of direct regulations is very limited in the sense that a given overall CO₂ reduction target can hardly be achieved accurately. As is well known, also the economic efficiency of direct regulations is rather low, since marginal abatement costs for different sources will differ considerably and there is no incentive for innovation. Contrary to that the economic security of direct regulations is relatively high, since the economic impact of command-and-control measures can be assessed relatively easily. And direct regulations are

⁴ A well-known example 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").

⁵ For a detailed comparison of these instruments with respect to their performance for CO₂ control see Heister (1991).

⁶ There is, of course, a multitude of further evaluation criteria in the literature, which cannot be discussed here because of limited space. See Heister, Michaelis (1991a).

almost always politically feasible. However, considering the size of the task, these two advantages can hardly outweigh the lack of effectiveness and efficiency of direct regulations, and hence, direct regulations appear to be an inappropriate instrument for CO₂ control.

With respect to CO₂ reduction subsidies a similar judgment holds. To determine the correct dosage for achieving a given reduction target is very difficult, particularly since band-waggon effects must be taken into account and base-lines for individual CO₂ sources would have to be established from which accomplished reductions can be measured. Furthermore, subsidies tend to be inefficient. When subsidies are given on a case-by-case basis marginal abatement costs will differ. Furthermore, prices for carbon-intensive products remain too low, which implies that the consumers' potential to save energy is being wasted. Although the direct economic effects of CO₂ subsidies can be evaluated relatively easily, fiscal side effects of a subsidy scheme of sufficient size may be serious. This also reduces the political feasibility of a subsidy scheme as a general instrument for CO₂ abatement.

Hence, from an economist's point of view, a reasonable choice can only exist between some form of a CO₂ charge and a system of tradeable permits. Although both instruments levy a price on CO₂ emissions, there is an important difference with respect to the establishment of this price. In a charge system the price is fixed politically and total CO₂ emissions result endogenously mainly as a function of abatement costs. Hence, choosing the right charge rate for a given reduction target is rather difficult if not impossible, since individual and future abatement costs are unknown to the policy maker. Consequently, a CO₂ charge is seriously defective with respect to ecological effectiveness: whether the ecological target will be reached remains uncertain. But the economic effects of a fixed charge rate can be appraised with relative certainty, and a fixed price provides a reliable planing base for firms and individuals, since they can calculate their future financial burden. Contrary to that, in a permit system total admissible CO₂ quantities are fixed directly in accordance with the political reduction target, and hence a permit system is ecologically safe. But this implies that the price for permits develops freely on the permit market depending on the relative scarcities and that it is not known ex ante. Hence, the macro- and microeconomic consequences of a permit system for CO₂ are much less certain.

The choice between a charge and a permit system must, in fact, face a trade-off situation between ecological and economic uncertainty, and the employment of permits instead of a charge system implies a partial relocation of uncertainty away from the ecological system into the economic system. It may, however, be argued that in the long run the economic system is less vulnerable to change than the ecological system, since experience shows that economies can, in the medium term, adapt to changes and deal with uncertainty relatively easily. Consequently, a permit system for CO₂ could be the more appropriate choice on the condition that it is sufficiently flexible with respect to permissible CO₂ emission quantities in the short run. The coupon system described below is able to satisfy this condition.

Furthermore, in traditional analyses, charge and permit systems are usually judged to be equally efficient, since in both systems the price for emissions will render marginal abatement costs equal for all sources. However, for permit systems this effect will only result if perfect markets for permits exist on which an equilibrium market price is established. Studying the US experience with emission trading programmes Hahn and Hester have shown that this condition is not automatically fulfilled and that cost savings through existing emission trading programmes lack far behind their potential (see Hahn, Hester, 1989a, 1989b). The reasons for these findings are manifold: in many cases permit rights are not a sufficiently guaranteed property, search and transaction costs are very high, permit markets are segmented and hence too small, there are problems with administration and enforcement, and there is a lack of experience and acceptance on the side of the market partners. In general, buying and selling tradeable permits implies a high risk. However, as will be seen below, the coupon system outlined in this paper is able to manage these problems efficiently.

To be politically feasible, charge and permit systems must both be in compliance with national and — for EC Member States — with EC legislation, and they must be harmonized with national energy policy. In contrast to a CO₂ charge, a permit system does not easily fit into the existing legal and institutional framework, and, moreover, permit systems are not easily adaptable or reversible, since the creation of guaranteed permit property rights depends on binding long-term political decisions. In the coupon system below a change of policy is much less a problem.

It may be due to these considerations, together with a lack of experience with permits and a lack of information on their possible economic impact, that permit systems have so far only played a minor role in political decision making, at least in Europe. However, since the CO₂ problem appears to be an almost ideal case for the application of a permit system, economists should try to solve the problems identified above and demonstrate the feasibility and, if possible, practical and political superiority of a skilfully designed permit system for CO₂. It is the objective of the following sections of this paper to present a practical solution to this task, particularly with respect to market creation, administrability and economic security.

2. The coupon system

The attempt to solve the problems mentioned above, thereby making use of the favourable circumstances of the CO₂ case, leads to the development of a refined permit concept, called the coupon system, which corresponds in its basic structure to a flexible CO₂ charge. The coupon systems distinctive feature, compared with traditional charge systems, is seen in the fact that the charge rate is not fixed in a political process, but determined as a price for emission coupons by the market mechanism. The most important features of the system are presented and discussed in the following sections.

2.1 The design of CO₂ coupons

A broad variety of permit systems have already been described in the literature (see, for instance, Tietenberg, 1980). These systems 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, it is the distinctive feature of emission coupons that they have only one dimension: CO₂ coupons are solely defined in quantities of CO₂, and they are valid for an unlimited period of time. CO₂ coupons have two functions: First, they permit the emission of the stated quantity of carbon dioxide, but only once although at any point of time (function of entitlement). Second, after their use, they have to be submitted to the coupon authority, which withdraws and invalidates them (function of verification). Hence, CO₂ coupons can be interpreted as a specific CO₂ currency, which exclusively serves for the settling of CO₂ emissions with the coupon authority. This approach has a number of advantages over traditional permit concepts:

- a) Whereas traditional emission permits may differ from each other with respect to emission quantity per unit of time, temporal and spatial validity of the permit and possibly further criteria, emission coupons represent perfect substitutes, even with respect to time, and they are fully divisible. This guarantees that a homogeneous market and thus a market price for CO₂ emissions will develop, which ensures the optimum spatial allocation of the total permissible quantity of emissions. As perfect substitutes, emission coupons can easily be traded on a stock exchange. This reduces transaction costs 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 whenever it changes hands 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 emission coupons, all supervision requirements are met if those economic agents who are charged with the coupon liability are obliged to submit a certain number of emission coupons to the coupon authority, which are then invalidated. The required number of coupons must correspond to the quantity of CO₂ emissions caused by the agent during the settlement period. The CO₂ emission quantity itself can be determined and supervised independently of the permits 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 CO₂ was released. These features greatly reduce the administration costs of the system.
- c) When employing emission coupons, the control of CO₂ emissions over time can be effectuated 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 emission permits as is necessary with traditional permit systems. The potentially unlimited validity of CO₂ coupons (until they are used) introduces a great deal

of intertemporal flexibility into the coupon market. The limit to CO₂ emissions is not strict in each period of time, and this improves the adaptability of the economy.

- d) A system of CO₂ coupons has a high degree of reversibility and adaptability. This is important, since there is almost no experience with well functioning permit markets 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, emission coupons in circulation will be permanently used up. Hence it is, if the occasion arises, possible to let the coupon system expire without having to expropriate those emission coupons that have already been granted. They could, for instance, be accepted as payments against CO₂ tax obligations if the coupon system were to be replaced by a CO₂ tax.

2.2 Controlling CO₂ emissions over time

From a theoretical point of view, it would be conceivable to leave the intertemporal allocation of CO₂ emissions completely up to the market. On introducing the system, the total amount of CO₂ 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 emission coupons. This stock would then be used up under the responsibility of the private sector just like the extraction of a non-renewable 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 emission 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 socially desirable reduction path will result. Furthermore, given the present state of scientific knowledge the total quantity of CO₂ emissions that would be admissible over time cannot be fixed definitively when initiating the system. Such a solution would, of course, also contradict the above mentioned reversibility requirement.

Due to these reasons, the CO₂ 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) emission coupons may enter the market which is equivalent to the (reduced) quantity of CO₂ emissions assigned to that very period. Hence, given the political will to reduce CO₂ emissions, the supply of emission coupons becomes ever tighter over time, which will naturally raise their market price and thereby induce further CO₂ abatement activities.

However, since the most economical 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 periodically issuing new emission coupons. The following two intertemporal flexibility mechanisms, which are inherent in the concept of emission coupons, enable market partners to react permanently to possible changes in technology and economy in a most

flexible way and thereby find the cheapest permissible path for the reduction of overall CO₂ emissions.

- First of all, it is possible to save emission coupons for later use, since their validity is not limited in time. Saving emission coupons is equivalent to transferring part of the CO₂ emissions assigned by the authorities for the current period to future periods. Contrary to that, it is not possible to take advantage of future emission possibilities in the same manner, because the necessary emission coupons are not yet on the market. Thus the emission path is sealed off asymmetrically with respect to time.
- Second, to resolve this asymmetry the coupon authority may allow postponing the submission of a part of the emission coupons normally due as payment for CO₂ quantities emitted during the relevant settlement period. Delaying submission of coupons is equivalent to shifting CO₂ emissions originally assigned to future periods into the present. Hence, this expands actual present emission possibilities and lowers the coupon price, but at the expense of future periods. Since paying for today's CO₂ emissions only in the next settlement period has virtually the same effect as a bank credit, a fee must be charged. This fee must be at least as high as the interest on the implicitly given bank credit. It may be progressive and should become prohibitive at a certain level of accumulated debt.

Based on these intertemporal flexibility mechanisms the coupon authority has instruments at its disposal with which it can — if necessary — influence the coupon market temporarily. With these instruments a fine-tuning can be effected which does not alter the number of emission coupons available in the long run.

- The coupon authority itself may keep a stock of emission 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 emission 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 by those involved on the basis of their expected total payment, due at the end of the settlement period.⁷

If the policy maker considers these flexibility mechanisms to be still insufficient, the government may fix the overall emission target in the form of a target corridor. Within the bounds of this corridor and with a view to the current economic situation, the coupon authority itself would then determine the number of emission coupons that it will actually issue in each period. Obviously, this flexibility provision renders uncertain the number of carbon coupons that will be available in the long run. Hence, it should be applied with great care in order to avoid any unnecessary interference with the expectations of the market partners.

⁷ Note that neither the settlement period nor the date of payment must be equal for all firms concerned.

In addition to the flexibility mechanisms introduced above, it could be of advantage for the firms concerned if they were able to increase the certainty of their operational planning by securing emission coupons for future operations ahead of schedule. This can be made possible by prematurely issuing a number of those CO₂ coupons that have been assigned to future periods in the form of "dated emission coupons". Such coupons would become valid for the settlement of CO₂ emissions only *after* the imprinted date.⁸

2.3 The distribution of emission coupons

There are two basically different procedures for the initial distribution of tradeable 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.⁹

In the literature it is often suggested that the vested rights of existing polluters should be protected by supplying emission permits to them free of charge in equivalence to their current real emissions at least for a transitional period. In the case of CO₂ this approach is to be rejected. The protection of acquired rights can also be ensured by announcing a permit system sufficiently in advance of its going into operation. This would render any grandfathering of emission coupons unnecessary, which, in the case of CO₂ emissions, would give rise to serious distributional problems: Since there are not yet any legal provisions for the limitation of CO₂ emissions, it is to be taken that to date *everybody* has a right to emit *any* quantity of carbon dioxide. If total CO₂ emissions were to be restricted now and allocated by tradeable emission permits, it would not be justifiable that scarcity-induced profits would accrue only to those who made use of their right to emit CO₂ 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, should be the beneficiary of any scarcity-induced profits arising from the privatisation of a common right. Accordingly, under legal considerations tradeable emission permits should not be distributed free of charge. Rather, they should be sold by auction to the highest bidders.

There are other important reasons for the initial sale of emission rights: Auctioning emission coupons guarantees immediate access to the market for any new firm. The signalling effect of the true scarcity price can come into play 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 obtain as many permits as possible. Any distribution formula would have to comply

⁸ It can be expected that markets in futures and options for emission coupons will develop naturally. However, they would probably only cover shorter time periods. Therefore, futures and options created in the private sector are not in direct competition with dated emission coupons issued by the coupon authority, but supplement each other.

⁹ The option of combining the allotment with a charge is only gradually different from a free-of-charge distribution of emission coupons, since additional criteria for discriminating between potential buyers have to be applied (unless the charge happens to equal the unknown market price).

with some notion of distributional justice and would certainly be disputed by the pressure groups concerned. If revenues from coupon sales are treated as an ordinary state income possible distributional problems can be solved within the framework of the national budget, which is preferable for reasons of transparency and political control. Finally, it should be noted that a rise in the public share is not an unavoidable side effect, since it can be compensated by adequate fiscal measures, and therefore it should not be an argument for a particular design of a permit system.

2.4 Assessment base and coupon liability

Due to the constant ratio between the carbon contents of fossil fuels and the CO₂ emissions caused by burning these fuels, the coupon liability can either be based directly on the measured CO₂ emissions or indirectly on the weighted fuel input. Deciding between these two options implies a decision between conflicting goals. On the one hand, the innovation processes induced are most substantial if the financial burden is put directly on CO₂ emissions measured at their source. On the other hand the existing substitution potential can only be fully exploited, if all sources of CO₂ emissions are included in the permit system. The latter, however, is not possible if directly measured CO₂ emissions are chosen as the coupon base, since a considerable share of the emissions is 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 can be realized that either do not include smaller sources or do not opt for directly measured CO₂ emissions as the coupon base.

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 an adequate supplementary mechanism (see below), the system developed here proposes determining the quantity of CO₂ emissions, for which emission coupons have to be submitted to the coupon authority, by weighting the fuel input with fuel specific CO₂ factors. This is equivalent with choosing fossil carbon as the relevant assessment base. This approach warrants the inclusion of almost all man-made CO₂ emissions into the coupon system as these emissions do not have to be directly measured at their individual source.

However, one modification is necessary, which is related to burning waste products in waste incineration plants. These products contain either non-fossil or fossil carbon. The emission of non-fossil carbon 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. Contrary to that, CO₂ 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 CO₂ quantities separately in waste incineration facilities and since these quantities account for a relatively unimportant proportion of total CO₂ emissions it seems reasonable to exclude them from the CO₂ coupon system. Moreover, the inclusion of CO₂ emissions from waste incineration could lead to an ecologically undesired substitution effect in favour of direct waste deposition (see below).

If fuel inputs are chosen as the assessment base, it is not necessary to place the coupon liability directly on the operator of a CO₂ source. This opens up an additional degree of freedom in choosing the licensee, a fact that can be used to reduce administration costs. These costs depend mainly on the number of licensees with which the coupon authority has to deal. Hence, leaving aside possible problems with competition, the coupon liability should be placed on that commercial level with the fewest participants. This is the level of importers and producers of fossil fuels. Placing the coupon liability on this group minimizes administration costs and reduces the possibilities for any unlawful circumvention of the permit liability.

In order to fulfil the coupon liability, fossil fuel importers and producers must procure emissions coupons. At the end of each settlement period they must transfer the required number of the coupons back to the coupon authority. In principle, the total CO₂ face value of the emission coupons to be handed in is directly equivalent to the quantity of fossil carbon supplied by a firm to the markets during the settlement period. The coupon costs will then be passed on to the consumers as a component of the price for the fuel. This results in a differentiated price increase, which is in direct proportion to the carbon contents and the CO₂ emissions of the respective fuel. This price increase is a signal to the consumer, which indicates the scarcity of permissible CO₂ emissions and induces the necessary energy saving 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 licensees 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 one hundred licensees should be the minimum to constitute an active market for emission coupons. The number of potential market partners could, however, be much higher, since anyone may be permitted to buy and sell emission coupons. Opening the coupon market to market participants that wish to hold emission coupons as part of their portfolio will ensure that the coupon market operates under the condition of perfect competition whatever the number of licensees involved may be.

Then, 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 emission coupons can be purchased, stocked and resold by anybody, the market for emission coupons is contestable. A cartel would therefore have to fight against an arbitrary large number of potential market participants, who have only small transaction costs. Furthermore, anyone who attempted to abuse the coupon market would undoubtedly have to reckon with open-market intervention by the coupon authority and by countermeasures on the part of the coupon exchange supervisory board.

2.5 End-of-pipe technologies and related problems

Basing the determination of CO₂ emissions on the fossil fuel that is sold by fuel producers and importers gives rise to the following major problems for which a solution must be found if the coupon system is to retain its efficiency and be applied successfully.

- a) If the fossil carbon input is the relevant assessment base for the coupon liability then industry has no incentive to develop end-of-pipe technologies for holding back CO₂ since there would be no remuneration for reducing CO₂ emissions by installing such devices. Furthermore, if end-of-pipe devices were nevertheless applied the coupon authority would in all extract more coupons from the economy than would be justified by total actual CO₂ emissions. The CO₂ target would then be undercut: it would de facto become tighter than was politically intended, and CO₂ emitting activities would have to be reduced by more than is required in order to reach the emission objective. Hence, CO₂ 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 CO₂ 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 similar problem of equivalence between actual CO₂ emissions and emission coupons extracted from the economy. 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 CO₂ 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 CO₂ 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 that bear the coupon liability themselves, 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. Any suitable mechanism would first of all have to compensate those who had to bear costs for CO₂ emissions that they have not caused, and second, it would have to neutralize the associated loss of CO₂ coupons to the economy. Such a mechanism must supplement the coupon system.

It should be clear from the explanations above that emission 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 CO₂ quantities that have not been released to the atmosphere are entitled to receive an equivalent amount of emission coupons. They are free to use these

coupons as they wish. They may, for instance, use them to pay their fuel supplier or to exchange them for cash on the coupon market. Compensation payments with emission coupons remunerate those who have invested in end-of-pipe devices and, by reflecting the correct relative prices, compensation payments are an efficient incentive to do so. At the same time these newly issued compensatory emission coupons bring the total CO₂ emissions allowed and the number of coupons in circulation back into exact balance, thus solving the equivalence problem.

It is a precondition for the functioning of this compensation procedure that the quantity of CO₂ or of fossil carbon that has not been released to the atmosphere inside the country can be determined accurately. 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 emission coupons for free in equivalence 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 thus is sealed off from the atmosphere. After checking their declaration, if necessary on the spot, the firms concerned receive the number of CO₂ 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 measuring of the CO₂ quantity held back should be easy to achieve, since this CO₂ must exist in some storable and disposable, possibly solid, form. As an innovation incentive, all large CO₂ sources should be entitled to compensatory emission coupons as soon as the coupon 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 CO₂ held back and deal with the coupon authority on behalf of their clients.¹⁰

2.6 Extending the coupon system to other greenhouse gases

Beside CO₂ there exist several other human-made pollutants which contribute significantly to global warming. Hence, there is no reason at all to believe that a coupon system that aims exclusively at the reduction of CO₂ emissions represents the most efficient way to sustain the desired climatic conditions. Such a one-dimensional policy with respect to CO₂ can only be efficient if abatement costs for other greenhouse gases are prohibitively high. A condition that cannot be expected to be fulfilled in reality.

Moreover, a financial burden levied solely on CO₂ may lead to substitution effects that may be problematic from an ecological point of view. If, for example, waste incineration becomes more expensive due to a CO₂ coupon system there will be a substitution effect in favour of direct waste deposition. However, landfills represent a major source of methane emissions,

¹⁰ 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.

which substantially contribute to the greenhouse effect. This example shows that an encumbrance solely on CO_2 may lead to a substitution of pollutants that may - in the extreme case - even speed up global warming. Hence, including other greenhouse gases into the coupon system would be of advantage from both an ecological and an economic point of view. It would require a redefinition of the emission coupons in terms of greenhouse gas equivalents, i.e. emission coupons would permit the emission of a stated quantity of CO_2 or of a quantity of another trace gas that is equivalent in terms of its greenhouse effect. However, such a redefinition leads to a vast number of problems that can only be touched upon in this paper.

Beside carbon dioxide, 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 to be included in a single coupon system. First of all, there is 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 and several other trace gases. Therefore, an unambiguous assignment of tropospheric ozone to individual polluters is not possible and hence nobody can be encumbered with the liability to provide coupons. The case of the 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 producers or suppliers of the CFCs. But according to international agreements, there will be a medium-term phasing out of CFC anyway, and their inclusion in a greenhouse coupon system could hardly speed up this process. Hence, it seems to be not worthwhile to integrate the CFCs in a coupon system.

As a consequence, only methane (CH_4) and nitrous oxide (N_2O) are candidates to be included in the coupon system. At present, CH_4 and N_2O contribute approximately 20% to the greenhouse effect, and this share will increase considerably after the CFCs have been phased out. Main sources of CH_4 and N_2O are energy use, agricultural activities (use of fertilizers, cattle) and waste deposition. At least in principle it seems to be possible to identify those individuals and firms that are responsible for CH_4 and N_2O emissions and to encumber them with the coupon liability. However, whether measuring these emissions at the individual sources, as would probably be necessary, would technically be feasible at justifiable costs must remain an open question here.

In an extended greenhouse coupon system, the specific global warming potential of CH_4 and N_2O , defined as the warming effect of one ton of these gases relative to that of CO_2 , would serve as a kind of "exchange rate" between the pollutants. According to estimates based on a time-horizon of 100 years¹¹ (IPPC, 1990), the greenhouse potential of one ton of CH_4 amounts to 21 tons of CO_2 , whereas the figure for N_2O is 290 tons of CO_2 . Therefore, it seems to be

¹¹ The global warming potentials are calculated such that they include the different lifetimes of CO_2 , CH_4 and N_2O in the atmosphere. Hence, the resulting figures are dependent on the time horizon applied in the calculation.

conceivable to define greenhouse emission coupons that permit the emission of one ton of CO₂ or 1/21 tons of CH₄ or 1/290 tons of N₂O. Admittedly, this is only a very rough approach, since it is not clear how, in the long run, the stock of greenhouse gases in the atmosphere would react to substitutions between the different greenhouse gases, how a moving time horizon can be integrated into the exchange rate and whether answering these questions would lead to an unfavourable differentiation of emission coupons with respect to time.

In a practical approach however, these difficulties may be less important, since the ecology of global warming should offer enough flexibility to deal with short-run fluctuation of the greenhouse potential persistent in the atmosphere. Economically, the approach of a single greenhouse gas emissions coupon system would enable the market mechanism to identify the most efficient way of reducing the emissions of greenhouse gases.¹² However, many unsolved practical problems remain. They include, for example, the definition of the assessment base, the choice of the licensees and the general institutional setting.

3. Emission coupons for CO₂ and the EC's Single Market

The implementation of a system of emission permits (or similar measures) by one partner country in the European Community in a national go-it-alone approach is not advisable, neither for economic nor ecological reasons. Such an approach would significantly reduce the competitiveness of CO₂-intensive commodities in the EC and on world markets without being able to secure a real reduction in world-wide CO₂ emissions. In fact, this approach could even result in a global increase of CO₂ emissions. It is conceivable that the production of CO₂-intensive commodities would shift at least partially to countries in which the production of these goods would result in higher CO₂ emissions per unit because the CO₂ intensity of the production processes applied there may be higher. Hence, a cooperative international carbon dioxide policy that would stipulate comparable abatement efforts at least for the industrialized world is required.

In view of the theory of institutional competition (Giersch, 1990) and the principle of secondary liability (Subsidiaritätsprinzip) it would be of advantage if the decision on what kind of environmental policy instruments should be applied (command and control, charges, permits) could be made on the level of individual countries and thus would remain decentral. However, the decentralized application of policy instruments could cause serious problems in the coming EC internal market since import restrictions will not exist any more and goods and services coming from all countries of the Community may be imported and sold in any other EC country without any restrictions. This means that the country-of-origin principle is generally in force, even with respect to product-related charges and directives as well as to other environmental regulations. For the case of the coupon system developed here it will be

¹² Another way to ensure efficiency in the case of multiple greenhouse gases is the implementation of an efficient charge system. For a formal and empirical treatment, see Michaelis (forthcoming).

shown below that under conditions of the Single Market a carbon dioxide policy with different instruments in the European Community is not viable.

Assume that one Member State implements the coupon system as described above whereas another EC country intends to fulfil her abatement obligations by employing adequate command-and-control regulations only (e.g. minimum effectiveness standards for power stations, etc.) and does not levy a financial burden on fossil fuel. In this situation, market prices for fossil energy (including coupon costs) would be higher in the "coupon country" than in the "command-and-control country". After the start 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 related costs (except transportation costs). Such arbitrage would continue to reduce the domestic demand for emission coupons just until the coupon price would be equal to the additional per unit transportation costs of purchasing fossil fuel in the command-and-control country. The coupon system would be undermined by the command and control system. 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.

Basically the same market arbitrage would occur if one country decided for a CO₂ charge on individually measured real emissions or a tax on fossil fuels. In the case of an emission charge the above analysis holds, since the retail price for fossil fuel is not affected. In the latter case, the tax rate would most likely differ from the price for emission coupons initially. However, due to trans-frontier arbitrage the price for emission coupons would adjust to the fixed tax rate by the process described above. The coupon system would thus degenerate to a tax system, where the coupon price would de facto be fixed by the "tax country's" tax rate (plus transportation costs). The finally single price for CO₂ emissions in the two countries would, of course, be economically efficient as all polluters would be charged the same price for CO₂ emissions. However, the quantity target in the coupon country would be missed and transportation costs would be excessive.

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

At first glance it does not appear to be necessary that national emission coupons be mutually tradeable in the whole Community in order to exploit the cross-country substitution potential which would minimize overall abatement costs. The prices for national emission coupons would adjust to each other throughout the Community through trade in fossil fuel, of course implying additional and unnecessary transaction and transportation costs. But 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 emission of CO₂ in the recipient country. Fixed national CO₂ emission limits on the basis of

fossil carbon quantities 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.¹³

This problem can be countered by extending the validity of the respective national CO₂ coupons to the entire Single Market so that national coupons can be traded Community-wide on a private basis and can be used to settle CO₂ accounts with all national coupon authorities. Under these conditions, the national prices for emission coupons would converge through cross-border private trade in coupons.

This situation, however, also implies that a Member Country cannot liberally choose its coupon policy any more without affecting all other national coupon markets.¹⁴ This would, in turn, require a very close harmonization of national coupon policies, which would at least have to comprise binding rules for the supply of national market with national emission coupons and for interventions in coupon markets by the national coupon authorities. But under these circumstances, a substantial difference with respect to a centrally organized Community coupon system, which would operate on the basis of a single CO₂ emission quantity for the entire Community, would de facto not exist.

Such a single Community coupon system, which could, of course, be opened up to include non-EC countries, would essentially be identical with the one described above for an individual country. Some differences would, however, occur with respect to the institutional setting, since a splitting-up of responsibilities between a Community coupon authority and corresponding national authorities seems to be advisable: in the Community system the CO₂ policy would be determined by the European Council of Environmental Ministers and implemented by the Community coupon authority. The latter would create the required quantity of Community CO₂ coupons and assign them to the respective national coupon authorities on the basis of a distribution key, which would have to be agreed upon in the preceding political negotiations.¹⁵ The marketing of these coupons and the supervision and settlement of individual CO₂ accounts could then remain the responsibility of the national coupon authorities. This approach would ensure that the revenues raised by selling the coupons would fall under national control, whereas the coupon policy would be controlled by the Community coupon authority.

¹³ It would, of course, be possible to channel fuel exports to Member States through non-member countries, thus making use of the compensation procedure described above. This would, however, imply excessive transportation and transaction costs.

¹⁴ 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 choose their monetary policy independently.

¹⁵ Particularly a distribution key on the basis of population numbers could be considered. See for instance Grubb (1989).

Finally, it should be noted that the problems which relate to the European Single Market are not specific for the case of CO₂ control by emission coupon. They arise whenever it is attempted to reduce CO₂ emissions by levying a financial burden on fossil fuel. Decentral decisions on how to curb CO₂ emissions would, under internal market conditions, only be possible if CO₂ emissions were measured directly at their source and levied accordingly. This, however, would imply that the tax or permit liability must be restricted to large CO₂ sources, and that a substantial proportion of the existing substitution potential cannot be exploited.

4. Applying the coupon system to hot-spot pollutants

The positive features of the coupon system suggest considerations on whether this instrument can be made applicable to other pollutants. The application of emission coupons for the control of pollutants other than greenhouse gases is, however, not straightforward, since the coupon system for CO₂ described above relies strongly on some distinctive features of the CO₂ case. In particular, the fact that dangerous ambient concentrations of CO₂ cannot occur has been exploited to design the coupon system as a feasible and efficient policy instrument.

In contrast to CO₂, most other environmental pollutants (e.g. SO₂, NO_x, CO) can have strong local and regional effects and thus can produce dangerous "hot spots". This fact must be taken into account, when adapting the coupon systems to other pollutants. But if an adaptation is possible, the use of emission coupons can render the control of hot-spot pollutants much more efficient than present-day command-and-control systems.

4.1 The problem

Hot-spot pollutants can become dangerous if high enough concentrations prevail in the environment. Their global effect, however, is usually unimportant compared with their local or regional effect. Moreover, the damage done to the environment by one unit of such pollutants may differ considerably from region to region depending on the already existing ambient concentration of the substance and the prevailing regional conditions.

For this reason, the coupon concept developed above for CO₂ emissions cannot be applied to hot spot pollutants without modifications. The fundamental features of emission coupons, namely that their validity is, at least in principle, neither restricted in space nor in time, makes them unsuitable for a treatment of hot spot pollutants. Coupons may accumulate in industrial zones and allow the emission of such a quantity of the pollutant in question as may be harmful to the local environment and the resident population.

Traditional permit concepts propose to solve this problem by restricting the validity of the permits with respect to time and space. This leads to a system of differentiated emission (or

ambient pollution) permits, which are traded on a number of different permit markets.¹⁶ This approach is not compatible with the coupon concept, since the use of coupons for the control of emissions in separated regions would waive the favourable property of a homogeneous coupon market. A segmentation of coupon markets would be inevitable. Moreover, sufficient competition for coupons and a competitive coupon price could not be ensured, and transaction costs would be too high. And finally, emission coupons that are differentiated with respect to time cannot be regarded as a specific kind of money any more, since they are not a store-of-value asset. Hence, the favourable administration and market procedures of the CO₂ case could not be retained here. A system of differentiated coupons would become considerably more complicated and more expensive in terms of transaction and administration costs. Hence, such a system is not likely to be an efficient instrument.

A further problem arises due to the fact that in many countries direct regulations for hot-spot pollutants are in force and cannot be replaced easily by a permit system for political reasons. Such direct regulations may consist of emission standards, sometimes in the form of product norms, and ambient quality standards, which refer to pollutants ambient in the environment and on which the licensing of industrial facilities may be based. These standards may be tightened in the wake of time. Often "dynamic" emission standards are used that demand the application of state-of-the-art abatement technology and thus imply a continuous reduction of emissions from each source. It is obvious that in particular dynamic emission standards are in conflict with any permit system, since they stifle exactly that flexibility which makes a permit system workable and efficient.

4.2 Two objectives of environmental policy

The way to a genuine coupon system for hot-spot pollutants can be found by distinguishing two objectives of environmental policy. The first such objective is described by the principle of hazard prevention (Gefahrenabwehrprinzip). To protect the country's population against major hazards that threaten their lives, their health and property is one of the major responsibilities of any government. Hence, it must be the fundamental objective of environmental policy to fend off any situation in which pollutants in the environment may accumulate to such concentrations that are harmful to people. Therefore, policy instruments must be applied that prevent dangerous hot spots reliably and keep emissions and hence local concentrations at a level that is compatible with hazard prevention.

However, such a minimum level of protection is usually not enough. Even in small concentrations, ambient pollutants may become harmful to people and their property in the long run, sometimes in a way that is not yet completely understood and, therefore, not foreseeable. Pollutants may accumulate in the environment and eventually alter natural living

¹⁶ For formal treatments of this problem see for instance: Montgomery (1972), Tietenberg (1974), Krupnick et al. (1983) and McGartland (1988). Compare also the literature on emissions trading rules, e.g. Atkinson, Tietenberg (1987) and Hahn (1986).

conditions for plants and animals, irreversibly destabilize fragile ecological equilibriums, reduce biodiversity and even severely impede living conditions for the human society in the long run. Global warming is only one example for such a threat. These effects cannot be countered on the grounds of the principle of hazard prevention, since they are not definite enough: they do not (yet) pose a well-known and imminent threat to people or to property.

As a response to such considerations, the precautionary principle (Vorsorgeprinzip) has emerged from the (German) environmental policy debate. It has become a standing rule of environmental policy in Germany and can be considered a second distinguished objective. The German Federal Government described the Vorsorgeprinzip in 1976 in the following terms: "Environmental policy is not fully accomplished by warding off imminent hazards and the elimination of damage which has occurred. Precautionary environmental policy requires furthermore that natural resources are protected and that demands on them are made with care."¹⁷ Hence, the precautionary principle surpasses the scope of hazard prevention, since it justifies and even demands government intervention already at a point in time when an immediate threat is not yet clearly discernible. The mere possibility of damage is enough. The precautionary principle aims at avoiding that environmental risks become manifest in the first place. Hence, it intends to generally reduce environmental risks. This usually requires pushing total emissions well below the level that is derived from the principle of hazard prevention.

4.3 Direct regulations as back-up for the coupon system

Neither of these two objectives can be met in an acceptable way by only one policy instrument. Direct regulations are a reliable source related and effective instrument, but economically they are inefficient. Charges are unreliable with respect to realizing a given emission target, since they depend on unrealistic information requirements, but they are spatially very well differentiatible. Tradeable permits and emission coupons realize a given emission target accurately, but differentiating them in space and time reduces their efficiency potential. However, after modifying those instruments such that they are mutually compatible, each instrument can be assigned to a particular policy objective in such a way that their individual advantages can be exploited whereas their disadvantages are avoided.

Direct regulations are best suited, if not indispensable for legal and political reasons, to accomplish the objective of hazard prevention, particularly in hot-spot areas. But, as part of an instrument set, they must be clearly restricted to this objective. In particular, *dynamic* emission standards must not be used, since they usually require abatement activities that go far beyond the standard that is necessary to guarantee hazard prevention. Consequently, emission and

¹⁷ Umweltbericht (1976). "Umweltpolitik erschöpft sich nicht in der Abwehr drohender Gefahren und der Beseitigung eingetretener Schäden. Vorsorgende Umweltpolitik verlangt darüber hinaus, daß die Naturgrundlagen geschützt und schonend in Anspruch genommen werden" (Rdnr. 4). The translation is taken from Moltke (1988), who offers a good introduction into the Vorsorgeprinzip in German environmental policy, which has no direct equivalence in the environmental policy of most other countries.

ambient quality standards should be frozen and may only be tightened if new scientific knowledge requires so in order to prevent hazardous situations. Product norms and licensing of new industrial sites may be based on such minimum standards. But direct regulations must definitely not be employed in order to accomplish a higher environmental quality that may be pursued on the basis of the precautionary principle or simply because political preferences require so.

This, however, has usually been the case. On the instrument level, the precautionary principle has always been somewhat blurred, and, to a large extent, it has served rather political aims than clear cut environmental objectives (Zimmermann, 1990). In German environmental policy the precautionary principle is usually simply associated with the application of state-of-the-art technology as required by direct regulations, which are adapted to the progress in abatement technology from time to time. A different approach is taken here. On the basis of a set of legal provisions that guarantee hazard prevention at any spot and any time, the precautionary principle can be interpreted as an objective that requires a more global improvement of environmental quality and is less interested in a particular local development. In this interpretation the precautionary principle can be made operational: it requires a certain level of *total* emissions, which is below the level consistent with hazard prevention.

In this form, the precautionary principle can and should, for efficiency reasons, be pursued by economic instruments. Compared with an emission tax, an overall emission coupon system seems to be particularly well suited for this purpose. It is able to realize directly and accurately any level of total emissions in the coupon market area that the policy maker deems consistent with the precautionary principle. For this, no knowledge on abatement cost functions is needed, as it would be necessary for finding the correct tax rate. With a minimum of direct regulations in force, a spatial and temporal differentiation of emission rights is unnecessary. Dangerous concentrations of pollutants cannot occur, since emission coupons only justify such an amount of emissions from an individual source that does not violate ruling emission or ambient quality standards. With the use of emission coupons also property right problems cannot occur in the presence of direct regulations, since coupons can always be saved for later use or sold at the market price. Consequently, the coupon system can display its advantages and ensure simultaneously a limitation or reduction of aggregate emissions and, within the bounds of hazard prevention, an efficient allocation of emission rights in space and time by means of a large and homogeneous coupon market.

Efficiency is reached in this setting for all those sources for which the coupon price is the binding constraint in the sense that these sources' marginal costs of compliance with the ruling direct regulations are lower than the coupon price. The coupon system induces these sources to abate so much more emissions than required by law that their marginal abatement costs are equal and equal to the single coupon price. And with an increase in the coupon price, for instance due to a tighter coupon supply, the coupon system becomes the binding constraint for more and more emission sources, and this renders emission control more and more efficient in the course of time.

Of course, the opposite effect can occur if direct regulations are tightened and thus become binding for more and more emission sources whereas the supply of emission coupons remains constant. Then, emission control becomes less efficient. The total demand for emission coupons is reduced and the coupon price decreases. Moreover, the coupon market collapses if direct regulations are tightened to such an extent that the available emission coupons cannot be used up in the foreseeable future. Such an incident is a political mistake. It can occur whenever the emission reduction path that results from direct regulations becomes tighter in the course of time than the reduction path steered by the supply of emission coupons. Also therefore, a freeze of direct regulations and their limitation to hazard prevention is inevitable for the functioning of the coupon system for hot-spot pollutants.

4.4 Emission charges for regional targets

Due to the market allocation of emission coupons, a certain regional differentiation of environmental quality may occur. In most cases, this quality differences, which occur within the bounds of the precautionary principle, may well be acceptable, since the average amount of emissions (or the average environmental quality) over the total emission space can be considered to be more adequate as a measure of precaution taken than the environmental impact in a rather small region.

However, the resulting environmental quality in a particular region may, nevertheless, be unacceptable for some (political) reason. For instance, emissions in an industrial area may remain on the highest permissible level, because the coupon price is too low to induce any reductions below the level of hazard prevention. In such cases a fine-tuning of emissions may become necessary in order to rectify regional ambient quality differences that are due to the market allocation of emissions coupon.

The use of direct regulations for this purpose would increase the already existing inefficiency of pollution abatement in this region. Instead, a regionally differentiated emission charge suggests itself as a supplementary instrument. In combination with a coupon system, an emission charge can easily be implemented and administered, since the charge can effectively be levied on the use of emission coupons. It would then be payable upon submission of the coupons to the coupon authority. Of course, the charge rate cannot accurately be targeted to realize the desired emission level. But this drawback is much less important here, since the emission charge should usually only be applied on a rather small scale as a supplement to the coupon system and is, therefore, probably less error-prone.

The additional emission charge increases the costs for emissions within the region concerned. If the charge rate is high enough this will bring regional emissions down to the desired level and improve the efficiency of pollution abatement in this region. But it will also reduce total demand for emission coupon and lower their price, which will result in an equal increase of emissions elsewhere. The price effect must be taken into account when setting the charge rate. The quantity effect will reduce the regional differences of environmental quality. Similarly to

the tightening of direct regulations, an emission charge narrows the scope of the coupon market and may lead to its collapse, if applied excessively. Hence, the supplementary emission charge should remain an exception.

In total, the mutual interactions between those three instruments demand that both, direct regulations and supplementary emission charges should be employed on a rather modest scale, so that their effect on the coupon market remains small. The coupon system should always carry the bulk of the incentive to abate the emissions dealt with and the coupon price should determine the abatement efforts of the large majority of sources.

Therefore, a thorough study into the relevant circumstances must be undertaken before this instrument set can be applied safely to a particular hot-spot pollutant. Such a case study would have to show that the scope of the planned coupon system would be large enough to generate an efficient coupon market. Furthermore, it would have to answer those questions that had to remain open

here, namely who should assume the coupon liability on the ground of which assessment base and which administration and enforcement provisions would be necessary.¹⁸ If favourable answers can be found to these questions, then the coupon system has the potential to render the control of hot-spot pollutants less expensive.

5. Conclusion

In the case of greenhouse gas emissions, in particular CO₂, a system of skilfully designed tradeable emission permits can have important merits as instrument of emission control. Making use of the favourable properties of the CO₂ case, the paper proposes a system of tradeable "emission coupons". Contrary to traditional permit concepts, emission (or CO₂) coupons are defined only in terms of a particular quantity of CO₂, and they are valid for an unlimited period of time. Hence, emission coupons allow the emission of the stated quantity of the pollutant in question only once, however at any time.

CO₂ coupons are issued periodically by auction and in accordance with an initially fixed reduction path. By placing the coupon liability on companies that produce or import fossil fuel, the available reduction and substitution potential can be fully exploited with moderate transaction and administration costs. The liable companies must procure CO₂ coupons and transfer them back to the coupon authority according to the quantity of fossil carbon that they have supplied to the markets.

CO₂ coupons can be interpreted as a kind of specific CO₂ money, which serves as a means of payment and control of CO₂ emissions. This particularly favourable property allows to repay compensatory coupons to those firms and individuals who initially had to pay the coupon

¹⁸ For the case of NO_x emissions, such a study is presented in Heister, Michaelis (1991a).

costs, but unduly, because they were able to avoid the related CO₂ emissions, e.g. by installing end-of-pipe equipment. Moreover, emission coupons for CO₂ can be redesigned to cover other greenhouse gases. In general, the coupon system for CO₂ emissions closely resembles a flexible charge system for CO₂, the charge rate of which is established on a market for emissions.

Under the conditions of the European Community's Single Market, a system of CO₂ coupons based on fossil fuel production and importation conflicts with alternative instruments that may be employed in other Member Countries. Hence, a decentral instrument choice is not possible, and a coupon system for CO₂ is only viable if applied to the entire European Community.

The emission coupon system can also have some merits when applied to hot-spot pollutants as part of an instrument set in which each instrument is assigned to a particular task. The instrument set comprises direct regulations that are employed to ensure hazard prevention and which are constrained to that effect, and an undifferentiated emission coupon system that pushes total actual emissions down to the protection level of the precautionary principle. Additionally, these two instruments may be supplemented by a regionally differentiated emission charge that may be applied to accomplish lower emission levels in an efficient way in such areas in which the single coupon price is not high enough to achieve the desired ambient quality level. The skilful application of the instrument set can render the control of hot-spot pollutants considerably more efficient if the coupon price is the relevant constraint for most sources and direct regulations and emission charges are kept to a minimum. The application of the instrument set to a particular case requires a thorough study into the practical problems associated with this case.

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